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**Federal Railroad
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Final Environmental Impact Statement/Report

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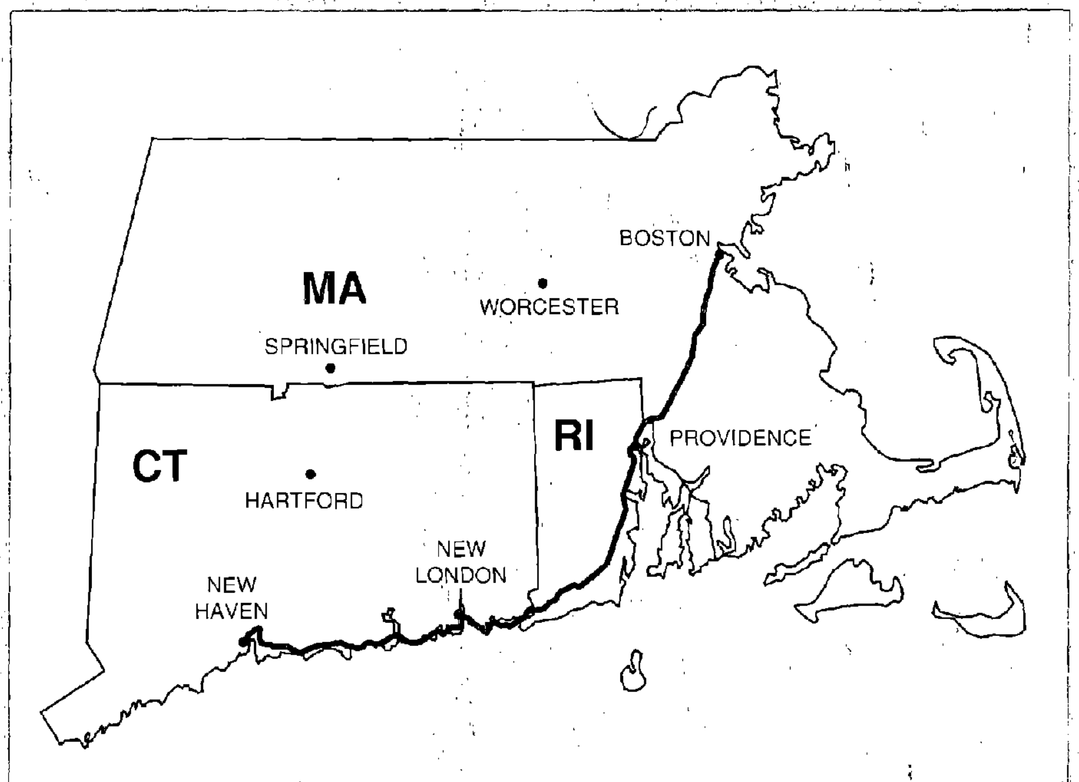
Northeast Corridor Improvement Project Electrification - New Haven, CT to Boston, MA



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13. ABSTRACT (Maximum 200 words)

This document is the final environmental impact statement and final environmental impact report (FEIS/R) on the proposal by the National Railroad Passenger Corporation (Amtrack) to complete the electrification of the Northeast Corridor main line by extending electric traction from New Haven, CT., to Boston, MA. This FEIS/R supplements the draft document published in October 1993 and made available for public comment through January 21, 1994. Comments received on the Draft EIS/R have been reviewed and evaluated. In some cases design refinements were made, additional analyses were performed, and further explanations of potential impacts were incorporated into the FEIS/R as a result of those comments.

This FEIS/R presents a comprehensive assessment of the consequences of each project alternative on the natural, physical and social environment. Environmental consequences are identified and, where possible, quantified. This document (Volume II) presents additional technical studies to supplement Volume III of the DEIS/R issued in October 1993. The FEIS/R consists of four volumes. Volume I is the main body of the FEIS/R and includes a 4(f) Statement on the proposed location of an electrification facility in the Great Swamp Wildlife Management Area. Volume III of the FEIS/R presents summaries of comments received on the DEIS/R and responses to these comments. Volume IV reprints the comments received on the DEIS/R.

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PREFACE

This document is Volume II: Technical Studies, of the final environmental impact statement and final environmental impact report (FEIS/R) on the proposal by the National Railroad Passenger Corporation (Amtrak) to complete the electrification of the Northeast Corridor main line by extending electric traction from New Haven, CT, to Boston, MA.

This FEIS/R has been prepared by the Federal Railroad Administration (FRA) and the John A. Volpe National Transportation Systems Center (VNTSC) of the Research and Special Programs Administration through a contract with the joint venture of Daniel, Mann, Johnson and Mendenhall, Inc., and Frederic R. Harris, Inc. (DMJM/Harris).

This FEIS/R supplements the draft document published in October 1993 and made available for public comment through January 21, 1994. Comments received both in writing and at a number of public hearings have been reviewed and evaluated. In some cases design refinements were made, additional analyses were performed, and further explanations of potential impacts incorporated into the FEIS/R as a result of those comments.

This FEIS/R presents a comprehensive assessment of the consequences of each project alternative on the natural, physical and social environment. Aspects of the natural environment addressed include noise, vibration, energy, air quality, aesthetics and natural or ecological resources. The physical environment includes land use, electromagnetic fields and interference, and archaeological resources. The social environment includes socioeconomics, historic resources, public safety, and transportation. Environmental consequences are identified and, where possible, quantified. Mitigation measures that will reduce or eliminate potential adverse impacts are also identified. Based on these factors, the environmental impact of each alternative was assessed.

Draft Record of Decision

Based on the analysis contained in the FEIS/R and other relevant considerations, FRA has selected the project proposed by Amtrak as modified by appropriate measures to mitigate adverse impacts as FRA's preferred alternative.

The executive summary of this FEIS/R includes the draft Record of Decision by the FRA regarding its decision in selecting the preferred alternative. The final Record of Decision will be issued by FRA no sooner than 30 days after the release of this FEIS/R.

Organization of the FEIS/R

This FEIS/R consists of four volumes. Volume I is the main body of the FEIS/R. Volume II presents additional technical studies to supplement Volume III of the DEIS/R issued in October 1993. Volume III of the FEIS/R presents summaries of comments received on the DEIS/R and responses to these comments. Volume IV reprints the comments received on the DEIS/R.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2 = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2 = 0.09 square meter (m_2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

$[(x-32)(5/9)]\ ^{o}F = y\ ^{o}C$

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yeards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliters (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

$[(9/5)\ y + 32]\ ^{o}C = x\ ^{o}F$

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0		1			2			3		4			5			6		7			8		9		10
CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25 / 25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

Final Environmental Impact Statement/Report

Northeast Corridor Improvement Project
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CHAPTER 1
DESIGN MODIFICATIONS AND SELECTED MITIGATION ANALYSIS

The following sections summarize the environmental impacts associated with site design modifications to the Proposed Action that were made after the publication of the Draft Environmental Impact Statement/Report (DEIS/R). The technical analysis for the summary is found in the remaining sections of this volume and in Volume III of the DEIS/R. References to the DEIS/R and Final Environmental Impact Statement (FEIS/R) volumes are noted in the narrative where appropriate. This chapter also identifies select environmental impacts of two mitigation measures: restoring passing sidings and providing fencing at illegal pedestrian crossings on the segment of Northeast Corridor (NEC) between New Haven, CT, and Boston, MA.

1.1 AMTRAK DESIGN MODIFICATIONS

Since publication of the DEIS/R, several site modifications have been made to the Proposed Action:

- relocation of the Branford Substation
- relocation of the Westbrook and Richmond switching stations
- relocation of the Millstone, Noank, Elmwood, Providence, Canton, and Readville paralleling stations
- relocation of the utility corridor to the New London Substation

Some site refinements are significant, e.g., the Elmwood Paralleling Station would be relocated 1,090 feet; the Noank Paralleling Station would be moved to the other side of the right-of-way (ROW). Others are relatively insignificant, as in the slight shift (approximately 80 feet) in the location of the Readville facility.

The reasons for these modifications are various and encompass engineering, real estate, and environmental considerations. A key example of the latter is the effort spent in considering alternatives to the original Noank Paralleling Station site. The new Noank site no longer displaces parking at Esker Point Beach and thus avoids a significant impact to beach visitors. A summary of the sites and the reasons for the site modifications are included in Table 1.1-1.

The facility relocations could potentially impact land use, historic and archaeological resources, noise and vibration, exposure to electromagnetic fields, sensitive views, and natural resources. To ascertain any changes in environmental impact levels, the site modifications have been reassessed and are addressed in the following sections. Mitigation of potential impacts are discussed in Chapter 5, Volume I, of the FEIS/R.

1.1.1 Land Use

Four types of land use benefits and impacts are evaluated: consistency with Federal and state land use policies, plans, and programs, including coastal zone policies and the Federal Farmland Protection Policy Act; limitations on access to recreational facilities; displacement of residences or businesses; and project-induced secondary growth and development. Although there are no quantifiable measures for assessing land use impacts, the qualitative criteria shown in Table 1.1-2 were applied to evaluate potential project impacts and benefits. The modified sites are analyzed below according to each of these land use evaluation criteria.

Table 1.1-3 indicates the impact of the modified sites on land use. All of the sites are consistent with adjacent and existing land use.

TABLE 1.1-1 Modifications in Facility Sites and Utility Feed Corridors since the DEIS/R

SITE	MILEPOST, DEIS/R	MILEPOST, NEW	CHANGES	REASON(S) FOR MODIFICATIONS
Branford SS	79.26	79.26	Moved approx. 80' away from main line	Moved per request by ConnDOT to allow use of original site as a staging area for a state bridge repair project
Westbrook SwS	103.78	103.74	Moved approx. 150' towards NH	Design refinement
Millstone PS	117.56	117.54	Moved approx. 100' towards NH	Design refinement
New London SS Utility Corridor	N/A	N/A	New feeder line route	Moved feeder line away from park and school grounds to streets and defined utility easements
Noank PS	129.46	129.52	Moved approx. 320' towards Boston and across tracks	Moved from a town recreational facility parking lot to a site more acceptable to Town of Groton
Richmond SwS	150.35	150.15	Moved approx. 1,080' towards NH	Moved to increase distance from an existing contaminated site and 100-year floodplain
Elmwood PS	181.70	181.49	Moved approx. 1,090' towards NH	Design refinement: moved to opposite end of Gorham plant because prior location contained contamination
Providence PS	187.55	187.45	Moved approx. 550' towards NH and 160' away from main line	Moved to accommodate future siting of an MBTA layover facility
Canton PS	212.40	212.38	Moved approx. 110' towards NH and 100' away from main line	Moved at the request of MBTA to eliminate partial view obstruction to rail engineers and to increase distance from fiber optic cables/utility lines
Readville PS	219.10	219.08	Moved approx. 90' towards NH	Design refinement to minimize retaining wall requirements

Note: N/A - not applicable SS - substation SwS - switching station PS - paralleling station

Source: Morrison Knudsen/L.K. Comstock/Spie Group, DMJM/Harris, 1994

Zoning ordinances divide a municipality into districts to regulate the use of land. Table 1.1-3 indicates the modified facility sites, gives the zoning classification of the site, and notes whether the site would be consistent with the allowable uses in each zone and with existing land uses surrounding the proposed site. Only two sites would be inconsistent with zoning: the Branford Substation and the Noank Paralleling Station.

TABLE 1.1-2 Land Use Evaluation Criteria

IMPACT CRITERIA	MEASURE
Consistency with local, state, or Federal land use policies, regulations, and programs.	Conflicts with local, state, or Federal land use policies.
Secondary growth or development impacts.	Project-induced changes in land use or growth patterns.
Severe limitations on access to recreational facilities.	Change in accessibility or attractiveness of recreational areas and facilities.
Displacement of existing residences or businesses.	Number and type of uses to be relocated.

Source: DMJM/Harris, 1993

TABLE 1.1-3 Zoning Considerations

FACILITY	ZONING	CONSISTENT WITH ZONING	CONSISTENT WITH EXISTING LAND USE
Branford SS	Residential (R-5)	No	Yes
Westbrook SwS	Industrial (I-1)	Yes	Yes
Millstone PS	Gen. Ind. Park Dist. (IP-I)	Yes	Yes
New London SS Utility Corridor	N/A	N/A	N/A
Noank PS	Residential	No	Yes
Richmond SwS	Industrial (I)	Yes	Yes
Elmwood PS	Industrial (M-1)	Yes	Yes
Providence PS	Industrial (MO)	Yes	Yes
Canton PS	Single Residence B (SRB)	Yes[1]	Yes
Readville PS	Industrial (M-1)	Yes	Yes

Notes: [1]Considered exempt
N/A - not applicable

Sources: Municipal Zoning Maps, for the Affected Communities, 1994

In accordance with the Federal Farmland Protection Policy Act, the agricultural potential of the modified sites were assessed. Table 1.1-4 lists the prime and important farmland status of the revised sites. Four sites are noted as having prime or important farmland soil types: the Branford Substation, Westbrook Switching Station, Richmond Switching Station, and Canton Paralleling Station. However, none are used for agricultural purposes.

Branford Substation. Located in Branford, CT, at milepost (MP) 79.26 on the northern side of the railroad, this proposed facility would be located adjacent to Interstate 95 in a heavily vegetated area. South of the substation is an access road, and northeast are three residences. West of the site is a former toll plaza and state administration building site and to the east is Hosley Avenue, a secondary road. There is no impact to existing land use.

The site is located in a residential zone and the proposed use is incompatible with existing zoning. Although the site is inconsistent with the existing residential zoning, given the forested character of the site and surrounding area, the impact of this facility on nearby residences would be insignificant.

This site is also identified as containing prime and important farmland soils. However, the changing topography and dense vegetation limit its agricultural use.

Westbrook Switching Station. Located in Old Saybrook, CT, at MP 103.74 on the southern side of the railroad, this proposed facility would be located directly east of School House Road and northwest of an industrial building. The site contains vegetation and some standing water. There is no impact to existing land use and the proposed use is consistent with zoning.

This site is identified as containing important farmland soils. Despite its classification, the topography, size, and proximity of this site to industrial uses restrict its agricultural value.

Millstone Paralleling Station. Located in Waterford, CT, at MP 177.54 on the southern side of the railroad, this proposed paralleling station would be located just outside the power transmission right-of-way for the Millstone Nuclear Power Facility. The site is located on an undeveloped knoll within the ROW. There is no impact to existing land use, the proposed use is consistent with zoning, and the site does not contain prime or important farmland.

New London Substation Utility Corridor. This feeder would be located in New London, CT, within street ROWs following this route: west from the proposed Branford Substation along Fourth Street, north on Crystal Avenue, west on Lewis Street, north on Cole Street, and north on Williams Street to an existing Connecticut Light and Power Company (CL&P) substation. There is no impact to existing land use, the proposed use would be consistent with zoning, and the site is not considered as prime or important farmland.

Noank Paralleling Station. Located in Groton, CT, at MP 129.52 on the northern side of the railroad, this proposed facility would be located on a triangular parcel between Groton Long Point Road, Route 215 (Elm Street), and the main line. The entire site is undeveloped and heavily vegetated. There is no impact to existing land use.

Although the site's proposed use is inconsistent with residential zoning, it is completely surrounded by highway and railroad infrastructure and has a low elevation. Because of the steeply sloped character and location of the site, the chance of it being developed as a residence is unlikely. The site is not identified as containing prime or important farmland soils.

Richmond Switching Station. Located in Richmond, RI, at MP 150.15 on the northern side of the railroad, this proposed facility would be located on the ROW near Meadowbrook Pond in Wood River Junction. The site is located in an abandoned industrial siding. There is no impact to existing land use and the proposed use is consistent with zoning.

TABLE 1.1-4 Prime and Important Farmlands

PROJECT FACILITY	COUNTY	SOIL TYPES	DEGREE OF AGRICULTURAL IMPORTANCE
Branford Substation	New Haven	Ludlow silt loam (LpB), Weathersfield loam (WkC), Walpole sandy loam (Wa), Manchester gravelly sandy loam, 8 to 15 percent slope (MgC)	LpB - Qualifies as Prime Farmland WkC, Wa, and MgC - Qualify as Additional Farmlands of Statewide Importance
Westbrook Switching Station	Middlesex	Hinckley gravelly sandy loam, 3 to 15 percent slopes (HkC), Udorthents - Urban land complex (Ud)	HkC - Qualifies as Additional Farmland of Statewide Importance Ud - Does not qualify as agriculturally important
Millstone Paralleling Station	New London	Udorthents, smoothed (Ud)	Ud - Does not qualify as agriculturally important
New London Substation Corridor	New London	Udorthents, smoothed (Ud)	Ud - Does not qualify as agriculturally important
Noank Paralleling Station	New London	Sutton extremely stony fine sandy loam, 0 to 8 percent slope (SxB), Udorthents - Urban land complex (Ud)	SxB and Ud - Do not qualify as agriculturally important
Richmond Switching Station	Washington	Hinckley gravelly sandy loam, 0 to 3 percent slopes (HkC)	HkC - Qualifies as Additional Farmland of Statewide Importance
Elmwood Paralleling Station	Providence	Udorthents - Urban land complex (Ud)	Ud - Does not qualify as agriculturally important
Providence Paralleling Station	Providence	Udorthents - Urban land complex (Ud)	Ud - Does not qualify as agriculturally important
Canton Paralleling Station	Norfolk	Deerfield loamy sand, 3 to 8 percent slopes (DeB), Canton fine sandy loam, 15 to 35 percent slopes (CaD)	DeB - Qualifies as Farmland of State/Local Importance.
Readville Paralleling Station	Suffolk	Udorthents, loamy (Ud), Merrimac - Urban land complex, 0 to 8 percent slopes (MnB)	Ud and MnB - Do not qualify as agriculturally important

Source: U.S.D.A. Soil Conservation Service, 1978

This site is identified as containing soils which designate it as Additional Farmland of Statewide Importance. However, since the former use was a railroad siding, the soils have been substantially modified and would not be able to sustain agricultural uses. The size and location of the site would also preclude agricultural use.

Elmwood Paralleling Station. Located in Providence, RI, at MP 181.49 on the northern side of the railroad, this proposed facility would be located in a vacant area that formerly served as a parking area for the Gorham Plant Complex. Adelaide Avenue is directly south, a rail spur is directly north, and the main line is directly east. The Gorham Complex buildings are approximately 1,000 feet to the west. There is no impact to existing land use, the proposed use is consistent with zoning, and the site is not considered prime or important farmland.

Providence Paralleling Station. Located in Pawtucket, RI, at MP 187.45 on the northern side of the railroad, this proposed facility would be located within the Providence Maintenance-of-Way yard north of Interstate 95. There is no impact to existing land use, the proposed use is consistent with zoning, and the site is not considered prime or important farmland.

Canton Paralleling Station. Located in Sharon, MA, at MP 212.38 on the southern side of the railroad, this proposed facility would be located within an existing Boston Edison Company 345 kilovolt (kV) power transmission right-of-way. The site is cleared of all heavy vegetation due to its location within the easement. There is no impact to existing land use and the proposed use is consistent with zoning.

Although this site is identified as containing Farmland of State/Local Importance, the proposed site is an existing Boston Edison right-of-way. Thus, the current use of the property precludes it from agricultural use.

Readville Paralleling Station. Located in Boston, MA, at MP 219.08 on the southern side of the railroad, this proposed facility would be located on a small vacant parcel between the NEC main line and two rail spurs. There is no impact to existing land use, the proposed use is consistent with zoning, and the site is not considered prime or important farmland.

1.1.2 Historic Resources

This section summarizes potential effects, as defined in Section 106 of the National Historic Preservation Act of 1966 (NHPA), on resources listed or eligible for listing on the National Register of Historic Places. An inventory of historic properties along the corridor was conducted and is documented in Section 3.3, Volume I of the FEIS/R. The inventory identified historic resources listed or eligible for listing on the National Register in the project area. After consultation with the State Historic Preservation Office (SHPO) in each state, it was determined that all listed or eligible properties adjacent to or within sight of the ROW or electrification facilities would be considered within the zone of potential project impact. The potential for project effects to historic properties listed or eligible for listing on the National Register were evaluated in accordance with the NHPA Section 106 impact criteria of effect and adverse effect, as described in Table 1.1-5.

The only site modification where historic resources may be adversely affected is the Elmwood Paralleling Station. The proposed site could impact the Gorham Silver Company complex which is determined to be eligible for the National Register of Historic Places. Further consultation with the SHPO is anticipated to take place in order to arrive at an acceptable design. The Memorandum of Agreement developed among FRA, Amtrak, and the Rhode Island SHPO (included in Appendix D of Volume I) stipulates that, prior to construction, Amtrak will provide additional documentation showing the location and design of the proposed paralleling station.

TABLE 1.1-5 Historic Resources Evaluation Criteria

IMPACT CRITERIA	MEASURE	SIGNIFICANCE THRESHOLD
Alteration of the characteristics of a property that contribute to its significance.	Effect on characteristics of a property that contribute to its significance and National Register eligibility.	Effect on characteristics of property is adverse[1]

Notes: [1]As defined in Section 106 of the National Historic Preservation Act of 1966, an effect is adverse when the effect on a historic property may diminish the integrity of the property's location, design setting, materials, workmanship, feeling, or association. Adverse effects include but are not limited to: (1) physical damage or destruction of all or part of the property; (2) isolation of the property or alteration of the character of the property's setting, when that character contributes to the property's qualification for the National Register; (3) introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting; (4) neglect of a property resulting in its deterioration or destruction; and (5) transfer, lease, or sale of the property without adequate restriction or conditions included to ensure preservation of the property's significant historic features.

Source: Historic Resource Consultants, Inc., 1994

1.1.3 Noise

The evaluation protocol includes projection of noise from normal electrification facility operations, as well as noise from the construction of such facilities. The criteria and methodology used are consistent with those developed for the Technical Study 4, Volume III, of the DEIS/R. In general, the design modifications reflect small changes in the overall impact inventory from the DEIS/R, with a slight reduction in noise impacts at the Westbrook Switching Station and Canton Paralleling Station sites and a slight increase at the Noank Paralleling Station site (see Table 1.1-9).

1.1.3(a) Evaluation Criteria

Electrification Facility Noise Criteria. Noise impacts from electrification facilities were assessed based on the projected A-weighted sound level and tonal characteristics at the property line of nearby noise-sensitive receptors, as well as on the type of receptor and existing background noise. The evaluation criteria are based on a review of state and local regulations applicable to such facilities (see Table 1.1-6).

Construction Noise Criteria. Noise impacts from construction were evaluated based on the predicted day-night sound level (L_{dn}) for construction noise. Based on the standards established by the U.S. Department of Housing and Urban Development (HUD), an L_{dn} greater than 75 A-weighted decibels (dBA) for long-term residential use would likely require mitigation. However, to account for the limited duration of construction, impact is assessed only when the activity will occur for 30 days or more at a given location.

1.1.3(b) Methods of Analysis

Analysis of Noise from Electrification Facility Sites. The major sources of equipment noise at the project facilities are expected to include outdoor, oil-cooled transformers, and ventilation equipment. Noise levels were calculated as a function of distance for these sources based on their anticipated operating characteristics.

TABLE 1.1-6 Noise Evaluation Criteria

IMPACT CRITERIA	MEASURE	SIGNIFICANCE THRESHOLD
Substation noise at property line of noise-sensitive land use.	Projected A-weighted substation sound level compared with existing conditions.	Projected level exceeds minimum hourly L_{90} by more than 5 dBA, and is: >55 dBA (daytime[1] occupancy) >50 dBA (nighttime[2] occupancy) Where audible discrete tones (e.g., transformers) are present, adverse impacts are assessed at levels 5 decibels lower than indicated above.
Construction noise at noise-sensitive land use.	Projected L_{dn} from construction.	Projected L_{dn} > 75 dBA for 30 days or more

Notes: [1]Daytime = 7 AM to 10 PM
[2]Nighttime = 10 PM to 7 AM

Source: HMMH, Inc., 1993

TABLE 1.1-7 Noise Impact Criteria for Fixed Facility Operations

LAND USE	BACKGROUND NOISE LEVEL (dBA)	PROJECT NOISE IMPACT THRESHOLD (dBA)
Daytime (schools, churches, etc.)	≤50	50
Nighttime (residences, hospitals, etc.)	≤45	45
Daytime (schools, churches, etc.)	>50	Same as background level
Nighttime (residences, hospitals, etc.)	>45	Same as background level

Source: HMMH, Inc., 1993

The fixed facilities affected by the design modifications include one substation, two switching stations, and six paralleling stations. Such facilities contain noise-generating electrical and mechanical equipment that may affect nearby noise-sensitive receptors during normal operation. The major sources of noise at these facilities are expected to include transformers and heating, ventilating, and cooling (HVAC) units. Because these sources contain discrete acoustic "tones" which are considered more annoying than broadband noise, there is a 5 decibel penalty imposed in assessing their noise impact. The one utility corridor modification will have no fixed facilities; thus, there would be no operational noise associated with it.

The noise impact thresholds defined for daytime occupancy (e.g., schools and places of worship) and nighttime occupancy (e.g., residences, hospitals, and hotels) differ by 5 decibels because the criteria are based on the background land use noise level during the occupied hours.

Noise projections from facility operation are calculated using baseline noise levels at some reference distance, anticipated operating characteristics, and standard sound propagation prediction methods. Baseline noise levels as a function of the operating parameters are generally taken as empirical relationships found in the literature. These projections are then evaluated according to the criteria given in Tables 1.1-6 and 1.1-7 to obtain screening distances for noise impact. A summary of the resulting noise projections and impact distances is shown in Table 1.1-8.

Analysis of Construction Noise. Construction noise impacts were evaluated based on: (1) the type of construction machinery likely to be used for catenary installation, construction of electrification facilities, and bridge modifications, and (2) the duration of the construction. Projected construction noise during catenary installation and bridge modifications (including raising, replacement, and undercutting) was based on projections made in the Programmatic Environmental Impact Statement (PEIS). Projected construction noise at the electrification facilities was based on noise levels for the type of equipment used in nonresidential construction.

1.1.3(c) Facility Operation Impact

A revised noise impact assessment was carried out for the modified facility locations, based on the distances in Table 1.1-8 and the aid of aerial photographs. The results, along with revisions to the DEIS/R inventory, are provided in Table 1.1-9. Compared to the number of noise impacted residences identified in the DEIS/R there would be no change in the number of noise impacted residences at the Branford Substation; Millstone, Elmwood, Providence, and Readville paralleling stations; New London utility corridor; and Richmond Switching Station. At the modified Canton Paralleling Station location, the six residences identified in the DEIS/R are no longer within the impact distance. At the revised Westbrook Switching Station site, only one of three residences on Gilbert Road identified in the DEIS/R is within the impact screening distance. At the relocated Noank Paralleling Station site, five residences at the end of Seneca Drive are identified within the noise impact zone, compared with four identified in the DEIS/R.

TABLE 1.1-8 Noise Projection and Impact Distance Summary

FACILITY	OPERATING ASSUMPTIONS		PROJECTED TOTAL NOISE LEVEL AT 500 FT (dBA)	DISTANCE to NOISE IMPACT	
	TRANSFORMER RATING	HVAC COOLING CAPACITY (tons)		DAYTIME LAND USE (ft)	NIGHTTIME LAND USE (ft)
Traction Power Substation	2 @ 50 MVA	10	45	280	500
Switching Station	3 @ 5 MVA	10	42	200	350
Paralleling Station	3 @ 5 MVA	10	42	200	350

Note: MVA = megavolt ampere

Source: HMMH, 1993

1.1.3(d) Construction Period Impacts

The primary source of construction noise is construction equipment. For the electrification facilities, construction machinery likely would include the types of equipment typically used for light industrial construction, such as graders, bulldozers, backhoes, cranes, and trucks. Based on the construction activities and equipment, it was determined that the distance from the construction sites at which the 75 dBA impact criteria would be exceeded is 180 feet for electrification facilities. The effects of construction noise would occur intermittently and would be of limited duration, ranging from 2 to 4 months for the electrification facilities.. Such noise would occur only during weekdays and during daylight hours, and would not exceed the impact thresholds at any of the modified facility sites.

TABLE 1.1-9 Noise Impact Summary for Facility Modifications

FACILITY	MILEPOST (new)	NUMBER OF NOISE IMPACTED RESIDENCES		DESCRIPTION
		DEIS/R	REVISED	
Branford Substation	79.26	1	1	Single family (SF) off Hosley Ave. 300 ft from center of substation site
Westbrook Switching Station	103.74	3	1	SF off Gilbert Rd, 180 ft from center of site
Millstone Paralleling Station	117.54	0	0	N/A
New London Utility Corridor	N/A	N/A	N/A	No operational activity will occur along utility corridor
Noank Paralleling Station	129.52	4	5	SF at end of cul-de-sac (Seneca Drive)
Richmond Switching Station	150.15	0	0	N/A
Elmwood Paralleling Station	181.49	0	0	N/A
Providence Paralleling Station	187.45	0	0	N/A
Canton Paralleling Station	212.38	6	0	N/A
Readville Paralleling Station	219.08	6	6	SF on Prescott St

Source: HMMH, Inc., 1994

1.1.4 Archaeology

Information on previously known or reported archaeological sites was obtained from the site files of the Connecticut Historical Commission (CHC), the Connecticut Office of State Archaeology (COSA), the Rhode Island Historical Preservation Commission (RIHPC), and the Massachusetts Historic Commission (MHC). In addition, the survey team consulted the National Register of Historic Places to identify any National Register-listed sites within or adjacent to project areas, as well as archaeological assessment reports associated with the Northeast Corridor Improvement Project (NECIP) PEIS.

In each state the archaeological survey was conducted according to that state's regulations, but the methods and goals of the survey were the same: to assess the site's potential for containing buried cultural remains through documentary research and field inspection.

Archaeological sensitivity is defined as the likelihood for prehistoric and/or historic cultural resources to be present within the project area. Based on project-specific environmental factors and information on known cultural resources and human land-use patterns, portions of the study corridor were stratified as having a high, moderate, or low potential for prehistoric and/or historic resources. The evaluation of the prehistoric archaeological sensitivity of the project area considered the following information: (1) the presence of known prehistoric sites within or in close proximity to the project area; (2) the level of ground disturbance to the project area; and (3) the environmental characteristics and available natural resources of the area (see Table 1.1-10). The evaluation of the historic archaeological sensitivity of the project area considered the following information: (1) the inventory of known historic sites and/or districts within or in close proximity to the project area; (2) developmental history, historical demography, and geography; (3) the level of ground disturbance to the project area; and (4) the locational attributes of the project area (see Table 1.1-11).

Of the 10 site modifications, two are at locations that were cited as having moderate archaeological sensitivity: the Canton Paralleling Station and the New London utility corridor. Since the DEIS/R, systematic subsurface testing was conducted at the undisturbed Canton site and no intact cultural remains were found. The Canton site was subsequently redefined as having low archaeological sensitivity. The New London utility corridor lies along paved streets and subsurface exploration is not practical during this phase of the project. Thus, the corridor remains classified as having a moderate level of archaeological sensitivity.

TABLE 1.1-10 Environmental Attributes Contributing to Prehistoric Archaeological Sensitivity Rankings

CRITERIA	HIGH	MODERATE	LOW
Distance to water/wetland	adjacent or < 150 m	150 to 300 m	> 300 m
Slope	minimal 0 to 3%	moderate 3 to 15%	steep > 15%
Soil types	sandy, well-drained	gravelly, fair drainage	very gravelly, poor drainage

Source: PAST, Inc., 1993

TABLE 1.1-11 Locational Attributes Contributing to Historic Period Site Distribution

CRITERIA	HIGH SENSITIVITY	MODERATE SENSITIVITY	LOW SENSITIVITY
Known historic sites in vicinity	known site adjacent or near	known site in general vicinity	no known sites in vicinity
Proximity to fresh water source	adjacent or <100 m	moderate 100 to 300 m	distant >300 m
Proximity to water power source	adjacent or <50 m	moderate 50 to 150 m	distant >150 m
Access to transportation network	excellent <200 m	moderate 200 to 1500 m	distant >1500 m
Proximity to settlement concentration	adjacent or <800 m	moderate 800 to 1500 m	distant >1500 m
Proximity to agriculture	adjacent or <100 m	moderate 100 to 300 m	distant >300 m
Disturbance	none to minimal	minimal to moderate	moderate to severe

Source: PAST, Inc., 1993

1.1.5 Electromagnetic Fields and Interference

Epidemiological and biological studies have not been conclusive in determining if any link exists between electromagnetic field (EMF) exposure and health impacts. As a result, regulations regarding EMF exposure have not been promulgated by the Federal government or by any states; some states have, however, established guidelines as described below.

Two states (Florida and New York) have issued guidelines for maximum EMF intensities associated with transmission lines, and a number of national and international agencies have suggested interim guidelines for EMF exposure. The two state guidelines and the national and international interim guidelines have been adopted as evaluation criteria in this report; they are summarized in Table 1.1-12. The two state guidelines are designed to limit emissions from new facilities, but clearly state that they are not based on conclusions regarding the potential health impacts of EMF. There are no applicable evaluation criteria for electromagnetic interference.

All site refinements, except the New London feeder line route, resulted in no net change to the population estimates provided in the DEIS/R. The New London feeder line route resulted in an increase in potentially exposed residents, but a decrease in the industrial/commercial potentially exposed population. Overall, the electrical facility location modifications resulted in increases to potential exposed residential population of approximately 244 (current) and 268 (projected) people within the 150-foot study area. Conversely, the current and projected employee population estimates decreased by 174 and 190 employees, respectively. Chapter 5 of this volume discusses EMF impacts in greater detail.

For radio interference, the potential impacts were assessed by examining previous experience with electrified train lines. In the absence of any relevant evaluation criteria, the Federal Communications Commission (FCC) and the Communications Division of the U.S. Coast Guard were contacted to determine if the existing electrified section of the NEC has been a source of radio communications interference. The Coast Guard reported that although it uses high frequency (HF), very high frequency (VHF), and ultrahigh frequency (UHF) communications equipment, it had not experienced any interference as a result of the existing electrified rail line between New York and New Haven.[1] The FCC indicated that it had no knowledge of any interference with radio or television communications resulting from the existing electrified rail line.[2] Thus, no impact to radio and television communication is anticipated.

TABLE 1.1-12 Evaluation Criteria for EMF Emissions

IMPACT CRITERIA	MEASURE	SIGNIFICANCE THRESHOLD
Level of EMF Exposure	Florida DER[1] Guideline for Edge of Right-of-Way of Transmission Line	150 mG[2] for ≤ 230 kV 200 mG for ≤ 500 kV 250 mG for ≤ 500 kV, closed circuit
	New York SPSC[3] Guideline for Edge of Right-of-Way of Transmission Line	200 mG for ≥ 345 kV
	ACGIH[4] Interim Guideline for Occupational Exposure	10,000 mG for 60 Hz
	CDRH/FDA[5] Interim Guideline for General Exposure	5,000 mG for static field
	IRPA/INIRC[6] Interim Guideline for: 24 hr/day Public Exposure Whole Day Occupational Exposure Few Hours Occupational Exposure	 1,000 mG for 50-60 Hz 5,000 mG for 50-60 Hz 50,000 mG for 50-60 Hz
	NRPB[7] Interim Guideline for General Exposure	2,000 mG for < 100 Hz
	DIN[8] Interim Guideline for General Exposure	46,000 mG root-mean-square[9] amplitude for 50 Hz 69,000 mG peak amplitude for 50 Hz

Notes: [1]Florida Department of Environmental Regulation.
[2]mG - milliGauss
[3]New York State Public Safety Commission.
[4]American Conference of Governmental and Industrial Hygienists.
[5]Center for Devices and Radiologic Health of the Food and Drug Administration.
[6]International Non-Ionizing Radiation Committee of the International Radiation Protection Association.
[7]National Radiological Protection Board (Great Britain).
[8]Deutsche Elektrotechnische Kommission (Germany).
[9]Root-mean-square is a procedure for averaging data.

Source: Roy F. Weston, Inc., 1993

1.1.6 Visual and Aesthetic Resources

This section provides an evaluation of the potential effects of the design modifications on visually and architecturally sensitive areas in close proximity to the facility sites. The objectives of this evaluation are to determine the visual effect of the design modifications on views from visually sensitive receptors (VSR) and to determine the compatibility of electrification facilities with the character of architecturally sensitive areas (ASA). VSRs are comprised primarily of residences in the coastal areas of Connecticut and Rhode Island where the rail line abuts the Long Island Sound and Greenwich Bay, respectively. Table 1.1-13 describes the criteria, measures of impact, and thresholds for determining visual and architectural impacts that may require mitigation.

None of the modified facility sites would have an adverse impact to visual and aesthetic resources except the Noank Paralleling Station. One component of the relocated Noank station could visually impact surrounding areas. Under the current design, the component known as the gantry would extend approximately 10 feet above the existing tree line. Unless the gantry can be redesigned, this facility would be out of scale and character with the scenic areas surrounding the site.

TABLE 1.1-13 Evaluation Criteria for Visual and Architectural Impacts

IMPACT CRITERIA	MEASURE	SIGNIFICANCE THRESHOLD
Project-generated effect on VSRs	Existing views of waterfront or scenic area would be permanently impaired or diminished	Visual Modification Classification of 3 or 4
Project-generated effect on ASAs	New structure would be out of scale in height or mass, or out of character in style or substance from existing neighborhood	None

Source: DMJM/Harris, 1993

1.1.7 Natural Resources

This section summarizes the anticipated effects of the site modifications for the proposed electrification upon the natural environment in proximity to the relocated facility sites. The methods for identifying these resources are described below.

1.1.7(a) Methods of Analysis

Wetlands. Wetlands within the study area were identified by the interpretation of available data including National Wetlands Inventory (NWI) maps prepared by the U.S. Fish and Wildlife Service (USFWS), Soil Conservation Service Soil Surveys, and state and local wetlands and soil maps; and through field verification of the presence of wetlands during site walks of the project sites.

Wildlife Habitat. Fish and wildlife resources in the NEC project study area include amphibians, reptiles, birds, and mammals. Previous studies, contact with government agencies, and existing and project-specific field review data were utilized to make determinations of whether species or habitat types occur in the study area.

The NEC passes through two land areas identified as Areas of Critical Environmental Concern (ACEC) by the Massachusetts Department of Environmental Protection (DEP). These are the Fowl Meadow/Ponkapoag Bog and Canoe River ACECs. These areas are considered to be unique clusters with natural and human resource values worthy of a high level of concern and protection. Additional efforts are made to preserve and restore these areas and all Massachusetts Executive Office of Environmental Affairs (EOEA) agencies are directed to evaluate actions with this in mind. Apart from Massachusetts, there are other protected areas in the corridor, most notably the Great Swamp in Rhode Island.

Threatened and Endangered Species. Species, communities, and natural resource areas that are considered threatened or endangered are protected by the Endangered Species Act of 1973. Protected species are defined as species which are currently listed as endangered, threatened, or a species of special concern. The USFWS has been delegated the responsibility for administering the Endangered Species Act and maintains a list of species which are: endangered, i.e., in danger of extinction throughout all or a significant portion of its range; or threatened, any species which is likely to become an endangered species within the foreseeable future throughout all or a significant part of its range.

Floodplains. The study area crosses a variety of floodplains associated with rivers, streams, and surface waters. Since the Proposed Action may impact some portion of the floodplain, an evaluation of potential effects to the floodplains is required pursuant to the provision of Executive Order 11988 (Floodplain Management), 23 CFR 650A, and the National Flood Insurance Program. The Federal Emergency Management Agency (FEMA), which is charged with the administration of floodplain requirements, has mandated that local and state agencies be notified prior to the commencement of work in any area that would be inundated by a 100-year storm event. A 100-year storm is defined as a storm having a 1 percent chance of occurring in any given year. Data for the floodplain section of this report was taken from flood insurance studies conducted for FEMA and HUD.

Coastal Resources. Coastal resources include coastal waters, related marine and wildlife habitat, and adjacent shorelands, which together constitute an ecosystem of both terrestrial and estuarine environments. Examples of these resources include coastal bluffs, shorefronts, beaches and dunes, intertidal flats, tidal wetlands, adjacent freshwater wetlands, estuarine embayments, coastal hazard areas, developed shorefront, nearshore waters, islands, shorelands, and shellfish concentration areas. All coastal resources were identified, delineated, and classified according to accepted methods.

Ground and Surface Water Resources. The construction of railroad improvements and associated structures such as those associated with the Proposed Action has the potential to adversely impact groundwater quality during the construction phase by the alteration of the terrain and the staging of construction equipment and supplies, and subsequently by increased urban runoff from paved areas. Shallow sand and gravel aquifers are susceptible to contamination by water quality contaminants in runoff. While less susceptible than consolidated aquifers, bedrock aquifers are also subject to contamination by polluted recharge. The addition of impervious surfaces and the potential for localized diversion of runoff may have some impact upon groundwater recharge.

Surface water (ocean, lake, pond, river, and stream) is an important resource not only for human and wildlife consumption, but also for recreation. Each of the three states provides water quality standards for evaluating impacts from activities (particularly dredge and fill) that may affect such resources.

The criteria used to evaluate the project impacts on natural resources are summarized in Table 1.1-14. Chapter 8 of this volume discusses natural resource impacts in greater detail.

TABLE 1.1-14 Evaluation Criteria for Impacts to Natural Resources

RESOURCE	IMPACT CRITERIA	MEASURE	SIGNIFICANCE THRESHOLD
Wetlands	Alteration[1] or destruction of wetland or resource area[1] including dredge or fill.	Volume or area of wetland or resource area altered or destroyed by the project; change in flow of water into or from a wetland.	Violation of Federal or state limitations.
	Effect of project on functional value[1] of wetlands or resource area.[1]	Potential for altering character of wetland; project-generated change in functional value of wetland.	Any alteration or adverse impact on functions or areas subject to protection.
Habitat and Wildlife	Effect of project on wildlife habitat (including wetlands), resources, migration, and critical life stages (breeding, nesting, spawning, and migration).	Amount, functional value, and regional scarcity of wildlife habitat; project-generated change of carrying capacity of wildlife habitat; project activity during critical life stages.	Predicted long-term displacement of wildlife or blockage of migratory routes. Predicted long-term change in habitat incompatible with the existence of wildlife.
	Effect of project on Special Protected Areas.	Change in qualities or characteristics that make area eligible for special protection.	Any impact triggers agency review.
Endangered Species	Effect of project on habitat or local population of threatened or endangered species and species of general concern	Project-generated change in carrying capacity of habitat; project activity during critical life stages.	Any predicted change in habitat or blockage of migratory routes. Any action that jeopardizes threatened and endangered species or species of special concern.
Floodplains	Effect on human health and safety and property downstream.	Project-generated change in flood storage volume.	Net reduction in flood storage capacity.
	Effect on natural beneficial values of floodplain.	Same as above.	Same as above.
Water Resources	Stormwater runoff effects during and after construction.	Amount, duration, and extent of project-generated increase in runoff and contaminant or sediment transport.	Potential for violation of Federal or state water quality criteria and standards; sedimentation of wetlands or surface water.

Notes: [1]As defined in Federal and state regulations.

Source: Smart Assoc., 1994

1.1.7(b) Branford Substation

Wetlands. There are no wetlands associated with the Branford Substation site. A forested wetland does occur within 50 feet of the site on the west side of the facility access road.

Habitat and Wildlife. Site characteristics include a mixed forest community with steep slopes associated with the south and west sides. The New Haven County Soil Survey describes site soils as Urban Land with Cheshire fine sandy loam and Weathersfield loam. Wildlife noted included songbirds; however, the forested nature of the site and lack of diversity limit the overall value to wildlife. Potential habitat and wildlife impacts associated with the Branford Substation are insignificant.

Endangered Species. The Connecticut Natural Diversity Database Search indicated no Federal or State Endangered, Threatened, or Special Concern Species.

Floodplains. The substation site does not impact any floodplains, according to the FEMA Flood Insurance Rate Map for Branford, Connecticut, Community Panel 090073-0005C.

Coastal Resources. The Connecticut Coastal Resources map (Branford Quadrangle, 1979) indicates the proposed substation site and utility corridors are outside of the Coastal Boundary.

Water Resources. There are several private water supply wells in the area east of this substation site. However, none of these wells occurs in proximity to the site, or would be expected to be impacted by this facility. No record of municipal wells exists in the area of the project according to the Town Planning Department. Lake Saltonstall, a water supply reservoir, is located approximately 1,200 feet to the west of the substation site and would not be affected by the project.

No direct impacts to any wells or water supplies would be expected as a result of the development of the substation site. A potential indirect impact to the private wells adjacent to the site could result from accidental discharge from on-site storage or maintenance of construction vehicles.

Summary of Impacts. No significant impacts are anticipated to any of the resource categories.

1.1.7(c) Westbrook Switching Station

Wetlands. There are no wetlands on the proposed site. Wetlands in the vicinity include a small isolated pocket of scrub-shrub wetlands approximately 55 feet from the south side of the proposed facility, a large forested wetland on the west side of School House Road, and a small emergent wetland across the tracks to the north. No direct impacts to wetlands or degradation of adjacent wetland characteristics are expected. Potential indirect impacts could be from erosion and sedimentation.

Habitat and Wildlife. Characteristics of the area include a large industrial warehouse/office complex immediately adjacent to the south and scattered housing to the north. The site is currently dominated by a mowed lawn. The Middlesex County Soil Survey indicates the site is Paxton and Montauk fine sandy loams. The surrounding wetlands and diverse habitats in the area add to the diversity of wildlife habitat values; however, the limited cover restricts wildlife habitat values. Because of the lack of cover and industrial land use, there would be no significant impact to habitat and wildlife.

Endangered Species. The Connecticut Natural Diversity Database Search indicated no Federal or State Endangered, Threatened, or Species of Special Concern.

Floodplains. The proposed site does not impact any floodplains; according to the FEMA Flood Insurance Rate Map for Old Saybrook, Connecticut, Community Panel 090069-0004D.

Coastal Resources. The Connecticut Coastal Resources Map (Essex Quadrangle, 1979) indicates the proposed switching station site is outside the Coastal Boundary.

Water Resources. The Health Department for the Town of Old Saybrook indicated no municipal wells exist in the area of the project. However, a non-operating industrial processing well is located within 50 feet of the site. No groundwater protection districts are located in the vicinity of the site. Surface waters include a large forested wetland on the west side of School House Road. Direct impacts to water resources are not expected at this site. Indirect impacts could be from erosion and sedimentation.

Summary of Impacts. No impacts are anticipated to any of the resource categories.

1.1.7(d) Millstone Paralleling Station

Wetlands. There are no wetlands occurring on the site. A narrow drainage channel does occur across the railroad tracks within 50 feet of the site which eventually empties into a tidal marsh approximately 500 feet away. Although possessing limited wetland vegetation, the fill materials in which the drainage area is located do not qualify as poorly drained or hydric soils. No direct impacts to wetlands or degradation of adjacent wetland characteristics are expected.

Habitat and Wildlife. Situated within a managed vegetative community associated with power lines (the Millstone Station power lines are directly overhead), site characteristics include an open field/shrub community with no overstory species. Adjacent habitats include mixed hardwood forest and estuarine marsh. The New London County Soil Survey describes the site soils as Chatfield-Hollis fine sandy loam.

As part of a vegetative community which provides forest openings as well as edge habitat, the paralleling station site would provide wildlife habitat values to many species, especially songbirds which can utilize the shrubs. Overall, however, the proposed paralleling station would have an insignificant impact on habitat and wildlife, with the power line corridor and similar habitat types continuing to the north.

Endangered Species. The Connecticut Natural Diversity Database Search indicated no Federal or State Endangered, Threatened, or Species of Special Concern.

Floodplains. The site does not impact any floodplains, according to the FEMA Flood Insurance Rate Map for Waterford, Connecticut, Community Panel 090107-0015E.

Coastal Resources. The Connecticut Coastal Resources Map (Niantic Quadrangle, 1979) indicates the proposed switching station site would be considered Shorelands within the Coastal Boundary. As such, this site would be subject to provisions of the Connecticut Coastal Management Act. As Shorelands, which are described as upland communities not subject to dynamic coastal processes, the development of this site would be expected to be consistent with the policies set forth in C.G.S. section sa-92 and is not considered to have a significant impact.

Water Resources. The Town Planning Department indicates no municipal wells are located in the vicinity. Although a stratified drift aquifer is situated to the east, no groundwater protection districts or formal restrictions are in place. The Millstone Station power plant has industrial process water wells in the general area of the proposed site. Surface waters include a narrow drainage ditch on the north side of the tracks. However, the drainage ditch would not be disturbed. Potential indirect impacts could be from erosion and sedimentation.

Summary of Impacts. No significant impacts are anticipated to any of the resource categories.

1.1.7(e) New London Utility Corridor

Wetlands. No wetlands occur along the utility corridor. No direct wetland impacts are associated with the substation feeder line.

Habitat and Wildlife. The power line would be buried underground and is not expected to disturb existing vegetation or communities. The utility corridor will be in defined utility easements and avoid disturbing the hardwood forested/parkland habitat of Riverside Park.

Endangered Species. The Connecticut Natural Diversity Database Search indicated no Federal or State Endangered, Threatened, or Species of Special Concern are associated with the substation site.

Floodplains. The utility corridor is located within a 500-year floodplain and within the 100-year floodplain at the substation site. The utility corridor would be within existing topography and would not change associated slopes and floodplain storage.

Coastal Resources. The Connecticut Coastal Resources map (New London Quadrangle 1979) indicates the site lies within the Coastal Boundary. All potential adverse impacts to coastal flood hazard areas or other coastal resources would be minimized as defined in C.G.S. section 22a-93(15). Degradation of coastal resources along the utility corridor as well as the coastal resources associated with the Shorelands portion of the site would not be expected to be impacted by the temporary disturbance associated with construction activities.

Water Resources. The City Engineer's office has no record of municipal or private water wells. Surface water associated with the utility corridor is restricted to the Thames River, approximately 400 feet adjacent to the corridor. Indirect impacts to water resources from erosion and sedimentation are not anticipated.

Summary of Impacts. No significant adverse impacts are anticipated to any of the resource categories.

1.1.7(f) Noank Paralleling Station

Wetlands. A scrub-shrub wetland occurs adjacent to the proposed site, located southeast of the intersection of Groton Long Point Road and Elm Street. This wetland appears to be connected to a larger phragmites wetland to the southeast of the site, which flows into Palmer Bay to the west. The proposed facility is sited to avoid direct impacts to the wetlands. Indirect impacts to the wetland could be from erosion and sedimentation.

Habitat and Wildlife. Site characteristics include steep road embankments on the north and west sides and a gently sloping site from the northwest to southeast. Vegetation on most of the site includes an extremely dense layer of vine. The density of the vines on this site preclude most wildlife values other than songbird habitat and small mammal cover and nesting. The New London County Soil Survey indicates the site is primarily Charlton-Hollis fine sandy loams.

Direct impacts to wildlife would be limited due to the availability of similar habitats adjacent to the rail line. Construction of the proposed paralleling station would not be expected to impact significantly the overall habitat and wildlife values in the area.

Endangered Species. The Connecticut Natural Diversity Database Search indicated no Federal or State Endangered, Threatened, or Species of Special Concern.

Floodplains. The proposed site is not within the 100-year floodplain, according to the FEMA Flood Insurance Rate Map for Groton, Connecticut, Community Panel 090129-0002B.

Coastal Resources. The Connecticut Coastal Resources Map (New London, 1979) indicates the proposed site lies within the Coastal Boundary. The site is listed as Shorelands, an upland community not subject to dynamic coastal processes, and is not considered to have a significant impact.

Water Resources. The Planning Department in Groton indicates no municipal wells or water protection districts associated with the proposed site.

Summary of Impacts. No significant impacts are anticipated to any of the resource categories.

1.1.7(g) Richmond Switching Station
Wetlands. No wetlands occur on the proposed site. Wetlands are adjacent to the site; however, no direct impact to the adjacent wetlands are anticipated. Potential indirect impacts could be from erosion and sedimentation.

Habitat and Wildlife. Site characteristics include a 70-foot-wide ROW with limited vegetation. Outside the fenced ROW, vegetation includes red pine, black oak, and little bluestem. The adjacent area includes an old factory complex to the northeast. Overall, the proposed site provides little wildlife value with its disturbed soils, fenced surroundings, and limited vegetation. Impacts to habitat and wildlife would be insignificant.

Endangered Species. The Rhode Island Natural Heritage Program indicates no rare species occurrences in the vicinity.

Floodplains. The proposed site is not within a 100-year floodplain, according to the FEMA Flood Insurance Rate Map for Richmond, Rhode Island, Community Panel 440031-14.

Coastal Resources. The site lies outside the area of coastal influence and the jurisdiction of the Coastal Resources Management Program.

Water Resources. No municipal wells or water protection districts occur on the site. The watershed of the Wood and Pawcatuck Rivers, in which this site is located, has been designated a Sole Source Aquifer area by EPA. According to the Charlestown Comprehensive Plan (1991), the site is located within a high-yield aquifer and recharge area. Surface waters associated with the site include the Meadow Brook, approximately 250 feet northwest of the western edge of the proposed station.

No direct impacts to water resources are expected at this site. Its location in a Sole Source Aquifer area requires a review by EPA to determine if siting the project at this location could contaminate the aquifer or cause a public health hazard. No municipal wells are located in the vicinity. Any potential contaminants from runoff are expected to have an insignificant indirect impact. Transformers and electrical equipment associated with the operation do not contain PCBs and generally do not pose a threat to water quality.

Summary of Impacts. No significant impacts are anticipated to any of the resource categories.

1.1.7(h) Elmwood Paralleling Station
Wetlands. No wetlands occur on the site. Mashapoag Pond is located over 1,200 feet north, beyond any buffer zone regulated by the Rhode Island Department of Environmental Management (RIDEM).

Habitat and Wildlife. The proposed site is located south of the Reservoir Avenue bridge in an industrial rail siding area. Site characteristics include industrial buildings to the east and west of the tracks. Vegetative cover is scattered across the site. With limited vegetation in a heavily developed area, the site provides very limited wildlife habitat values. The development of the site would not be expected to impact wildlife habitat.

Endangered Species. The Rhode Island Natural Heritage Program indicates no rare species occurrences in the vicinity.

Floodplains. The proposed site does not impact any floodplains, according to the FEMA Flood Insurance Rate Map for Providence, Rhode Island, Community Panel 445406-0007E.

Coastal Resources. The site lies outside the area of coastal influence and the jurisdiction of the Coastal Resources Management Program.

Water Resources. No municipal water wells or water protection districts are located in the vicinity, according to the City Planning Department. Adjacent surface waters include Mashapoag Pond, located approximately 1,200 feet to the north. Direct impacts to water resources are not expected due to the lack of wells in the vicinity and the distance to Mashapoag Pond.

Summary of Impacts. No significant impacts are anticipated to any of the resource categories.

1.1.7(i) Providence Paralleling Station

Wetlands. There are no wetlands occurring on the proposed site, or within 100 feet of the area.

Habitat and Wildlife. The site is currently used as a fenced storage yard and thus lacks overstory or herbaceous species. Adjacent habitat includes scattered hardwoods. The Rhode Island Soil Survey describes the site soils as Udorthents - Urban Land Complex. Availability of habitat to wildlife is limited due to the restricted access, with I-95 and a chain link fence on the west side and industrial land use predominant around the rest of the site. Overall, the site has no cover or vegetative diversity to provide wildlife habitat values; therefore, construction of the paralleling station would have an insignificant impact to habitat and wildlife.

Endangered Species. The Rhode Island Natural Heritage Program indicates no rare species occurrences in the vicinity.

Floodplains. The site does not impact any floodplains, according to the FEMA Flood Insurance Rate Map for Pawtucket, Rhode Island, Community Panel 440022-0002D.

Coastal Resources. The site lies outside the area of coastal influence and outside the jurisdiction of the Coastal Resources Management Program.

Water Resources. The Pawtucket Planning Office indicates no municipal wells exist in the vicinity. Surface waters associated with the site are limited to the Moshassuck River, located approximately 400 feet to the east across the interstate highway. The Moshassuck River also crosses under the railroad approximately 1,200 feet to the north. Direct impacts to water resources are not expected, since no public wells or groundwater reservoirs are located in the vicinity.

Summary of Impacts. No significant impacts are anticipated to any of the resource categories.

1.1.7(j) Canton Paralleling Station

Wetlands. There are no wetlands occurring on the proposed site. A large forested and emergent wetland exists to the south, with a small finger of wetlands which meet the Massachusetts vegetative criteria occurring within 100 feet of the site. The site does occur within the 100-foot wetland buffer zone regulated by the State of Massachusetts and is not considered to have a significant direct impact. No direct impact to the adjacent wetland is expected to occur.

Habitat and Wildlife. Site characteristics include a mixed hardwood/white pine forest community with an open field power line easement located between the site and the right-of-way. The Norfolk County Soil Survey describes the site soils as well drained Canton fine sandy loams. The wildlife habitat functions this area may provide are more closely related to the juxtaposition of woods and open field habitats. However, the overall impact to habitat and wildlife would be expected to be insignificant since similar habitats are available to wildlife in the surrounding area.

Endangered Species. A Massachusetts Natural Heritage Database search indicated no rare species or significant natural communities near the site.

Floodplains. The site does not impact any floodplains, according to the FEMA Flood Insurance Rate Map for Sharon, Massachusetts, Community Panel 440032-0029A.

Coastal Resources. The site is located outside the area of coastal influence and the Coastal Zone Boundary.

Water Resources. The site is located outside the area of any wells, surface water protection district, or groundwater protection district for the Town of Sharon, according to the Town of Sharon Zoning Map (1989). No impacts to water resources are expected since no municipal wells or aquifer protection districts are associated with the site.

Summary of Impacts. No significant impacts are anticipated to any of the resource categories.

1.1.7(k) Readville Paralleling Station

Wetlands. No wetlands occur on the proposed site. No wetlands occur within the 100-foot buffer zone regulated by the State of Massachusetts and the City of Boston. Thus, the site does not have a significant adverse impact.

Habitat and Wildlife. Site characteristics include a lack of overstory. Surrounding land use includes a major train yard and passenger station, and industrial/residential development. The Suffolk County Soil Survey indicates the area soils are Udorthents, described as a loamy fill material. Wildlife use of the area is limited by the lack of vegetative diversity and available cover. The site lies approximately 250 feet inside the northern boundary of the Fowl Meadow ACEC. A review will be required by the Commonwealth of Massachusetts, Department of Environmental Management, Inland ACEC Program under 301 CMR 12.00 of the Massachusetts Code of Regulations. However, habitat and wildlife impacts associated with the site are insignificant since the project area is heavily developed and the presence of these resources is limited. Located in a heavily developed area with a large rail yard adjacent, development of this station would have an insignificant impact upon the limited habitat and wildlife of the area.

Endangered Species. A Massachusetts Natural Heritage Database Search indicated no rare species or significant natural communities near the site.

Floodplains. The proposed site does not impact any floodplains, according to the FEMA Flood Insurance Rate Map for Boston, Massachusetts, Community Panel 250286-0028C.

Coastal Resources. The site is located outside the area of coastal influence and the Coastal Zone Boundary as noted in 30 CMR 20.99 of the Massachusetts Code of Regulations.

Water Resources. No municipal water wells or water protection districts are located in the vicinity of the proposed site, according to the Boston Conservation Commission and the Massachusetts DEP. There are no surface waters associated with this site. No impacts to water resources are expected.

Summary of Impacts. No significant impacts are anticipated to any of the resource categories.

1.2 RESTORED TRACK SIDINGS

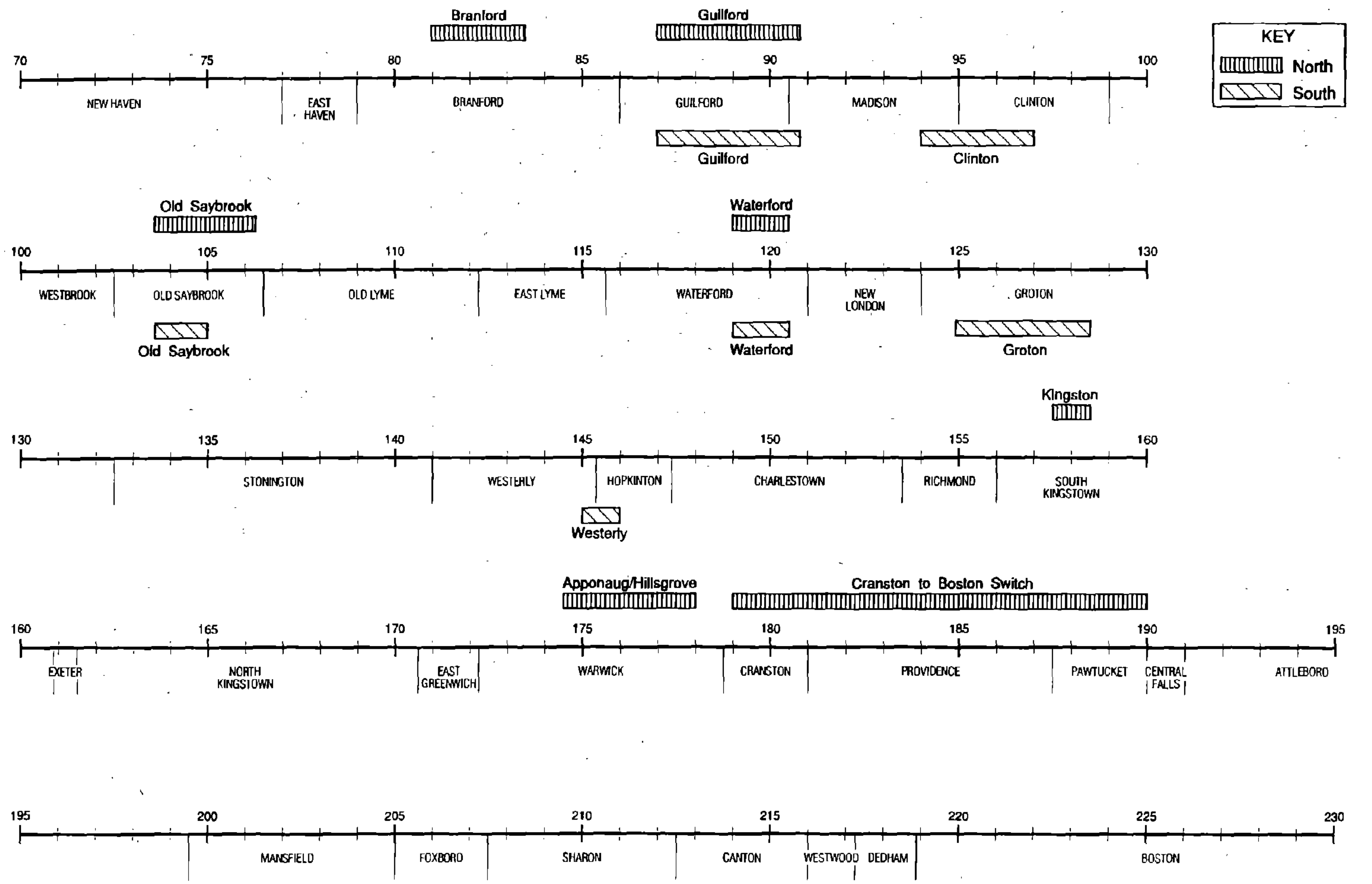
The projected year 2010 increase in daily passenger train service for the Proposed Action and No-Build Alternative - FF-125 and FRA-150 scenarios could conflict with freight rail traffic along portions of the NEC. Estimates of the potential interference from the increased passenger rail traffic is presented in Section 4.2, Volume I, of the FEIS/R. The analysis shows that windows of freight rail operations along the NEC could restrict future passenger rail service. A mitigation technique, as suggested in Chapter 5 of Volume I of the FEIS/R, that would allow the faster and more frequent passenger trains to operate simultaneously with the slower freight trains could be to provide separate lengths of track, at select intervals along the NEC, for a freight train to occupy while the faster passenger train continues unimpeded. These track lengths are commonly called sidings. Sidings would include restoring and/or installing rails for the Proposed Action and No-Build Alternative - FF-125 and FRA-150 scenarios. Because the main and siding tracks would be so close together, a portal structure supporting the catenary system would be required to span all the tracks for the Proposed Action.

An examination of the rail corridor indicates that several areas of abandoned sidings exist and could be restored. Figure 1.2-1 and Table 1.2-1 show the approximate locations of the proposed sidings. The locations of the sidings in Table 1.2-1 are an approximation for planning purposes. The siding lengths are generous to provide an opportunity for refining final locations based on environmental constraints.

The following analysis identifies some of the environmental impacts of the sidings for their potential use as mitigation. The analysis presented here was accomplished at a planning level to determine the initial feasibility of the use of sidings as a mitigation technique for year 2010 passenger and freight rail conflict. The sidings were reviewed for their potential impact on land use, historic resources, archaeology, visual and aesthetic resources, and wetlands. These impact categories were selected based on their potential of having a significant impact. Impacts are identified at this initial planning level to: (1) help determine whether sidings could useful as a potential mitigation technique, (2) help identify areas where future in-depth analysis should be focused, and (3) identify which sections of a particular siding should be avoided due to the significance of the potential environmental impact.

1.2.1 Land Use

The Proposed Action and the No-Build Alternative - FF-125 and FRA 150 scenarios would each require the same siding locations; thus their potential impacts would be the same. The small amount of additional land required for the Proposed Action's portal structure base would not be a consideration at this level of planning. Based on aerial photographic interpretation, a large section of the proposed Rhode Island siding ROWs and some of those in Connecticut are currently intact, and restoring them would not affect surrounding land uses. Aerial photographs indicate the addition of a third track in some locations along the NEC may be in close proximity to private and commercial structures and intersect existing bridges; this suggests a potential impact to existing land use.



RESTORED TRACK SIDINGS LOCATIONS

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 1.2-1

TABLE 1.2-1 Restored Track Sidings

SIDING	TRACK LOCATION[1]	MILEPOST LIMITS	CITY/TOWN LOCATION
Branford	North	81.0 - 83.5 (2.5 miles)	Branford, CT
Guilford	North	87.5 - 90.8 (3.3 miles)	Guilford and Madison, CT
	South	87.5 - 90.8 (3.3 miles)	Guilford and Madison, CT
Clinton	South	94.0 - 97.0 (3 miles)	Madison and Clinton, CT
Old Saybrook	North	103.6 - 106.3 (2.7 miles)	Old Saybrook, CT
	South	103.6 - 105.0 (1.4 miles)	Old Saybrook, CT
Waterford	North	119.0 - 120.5 (1.5 miles)	Waterford, CT
	South	119.0 - 120.5 (1.5 miles)	Waterford, CT
Groton	South	124.9 - 128.5 (3.6 miles)	Groton, CT
Westerly	South	145.0 - 146.0 (1.0 mile)	Westerly, RI
Kingston	North	157.5 - 158.5 (1.0 mile)	South Kingstown, RI
Apponaug/Hillsgrove	North	174.5 - 178.0 (3.5 miles)	Warwick, RI
Cranston to Boston Switch	North	179.0 - 190.0 (11 miles)	Cranston-Providence Pawtucket-Central Falls, RI

Notes: [1]New Haven to Boston rail line is considered to be in a west-to-east direction

Source: DMJM/Harris, 1994

1.2.2 Historic Resources

The historic resources associated with the siding locations are identified in Sections 3.3 and 4.3, Volume I of the FEIS/R. An effect to historic resources is defined as adverse when it may diminish the integrity of the historic property's location, design, setting, materials, workmanship, feeling, or association. Based on the historic resource inventory compiled in Volume I, none of the sidings would physically damage all or part of a historic property. Because restoring the sidings should not physically damage historic properties, the remaining adverse impact could be from diminishing the character of the historic property's setting. The

No-Build Alternative - FF-125 and FRA-150 scenarios would not require constructing catenary or portal structures and, therefore, would not have an adverse impact on the historic property's setting. However, adverse impacts from the Proposed Action's overhead portal structure could be associated with altering the character of the property's setting, resulting in an adverse impact. Of the 10 proposed siding locations, two could have adverse impacts to historic resources: both the Old Saybrook Station and Freight House (MP 105.04) and the Old Saybrook Interlocking Tower (MP 105.08) could be adversely impacted by the Old Saybrook siding; and the Kingston Railroad Station (MP 158.20) could be adversely impacted by the Kingston siding. Each of the adversely impacted historic resources was already identified in Volume I of the FEIS/R as being adversely affected if a catenary structure was constructed near the respective locations. Exchanging the overhead catenary system for the siding portal structure is considered not to be an increase in adverse impact. Therefore, there would be no further impact to historic structures than that caused by the proposed catenary, and the sidings would have no impact on historic resources.

1.2.3 Archaeology

Both track and portal structures were assessed for their potential impact on archaeological resources. The archaeological survey for the track sidings was conducted in two phases. First, a literature search was made to assess the potential of each project area for containing archaeological remains. Second, a site visit was performed to determine if the site was disturbed. Based on the combination of the literature search and actual site conditions, a sensitivity was assigned to indicate the potential of finding archaeological resources. Because the Proposed Action and the No-Build Alternative - FF-125 and FRA-150 scenarios would require disturbing the same area for track siding renovation work, their potential impact to archaeological resources would be similar. Although the portal footings for the Proposed Action could disturb land adjacent to the existing siding locations compared to the No-Build Alternative scenarios, the disturbed land would be so close to the existing siding locations that the archaeological sensitivity would be considered the same. In each of the siding locations the ground has been extensively disturbed to the point that the potential of discovering archaeological significant resources is minimal. The extensive disturbance of each of the siding locations reduces their archaeological sensitivity to very low.

1.2.4 Visual and Aesthetic

Portal structures were assessed for their potential impact on visual and aesthetic resources. Section 3.11, Volume I of the FEIS/R, describes specific locations along the NEC that could be visually impacted by the overhead catenary system. There are no visually sensitive resources located near the sidings. Therefore, the sidings for the Proposed Action and the No-Build Alternative - FF-125 and FRA-150 scenarios would not have an impact on visual and aesthetic resources.

1.2.5 Wetlands

Both track and portal installation were assessed for their impact on placement wetlands. Wetlands were identified after a wetlands biologist field-verified each of the proposed siding locations. Wetland vegetation was used as the criterion for wetland identification, and wetlands were approximated, but not delineated, in the field. The wetlands were approximated for planning purposes and are considered a reasonable representation of the field conditions. The Proposed Action and the No-Build Alternative - FF-125 and FRA-150 scenarios would each require the siding tracks to be constructed in the same way; thus, their impacts would be the same. Because some of the areas considered as potential locations of siding tracks included wetlands, there could be direct impacts to wetlands. Table 1.2-2 shows the location and approximate amount of potential wetlands disturbed from constructing the siding tracks. Based in part on this analysis, the sidings included in the mitigation required in this project (see Section 5.1.1 of Volume I) were adjusted to avoid these wetlands. Therefore, no impact is anticipated.

In addition to the construction of the siding tracks, the Proposed Action could require portal structures to span three or four tracks to support the catenary wires. The portal structure footings may need to be placed outside of existing disturbed surface areas. In some instances these footing areas would be in wetlands and could have an adverse impact as opposed to the No-Build Alternative - FF-125 and FRA-150 scenarios. Thus, the following wetland impact analysis concentrates on the Proposed Action portal structure footings. If wetlands are within 25 feet of the center of the tracks and a footing was to be located within the 25 feet, the footing was considered to have a direct impact. The footings could disturb an area of approximately 5 feet by 5 feet. Table 1.2-3 lists the amount of wetlands that could be directly disturbed by the Proposed Action portal structure footings. The majority of siding locations are projected to have minor direct impacts to wetlands. The Guilford siding could have a direct significant adverse impact to wetlands, disturbing approximately 875 feet.[2]

Construction of the siding tracks for the Proposed Action and the No-Build Alternative - FF-125 and FRA-150 scenarios could lead to indirect impacts to wetlands from construction runoff. If a wetland was determined to be within 100 feet of the center of the track, an indirect impact could result. Table 1.2-4 lists the wetlands that could be indirectly impacted. In each siding there is a potential for indirect impacts to wetlands, with the greatest potential at the Guilford site. However, such indirect impacts can be avoided through appropriate mitigation. Such mitigation is included in Sections 5.1.1 and 5.1.2 of Volume I of the FEIS/R.

1.3 FENCING AT ILLEGAL PEDESTRIAN CROSSINGS

Illegal pedestrian crossings along the NEC could lead to safety concerns for the faster moving train alternatives. A possible mitigation measure could be to install fencing at these locations. Wildlife impacts arising from fence locations were noted in the comments received by RIDEM as well as in comments from the general public. The wildlife assessment of these impacts and review of fencing locations were carried out through on-site review and agency input.

Fencing Locations: The length of new fencing would be limited to short segments, averaging less than 1,000 feet per site. All sites are associated with illegal pedestrian crossings (see Table 1.3-1).

Most of the fencing locations are associated with sensitive receptors or located in developed areas. Although fencing is not required, it is proposed to mitigate for potential public safety impacts. Although public safety is the overriding concern, these locations were also reviewed for impacts to wildlife, such as fragmentation of existing wildlife travel corridors.

Any type of fencing has the potential to become a problem with movement of wildlife, especially big game, if it restricts access to food and water or causes physical injury through entanglement. The fencing proposed for the NEC project is generally chain-link or woven-wire construction, which would reduce the potential for direct injury.

In order to minimize restrictions of wildlife movement, no new fencing is proposed within the sensitive habitats associated with the Fowl Meadow/Ponkapoag Bog ACEC in Massachusetts, the Great Swamp Wildlife Management Area in Rhode Island, or any of the wildlife management areas in Connecticut. New fencing is proposed adjacent to Rocky Point State Park for safety reasons.

TABLE 1.2-2 Directly Disturbed Wetlands From Siding Track

SIDING	TRACK LOCATION	MILEPOST LIMITS	DIRECTLY IMPACTED WETLANDS[1] (SF)
Branford	North	81.0 - 83.5 (2.5 miles)	500
Guilford	North	87.5 - 90.8 (3.3 miles)	8,500
	South	87.5 - 90.8 (3.3 miles)	
Clinton	South	94.0 - 97.0 (3 miles)	4,500
Old Saybrook	North	103.6 - 106.3 (2.7 miles)	0
	South	103.6 - 105.0 (1.4 miles)	
Waterford	North	119.0 - 120.5 (1.5 miles)	0
	South	119.0 - 120.5 (1.5 miles)	
Groton	South	124.9 - 128.5 (3.6 miles)	0
Westerly	South	145.0 - 146.0 (1.0 miles)	250
Kingston	North	157.5 - 158.5 (1.0 miles)	0
Apponaug/ Hillsgrove	North	174.5 - 178.0 (3.5 miles)	0
Cranston to Boston Switch	North	179.0 - 190.0 (11 miles)	0

Notes: [1]Disturbed area approximated for planning purposes. Wetlands were identified but were not delineated.

Source: DMJM/Harris, 1994

TABLE 1.2-3 Directly Disturbed Wetlands from Siding Portal Footings

SIDING	NUMBER OF PORTAL FOOTINGS	AREA DIRECTLY IMPACTED[1] (SF)	WETLANDS LOCATED WITHIN 25 FT FROM CENTER OF RAIL
Branford, CT	1	25	MP (83+490) to (83+550)=60 ft. (north)
Guilford, CT	1	25	MP (87+2,650) to (87+3,000)=350 ft. (north)
	4	100	MP (88+625) to (88+1,200)=575 ft. (north)
	16	400	MP (88+1,500) to (1,500+3,775)=2225 ft. (north)
	3	75	MP (89+600) to (89+825)=225 ft. (north)
	3	75	MP (89+2,100) to (89+2,600)=500 ft. (north)
	1	25	MP (87+2,650) to (87+3,000)=350 ft. (south)
	7	175	MP (88+1,500) to (88+2,500)=1000 ft. (south)
Clinton. CT	2	50	MP (93+5,270) to (94+20)=40 ft. (south)
	none	N/A	MP (95+1,930) to (95+1,950)=500 ft. (south)
	none	N/A	MP (95+1,370) to (95+1,430)=60 ft. (south)
Old Saybrook, CT	2	50	MP (105+2,905) to (105+3,080)=175 ft. (north)
Waterford, CT	1	25	MP (119+875) to (119+1,000)=125 ft. (north)
	4	100	MP (119+600) to (119+1,160)=560 ft. (south)
Groton, CT	none	N/A	MP (124+4,750) to (124+4,780)=30 ft. (south)
	2	50	MP (125+1,700) to (125+1830)=130 ft. (south)
Westerly, RI	2	50	MP (145+0) to (145+430)=430 ft. (south)
	1	25	MP (145+750) to (145+780)=30 ft. (south)
Kingston, RI	none	N/A	none
Apponaug/ Hillsgrove, RI	none	N/A	none
Cranston to Boston Switch, RI	none	N/A	none

Note: [1]Disturbed area approximated for planning purposes. Wetlands were identified but were not delineated. One footing disturbs a surface area of approximately 5 ft X 5 ft, equal to 25 square feet.

Source: DMJM/Harris, 1994

TABLE 1.2-4 Indirectly Disturbed Wetlands From Sidings

SIDING	SIDING LOCATION	SIDING MILEPOST LIMITS	WETLANDS (FT)
Branford	North	81.0 - 83.5 (2.5 miles)	3,000 (0.56 mile)
Guilford	North	87.5 - 90.8 (3.3 miles)	7,300 (0.38 mile)
	South	87.5 - 90.8 (3.3 miles)	8,000 (1.51 miles)
Clinton	South	94.0 - 97.0 (3 miles)	2,300 (0.43 mile)
Old Saybrook	North	103.6 - 106.3 (2.7 miles)	1,990 (0.37 mile)
	South	103.6 - 105.0 (1.4 miles)	1,330 (0.25 mile)
Waterford	North	119.0 - 120.5 (1.5 miles)	2,800 (0.53 mile)
	South	119.0 - 120.5 (1.5 miles)	3,400 (0.64 mile)
Groton	South	124.9 - 128.5 (3.6 miles)	5,500 (1.04 miles)
Westerly	South	145.0 - 146.0 (1.0 miles)	2,800 (0.53 mile)
Kingston	North	157.5 - 158.5 (1.0 miles)	700 (0.13 mile)
Apponaug/ Hillsgrove	North	174.5 - 178.0 (3.5 miles)	100 (0.01 mile)
Cranston to Boston Switch	North	179.0 - 190.0 (11 miles)	600 (0.11 mile)

Source: DMJM/Harris, 1994

TABLE 1.3-1 Fencing Locations

TOWN	LOCATION	MILEPOST	LENGTH (ft) (total-both sides)
CONNECTICUT			
Madison	Railroad Avenue	92.80	1,200
Clinton	Privateer LTD	96.00	900
Westbrook	No. Broadway	99.20	800
Westbrook	Westbrook Hgts Rd.	101.30	1,000
Old Saybrook	Boston Post Rd	105.20	1,600
Old Lyme	Near Shore Road	107.60	1,200
East Lyme	Ridgewood Drive	113.80	500
East Lyme	Gada Road	114.80	900
Groton	Near MP	128.30	900
Groton	Spicer Avenue	130.40	900
Stonington	Near MP	136.20	1,200
RHODE ISLAND			
Warwick	Old Baptist Rd.	168.50	1,100
Warwick	Rocky Hollow Rd.	170.00	5,400
Warwick	Queen Street	171.50	480
Warwick	Alger Avenue	172.90	150
Warwick	Folly Landing	173.90	275
MASSACHUSETTS			
Attleboro	Knight Street	193.70	900
East Foxboro	Morse/Summer Pl.	206.00	1,450
Sharon	Mohawk Avenue	208.50	1,000 (approx.)
Sharon	Garden Street	209.52	1,265

Source: DMJM/Harris, 1994

Site Review: Of the proposed new fencing locations, the following sites are predominately urban, commercial, or heavily developed locations, so only limited impacts to wildlife in the surrounding area would be expected.

- Madison - Railroad Avenue
- Clinton - Privateer LTD
- Westbrook - North Broadway
- Westbrook - Westbrook Heights Road
- Old Saybrook - Boston Post Road
- East Lyme - Gada Road
- Groton - Spicer Avenue
- Warwick - Old Baptist Road
- Warwick - Queen Street
- Warwick - Alger Avenue
- Warwick - Folly Landing
- Attleboro - Knight Street

The following fencing locations are somewhat less developed, and fencing would have limited impacts to the surrounding resources.

- East Lyme - Ridgewood Drive: This fencing location is adjacent to Rocky Point State Park in East Lyme. Installation of the fence would close off a segment of track with limited access in a developed area. Fencing would result in little impact to wildlife habitat.

- Groton - Near MP 128.3: Although this site is not in a heavily developed portion of the Town of Groton, fencing is proposed to limit access to an illegal crossing. Access to the road system, located to the south, would still be available through an underpass situated approximately 300 feet to the east. Impacts to the wildlife community would be expected to be minimal, as other access points are available.

- Sharon - Mohawk Avenue: The Mohawk Avenue location is a recently added site with extensive illegal crossing traffic. Due to the location adjacent to the Canoe River ACEC, fencing would be restricted to the west side of the tracks and limited to areas required to maintain safety. If these parameters are followed, fencing would not impact the adjacent wildlife habitat, which is a forested and marsh wetland.

- Sharon - Garden Street: The Garden Street site is located in a largely residential area, with an extensive wetland community to the south. The current fencing configuration would not be expected to impact on the adjacent wetland wildlife community; however, it is recommended that fencing on the south end be kept to the minimum required for public safety considerations.

The remaining sites would require modification to proposed fencing locations in order to minimize impacts to wildlife.

- Old Lyme - Near Shore Road: This site would be the most likely to impact wildlife habitat along the corridor. The crossing area is currently accessed by a dirt road from Shore Road which has no gate to restrict vehicle entrance. The crossing location is between an existing gravel road and an upland area which lies between two saltmarshes located on the south side of the tracks. The site to the south contains diverse upland vegetative cover and adjacent wetlands providing habitat for wildlife. Since there is also other available habitat located to the north, it would appear that fencing in this area would be inappropriate. The optimum measure would be a gate to restrict access to the site. If necessary, fencing should only be erected on the north side of the tracks.

- Stonington - Near MP 136.2: Located in the Stonington Village area, this site represents a crossing from the village to an area of limited development to the south. To limit impacts to the adjacent marsh community, fencing should be eliminated on the south side or limited to the minimum extent site safety allows.

- Warwick - Rocky Hollow Road: The RIDEM Division of Fish and Wildlife requested changes to this proposed fencing site. Located just north of Forge Road and continuing on to Rocky Hollow Road, in the East Greenwich area, this location has limited adjacent development on the southern half of the site. The proposed fencing would unnecessarily restrict movement. A revised fencing plan would limit any fence to the west (southbound) side of the tracks, south of the developed portion of the site.

- East Foxboro - Morse/Summer Place: This location would restrict access along a heavily utilized illegal crossing. Any fencing on the east side of the site should be restricted or limited due to its location within an ACEC.

Mitigation Measures: Fencing which would be required for safety reasons should incorporate the following mitigation measures for fence construction. Fences should be placed at least 4 to 6 meters from the edge of forested and brush cover, so that wildlife would see the fence. In areas of open farmland, a margin of low-growing vegetation should be retained to provide travel corridors along the fence and nesting cover for small mammals and songbirds.

Endnotes

1. Conversation between Mr. James Philcox (Roy F. Weston, Inc.) and Lt. Cmdr. Glidden (U.S. Coast Guard - Boston, MA), April 8, 1993.

2. Conversation between Mr. James Philcox (Roy F. Weston, Inc.) and Ms. Fran Reimham (FCC - Boston, MA), April 14, 1993.

CHAPTER 2
CONNECTICUT SUBSTATION ALTERNATIVES ANALYSIS

Among the major comments received on the DEIS/R were those relating to the placement of substation facilities in Connecticut and Massachusetts. The Connecticut Siting Council requested that information be provided detailing alternative locations for substation sites in Connecticut, and the Massachusetts Executive Office of Environmental Affairs requested alternatives to the proposed Roxbury Crossing substation. The following analysis provides a detailed discussion of environmental and technical considerations for the facility sitings in Connecticut. The analysis for the Roxbury Crossing siting is presented in Appendix K, Volume I, of the FEIS/R. Each analysis covers the issues and concerns appropriate to the respective commenter.

2.1 SITING ANALYSIS FOR CONNECTICUT SUBSTATION ALTERNATIVES

Overall technical considerations on the Northeast Corridor electrification between New Haven and Boston concluded that some of the electrical substation facilities should be located in Connecticut. Further site-specific screening along the rail corridor identified alternative sites for the substations. Based on Amtrak technical and environmental screening considerations, four alternative sites were identified for the Branford area and three for the New London area (see Table 2.1-1). The following is a summary of potential impacts from these alternatives on environmental resources, including noise and aesthetic damage to nearby cultural land features, parks, hospitals, schools, and residential development. This summary is abstracted from the *Draft Northend Electrification Project Evaluation of Preferred Electrical Facility Sites in Connecticut, Rhode Island and Massachusetts*, Morrison Knudsen/L.K. Comstock/Spie Group, 14 March 1994, which is available for review on request. Based on environmental and technical impacts, the Branford and New London locations were identified as the proposed sites for further consideration as part of the Proposed Action.

TABLE 2.1-1 Connecticut Substation Alternatives

AREA	SITE	MILEPOST	LOCATION
Branford	Branford	79.03	Branford, CT
	New Haven	73.64	New Haven, CT
	East River	89.69	Guilford, CT
	Madison	92.87	Madison, CT
New London	New London	123.56	New London, CT
	Waterford	120.04	Waterford, CT
	Millstone	117.56	Waterford, CT

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

2.1.1 Branford Area Alternative

2.1.1(a) Branford

The proposed Branford site and transmission line ROW fall within the property of the Connecticut Department of Transportation (ConnDOT) and the South Central Connecticut Regional Water Authority (SCCRWA). The ConnDOT property is part of the former turnpike tollgate plaza. ConnDOT plans to use the property immediately adjacent to I-95 as a staging area for the reconstruction of the Lake Saltonstall Bridge; therefore, the back portion of the ConnDOT property would be available for the traction power substation. The SCCRWA property is a primarily wooded area and falls within the Furnace Pond/Lake Saltonstall watershed. Any change in use proposed on this property is subject to review and the approval of the Connecticut Department of Health Services (DHS).

The substation would sit partially on the existing service road (former tollgate plaza), with the rest cut into a moderately wooded hillside. There are no rock outcroppings, and the exposed earth is granular. The hillside slopes upward at 6 percent to 1 percent approximately 400 feet and is basically level onto the 115 kV feeder line (1,200 feet).

The site is located on upland, and is not in any wetland buffer zone. Location of a facility here has been determined to have no adverse impacts on surrounding wetlands or water courses. The site is not located in a floodplain. The site is shielded from the view of the closest residents by wooded area and is set back from I-95 such that existing and planned landscaping could shield the facility from passing motorists. The site is in close proximity to I-95 with associated higher road noise levels. Operational noise could affect a nearby residence. Sound absorptive barrier walls, quiet fans, or fan silencers for transformers will be used to mitigate impacts.

Amtrak, through the Joint Venture's subconsultant Parsons Brinckerhoff, conducted environmental sampling to assess the risk of petroleum products and heavy metals that may exist on the ground surface at the proposed site. Seven grab soil samples were collected. One of the samples taken adjacent to the road gave an elevated total petroleum hydrocarbon (TPH) concentration of 620 parts per million (ppm). Another sample had a TPH concentration of 190 ppm. This problem was localized, and resulted from a small amount of waste oil that was deposited there, most probably by the dumping of used automobile oil.

There are no anticipated impacts to sensitive receptors from EMF emissions at the proposed Branford site. An investigation of overall EMF impacts of the Northend Electrification can be found in Chapter 5 of this volume.

The site has low potential for containing archaeological resources. However, the 115 kV transmission line corridor may have low to moderate potential to contain either prehistoric or historic period resources, due primarily to favorable environmental factors. Since the DEIS/R, systematic subsurface testing has been conducted and no intact cultural remains were found. The site was therefore reclassified as having a low potential for archaeological sensitivity.

No impacts to wildlife or endangered species are anticipated from construction of an electrification facility at the proposed Branford site.

2.1.1(b) New Haven

The 115 kV power supply would be via a direct aerial drop from the existing United Illuminating 8300 line directly adjacent to the site. The site's land use is compatible as a substation as it is in a rail yard and is zoned industrial. Existing terrain and access would provide for ease of construction and maintenance. However, property size is restrictive due to constraints of railroad tracks, and adjustments would have to be made to existing facilities.

Transmission line reliability for Amtrak and United Illuminating customers was considered acceptable. Feeder routing would be advantageous due to the site's close proximity to the rail and existing 115 kV power supplies. There were no EMF or wildlife habitat issues, or anticipated construction impacts at the site. The site is located primarily on Amtrak property thereby making availability a non-issue.

There are no wetland issues associated with construction of an electrification facility at the site. While hazardous materials did not appear evident, the site contains a propane storage tank that would have to be relocated.

Due to its location at the end of the rail line, the New Haven site is not practical in terms of the substation separations required for the traction power supply system. Voltage levels would drop below minimum required levels between New Haven and the next proposed substation in New London. Power simulation studies conducted indicated that a fifth substation would be required in the 2 x 25 kV power supply arrangement, as well as an additional paralleling and switching station. The additional substation would be required at Old Saybrook, which would have environmental impacts as well as economic impacts far greater than if a single substation would be sufficient at Branford. Thus, the New Haven substation site was dropped from further consideration.

2.1.1(c) East River

A 6-mile underground 115 kV line would be routed along Green Hill Road from Northeast Utilities' Green Hill Substation to the site trackside. This long feeder line would have greater environmental, economic, construction, and traffic impacts than the New Haven and the proposed Branford sites.

The site's access is advantageous, and there would be no conflicts with land use of regulatory/zoning issues since the site is on former industrial plant property. The site is not located within wetlands.

Demolition of the 15,000-square-foot concrete block structure would potentially be required to accommodate the substation. However, size of parcel and access were adequate; and an alternative could be to construct the substation at the rear of the factory site.

A substation at this site would require addition of a paralleling station to the west in the vicinity of New Haven and a paralleling station to the east in the vicinity of Old Saybrook. In addition, a lengthy feeder line would be required along the track in order to optimally locate the phase break and maintain voltage levels in the traction power system.

The 6-mile 115 kV feeder line would be in close proximity to residents. This would create traffic impacts during construction along Green Hill Road and Route 79. While no EMF impacts were anticipated, the potential for exposure was greater than at either the New Haven or Branford sites.

Due to the lengthy 115 kV underground feeder line required through highways and streets in residential areas, this site was eliminated from further analysis. While trackside location of the traction power substation was considered advantageous, substation separation also meant that additional paralleling stations would be required. Overall, the potential environmental, economic, construction, and traffic impacts were greater here than at any of the other alternative Branford sites.

2.1.1(d) Madison

The site would have a similar 115 kV feeder routing as at the East River site; the distance, however, would be considerably less. A 2.5-mile underground feeder line would originate at Northeast Utilities' Green Hill Substation and run along Green Hill Road to Route 79 to the Amtrak corridor.

While the site is close to the rail line and is undeveloped land, the land is classified as inland wetland. The existing terrain would require filling of wetland area.

As with constructing a facility at the East River site, substation separation would require two additional paralleling stations in the system and lengthy feeders along the track to the phase break.

Due to the existence of wetlands, the long 2.5-mile underground 115 kV feeder line, and the additional electrical facility requirements, this site was eliminated from further consideration.

2.1.2 New London Area Alternative

2.1.2(a) New London

The current site is unused land adjacent to Central Vermont Railroad property. The proposed substation would be compatible with the existing rail yard. The site is zoned industrial by the City of New London such that usage would be compatible. The terrain consists of a flat gravel base with scattered areas of deteriorated blacktop. There is only minor vegetation. The site is not located in wetlands; however, it is located on the Thames River 100-year floodplain. The site would be graded above flood stage. The proposed New London site is hidden from view of any residents. With appropriate screening, the substation would not be visible by boat traffic along the Thames River.

The proposed New London site is in the Central Vermont Railroad yard, away from residential areas. The site's classification as commercial/industrial waterfront zone allows noise levels of up to 70 dBA. Noise from operational equipment in the substation would not surpass this level.

Amtrak preliminary environmental investigation identified soil on the surface that is stained extensively with ink-blue color. There are two soil/debris stockpiles in addition to some junked white goods, discarded numerous old tires and car parts, railroad ties, and extensive rolls and piles of black filter fabric. One of the soil piles in the far northeast corner of the property at the end of the east boundary fence line was covered with black stained soil that gave a very high TPH concentration of 45,000 ppm. No heavy metals were found.

There are no anticipated impacts to sensitive receptors from EMF emissions from an electrification facility at the proposed New London site or along the underground 115 kV line that runs from Northeast Utilities' Williams Street substation.

The substation site and utility corridor have a low potential for containing archaeological resources. There are no anticipated impacts to wildlife or endangered species from location of a facility at the proposed New London site.

2.1.2(b) Waterford

A 2.5-mile overhead line would run parallel to the Amtrak ROW from the site of the Waterford substation site to the Northeast Utilities' substation at Millstone Point. This bulk supply station is a 345 kV power supply and would require special consideration from the Nuclear Regulatory Commission. An advantage of utilizing this site would be its trackside location and the ability to use Amtrak's ROW for the feeder line. There would be no conflicts with land use. However, hazardous materials due to the landfill are a concern, as is the presence of wetlands. Substation separation is at an acceptable distance. Voltage levels in power simulations indicate that an additional paralleling station would be required on the Groton side of the Thames.

While the substation site would be available at a fair market price, the interconnection at Millstone Point would require a lengthy procedure with Northeast Utilities and the Nuclear Regulatory Commission.

Due to the lengthy overhead feeder line, the difficulty of tapping into a 345 kV power supply, the presence of wetlands, and possible soil contamination, this site was rejected from further consideration. Overall, the potential environmental, economic, and construction impacts were greater than at the New London site.

2.1.2(c) Millstone

The site has several advantages in that it is located next to the rail line and Northeast Utilities' Millstone substation. However, as that substation is a 345 kV power supply, special permission would have to be obtained from the Nuclear Regulatory Commission to interconnect at that location. In addition, more equipment would be required to step down from 345 kV to 25 kV.

Investigation of the site indicates it is on upland, not in wetlands, and not in the 100-year floodplain. Property availability is not an issue as the site falls primarily on Amtrak property.

There were no hazardous materials apparent at this location, nor would the substation have any significant EMF, noise, construction, or wildlife habitat impacts. Reliability of service to Amtrak would be excellent, and there would be no impacts to existing CL&P customers.

Substation separation was such that voltage levels would drop below acceptable levels between Millstone and the proposed Warwick site, a distance of nearly 60 miles. Power simulations indicate that an additional power supply point would be required at Alton, RI, or two additional paralleling stations, in New London, and at another site to be determined. This indicates that environmental, economic, and construction impacts would be greater than at the New London site if Millstone were selected.

While the Millstone site has several distinct advantages, including proximity to railroad, property availability, and adjacent power supply, it was rejected from further consideration due primarily to electrical considerations. The site would necessitate additional equipment to tap into existing 345 kV power supply, as well as additional traction power facilities, and another substation or two paralleling stations This would have greater environmental, economic, and construction impacts than the proposed New London site.

2.2 SUMMARY

Table 2.2-1 shows a comparison of the effects for all the Connecticut substation alternatives. The Branford and New London sites were selected as the preferred sites based on their superior technical advantage and their lack of environmental impact compared to the other sites that were considered.

TABLE 2.2-1 Comparison of Alternative Substation Sites in Connecticut 2 x 25 kV system

EVALUATION CRITERIA FACTORS	PROPOSED BRANFORD SITE	ALTERNATIVE NEW HAVEN SITE	ALTERNATIVE EAST RIVER SITE	ALTERNATIVE MADISON SITE	PROPOSED NEW LONDON SITE	ALTERNATIVE WATERFORD SITE	ALTERNATIVE MILLSTONE SITE
115 kV Transmission Line Proximity	(1,500 feet) good	(direct aerial drop) excellent	(6 miles) poor	(2.5 miles) poor	(0.75 mile) acceptable	(2.4 miles (345 kV)) unacceptable	(direct aerial drop (345kV)) unacceptable
Land Use	no conflict	no conflict	no conflict	no conflict	no conflict	no conflict	no conflict
Regulatory/Zoning	requires action	no conflict	no conflict	no conflict	no conflict	requires action	no conflict
Existing Terrain	acceptable	good	acceptable (requires demolition)	poor (requires fill)	acceptable	acceptable	acceptable
Size	good	poor	acceptable	acceptable	acceptable	acceptable	acceptable
Access	good	good	good	good	good	good	good
Substation Separation	good	unacceptable	poor	poor	good	poor	poor
Load Proximity	good	excellent	poor	poor	excellent	excellent	excellent
Feeder Routing	acceptable	excellent	poor	poor	acceptable	acceptable	excellent
Water Issues	no impact	no impact	no impact	major impact (existing wetlands)	minor impact (major flood plain)	minor impacts	no conflict
Visual/Aesthetics	minor impact	no impact	no impact	minor impact	minor impact	no impact	no impact
Noise	minor impact	no impact	no impact	no impact	no impact	no impact	no impact
Hazardous Materials	none	requires mitigation	none	none	acceptable	requires investigation	none
Transmission Line Reliability - Amtrak/Existing Customer	excellent	excellent	good	good	excellent	excellent	excellent

TABLE 2.2-1 Comparison of Alternative Substation Sites in Connecticut 2 x 25 kV system (Continued)

EVALUATION CRITERIA FACTORS	PROPOSED BRANFORD SITE	ALTERNATIVE NEW HAVEN SITE	ALTERNATIVE EAST RIVER SITE	ALTERNATIVE MADISON SITE	PROPOSED NEW LONDON SITE	ALTERNATIVE WATERFORD SITE	ALTERNATIVE MILLSTONE SITE
EMF Proximity To Sensitive Receptors	no impact	no impact	no impact	no impact	no impact	no impact	no impact
Impacts To Historical Resources	minor impacts requires further investigation	no impact	no impact	no impacts	no impact	no impact	no impact
Construction Impacts	minor impact	minor impact	major impact	major impact	minor impact	no impact	no impact
Availability	yes	yes	yes	yes	yes	yes	uncertain requires NRC permission
Vandalism	no impact	no impact	no impact	no impact	no impact	no impact	no impact
Wildlife Habitat Impacts	no impact	no impact	no impact	no impact	no impact	no impact	no impact

Ratings:		
	Excellent	No impact/no conflict
	Good	Minor impact
	Acceptable	Major impact
	Poor	
	Unacceptable	

Source: Roy F. Weston, Inc., 1994

CHAPTER 3
SOCIOECONOMICS

This chapter deals with the socioeconomic impacts in two areas of concern as revealed in many comments on the DEIS/R: freight rail and moveable bridges. Section 3.1 describes the history and present status of freight rail, its ownership, movements, volume and value of goods moved, and direct and indirect wages realized. Section 3.2 provides data on the five moveable bridges within the corridor, marine traffic in the area of each bridge, and the marinas and marine-related businesses, both upstream and downstream of each bridge, that would be affected by the Proposed Action including the proposed increase in scheduled passenger trains.

3.1 FREIGHT RAIL

This section evaluates the potential effects of the Proposed Action and Amtrak's 2010 passenger train schedule on freight rail service in the NEC. The analysis follows expressions of public concern that the projected increase in daily passenger train service from 20 trains daily to 52 in 2010 would unduly restrict the ability of freight service providers to provide efficient, cost effective freight service to businesses in the NEC. The section assesses the likelihood that freight rail service could be impacted negatively by increased passenger rail service absent measures to address capacity constraints on the NEC main line and identifies the environmental and economic consequences of a shift of freight from rail to trucks. The impact criteria used for this analysis are:

- effect on current service schedules
- effect on future service schedules
- effect on current rail car volumes
- effect on future rail car volumes
- effect on truck volumes
- effect on air quality
- effect on energy consumption

The criteria measure:

- change in current service schedules
- change in future service schedules
- change in current rail car volumes
- change in future rail car volumes
- modal shift of freight from rail to truck
- change in levels of mass emissions due to modal shifts
- change in energy use due to modal shifts

3.1.1 Affected Environment

3.1.1(a) History of Freight Rail, New Haven to Boston

For most of the current century, extensive railroad freight services were provided along the Northeast Corridor "Shore Line" route between New Haven and Boston by the New York, New Haven, and Hartford Railroad Company (New Haven). The Shore Line was the scene of many daily local and through freight train operations as well as of intercity and local passenger train operations.

The adverse impacts of the Great Depression of the 1930s forced the New Haven into bankruptcy in 1935. For the period 1935 through the World War II years, the railroad was managed by Federal Court-appointed trustees. In 1947, the railroad was reorganized and returned to private sector control. Following reorganization, the railroad was confronted with a series of management changes, the creation of a competitive express highway network within its southern New England operating area, and the flight of much of its railroad-oriented manufacturing economic base elsewhere. These conditions resulted in a second bankruptcy filing in 1961 and the installation of trustees to manage the railroad and to pursue a reorganization plan.

During the decade of the 1960s, it became apparent that the New Haven system, with its staggering passenger and freight services losses, could not be returned successfully to private control and operation as an independent entity. This conclusion led to a trustee policy of seeking inclusion of the New Haven in the then pending merger of the Pennsylvania and New York Central Railroad Systems. This policy was supported vigorously by the political, business, and labor leadership within the New England region. As a consequence, the New Haven railroad properties were integrated into the merged corporate complex which was known as the Penn Central Railroad in 1969.

One result of this merger was a management decision to reroute the long-haul through freight train service away from the Shore Line to the Boston and Albany main freight line to the west. Only a local freight service remained to provide for the needs of industry dependent upon Shore Line operations. In the face of unfavorable competitive conditions within the Northeast, the Penn Central was forced into bankruptcy in 1970. Several other smaller railroads within the Northeast, including the Boston and Maine Railroad in northern New England, also fell into bankruptcy proceedings in that time period. Out of these bankrupt railroad systems, the Federal government acquired much of the railroad transportation properties of those railroads (excluding the Boston and Maine, which continued to seek independent reorganization) and created the Consolidated Rail Corporation (Conrail) to manage and operate the resulting railroad network. On April 1, 1976, Conrail became the operator of railroad services along the New Haven to Boston Shore Line.

While the Penn Central Trustees were in control of that railroad, it was determined to disaffirm the lease of the Providence and Worcester Railroad property which consisted of the railroad main line between Worcester (MA) and Providence (RI) along with extensive yard areas in both cities. Following this decision, the Providence and Worcester Railroad (P&W) Board of Directors determined to resume independent operation of their line after 100 years of leasing the 45-mile railroad property for operation by other railroads.

In 1973, P&W commenced operation of railroad freight services between the two cities which constitute its corporate name. Since that time, P&W has assumed freight service operations over many other route miles within the three-state Southern New England region. P&W now operates over approximately 470 miles of trackage of which it owns approximately 170 miles. In 1982, under the provisions of the Northeast Rail Services Act of 1981, P&W undertook the exclusive provision of railroad freight services along the NEC route from the Massachusetts-Rhode Island state line to Old Saybrook in Connecticut, a line segment owned by Amtrak. In 1991, P&W acquired Conrail's freight operating rights from Old Saybrook to New Haven in Connecticut. Thus, P&W is the provider of all Shore Line freight train services in Rhode Island and Connecticut.

In Massachusetts, Conrail continues to provide local freight services along the Shore Line route. P&W was granted limited overhead trackage rights along a segment of the Shore Line route between the Rhode Island state line to Attleboro in Massachusetts in order to connect to another part of the railroad system in Rhode Island, but, to date, the railroad has not exercised such rights. Within Massachusetts, the Shore Line is owned by the Massachusetts Bay Transportation Authority (MBTA).

Conrail provides local switching services to approximately 10 customer locations which have direct sidetrack connections to the NEC main line passenger tracks. Some of these sidetrack facilities serve more than one customer. In addition, Conrail utilizes segments of the main line to reach numerous customer locations along branch lines which connect to the NEC. These branch lines include the East Junction Secondary Track and the New Bedford Secondary Track connections in Attleboro and the Stoughton Branch connection in Canton. The NEC main line from Mansfield, where the Framingham Branch joins the NEC, to Attleboro also serves as a short "bridge route" to access customer locations such as Braintree, Brockton, Taunton, Fall River, New Bedford, and the Cape Cod region from Conrail traffic origins and destinations to the west. Although no specific customer traffic information is available from Conrail relative to its NEC freight operations in Massachusetts, it is clear that such operations are of considerable magnitude and substantial economic importance to the region.

3.1.1(b) Current Freight Rail Service

P&W provides service to 43 businesses which directly employ over 21,000 workers. These firms generate approximately $590,000,000 in direct wages annually. In addition, jobs directly generated by these firms generate an additional 49,000 indirect jobs, paying $1,200,000,000 in annual wages.[1] The annual freight shipped by these firms includes more than 455,000 tons of aggregate; 114,000 tons of chemicals; and 7,000,000 board feet of wood products. Stone, sand, and other forms of aggregate, the raw material for asphalt and concrete account for 44 percent of P&W rail car movements on the NEC; metals account for 16 percent; chemical products, 15 percent; paper, 9 percent; plastic resins, 5 percent; with the remaining 11 percent is divided between food and dry bulk products, and construction materials.

3.1.1(c) Freight Services in Connecticut

The EIS/R Process to Date. Many DEIS/R commenters have asserted that the proposed Amtrak 2010 schedule of passenger trains would impact negatively present and future Connecticut freight rail service operations with associated adverse environmental and economic consequences.

Present Freight Service Schedules. P&W presently operates four local freight trains over portions of the NEC Shore Line in Connecticut. A brief description of the daily movements of these trains is as follows:

SN-1: This local train leaves the Belle Dock Yard track at New Haven at 9:15 AM and serves all customer locations between New Haven and Old Saybrook along the Shore Line between MP 73.7 to MP 105.0 and also interchanges traffic at Old Saybrook with another P&W local freight train (NR-2). This train operates daily Monday through Friday inclusive. Upon completion of its daily work assignment, the local returns to Belle Dock Yard in New Haven about 8 hours after having left the Yard in the morning.

NR-2: This local train now operates daily each weekday along the Shore Line between Groton (MP 124.9) and Old Saybrook (MP 105.0). The train originates out of Plainfield Yard on the Norwich and Worcester Branch Line, approximately 30 miles north of the Shore Line. Departure time from Plainfield is at 8:30 AM and the local arrives at the Shore Line at Groton some 70 minutes later. The train then runs along the Shore Line to Old Saybrook where it serves customers and interchanges cars with local freight train SN-1. Upon completion of the Old Saybrook work, the train returns to New London to interchange traffic with the Central Vermont Railroad. The local then operates over the Thames River to the Old Groton Main Industrial Track to serve customers. When this switching job is completed, the train returns to Plainfield Yard some 8.5 hours after the train departed from Plainfield in the morning.

CT-1: This local train operates from Belle Dock Yard in New Haven to Reeds Gap on the so-called "Air Line Route" and returns to New Haven each weekday. This train has a very minor involvement with the NEC Shore Line route as it crosses the high-speed passenger tracks from the Belle Dock Line on the south to the Air Line connection on the north at MP 73.2 approximately 1 mile east of the New Haven Passenger Station.

CT-2: This freight train also operates out of Belle Dock Yard daily and moves westward along the NEC through the New Haven Passenger Station area to Danbury in western Connecticut and then returns to the Yard. This train is scheduled to avoid conflicts with passenger train movements along the NEC west of New Haven. This train does not serve any customers directly located along the high-speed passenger route.

Amtrak's proposed 2010 passenger train operations would pose little conflict with current and projected CT-1 and CT-2 operations. Both NR-2 and SN-1 local freight trains could confront delay and added operating costs created by more frequent Amtrak passenger train operations in the future assuming the current configuration of passing and industrial track sidings between Groton and New Haven. Figure 3.1-1 lists key rail sites.

Railroad Freight Service Volumes. Local freight trains SN-1 and NR-2 provide service to 18 Connecticut customers at 11 locations along the Shore Line. P&W traffic data indicate that these customers generated 4,156 cars inbound and 3,587 cars outbound at Shore Line locations in 1993. A substantial number of these inbound and outbound car counts represent both an origin and a destination along the Shore Line as the product handled (aggregate) lends itself to railroad transportation for short hauls. Thus, a simple addition of the inbound and outbound car counts (7,743) involves an overstatement of the volume of revenue cars handled insofar as Shore Line customer locations are concerned. Stone, sand, and other forms of aggregate account for 68 percent of Connecticut's NEC rail freight car movements east of New Haven; chemical products, 15 percent; metals, 8 percent; paper, 6 percent; with the remaining 3 percent divided between food and dry bulk products and construction materials.

P&W has operated local freight services in southern Connecticut along the Shore Line between the Rhode Island state line and Westbrook since 1982. Excluding the aforementioned aggregate traffic volumes, P&W handled 2,903 revenue carloads for this line segment in calendar year 1984. For the 1993 calendar year, the carload volume had declined to 1,918 cars, a decrease of 985 cars (33.9 percent) for the most recent 10-year period.

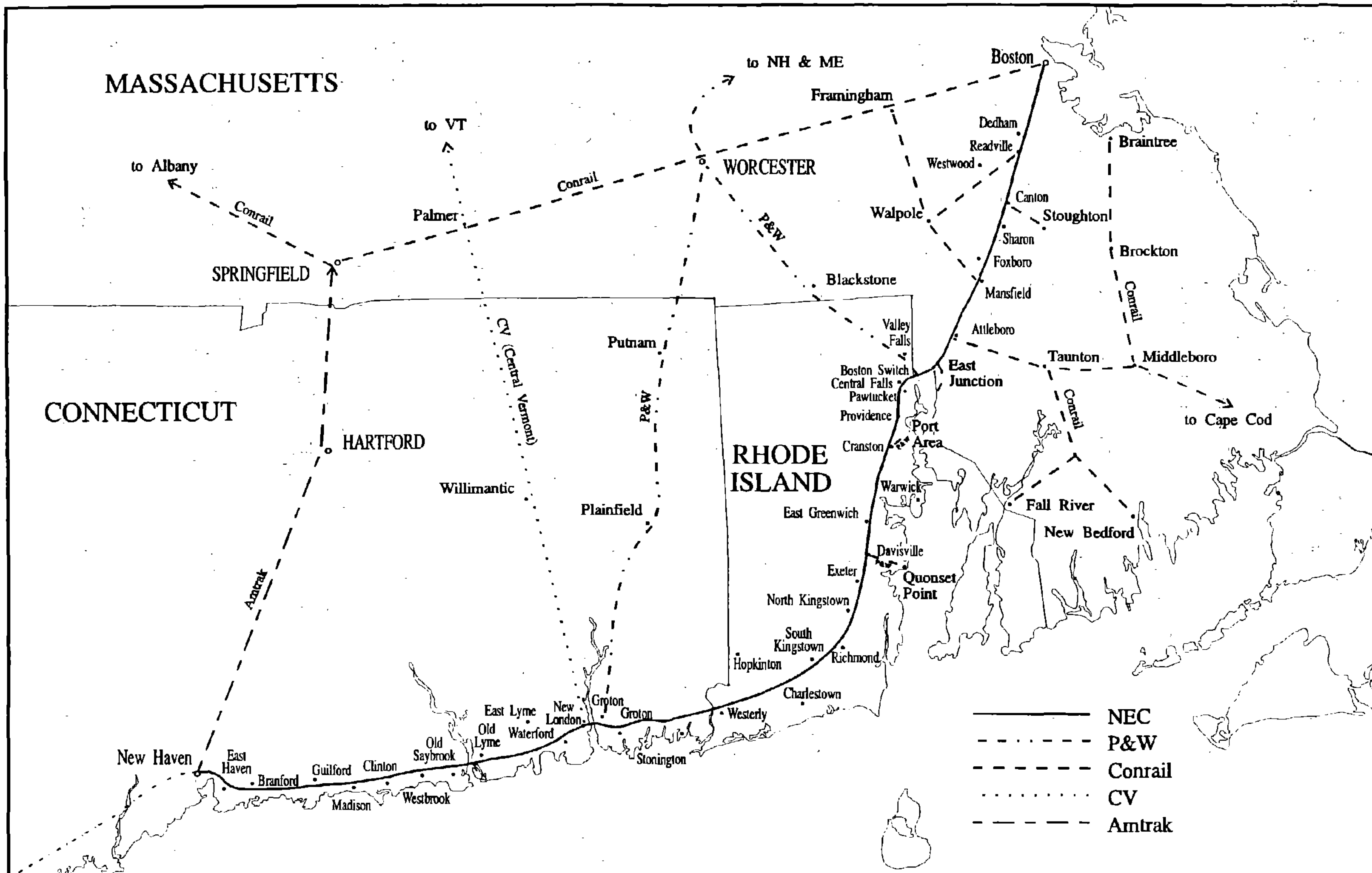
This 10-year period shows a contrast between southeastern Connecticut and Rhode Island where there was a modest (4.3 percent) increase in NEC Shore Line traffic volume.

Present Railroad Freight Customers. Companies served by P&W's Connecticut operations occupy 17 manufacturing, transportation, and mining standard industry classifications. These firms employ 15,833 workers paying in excess of $441,000,000 in direct wages annually. In addition, jobs generated indirectly by these firms employ over 39,000 workers, paying $972,000,000 in annual wages.[2]

3.1.1(d) Freight Services in Rhode Island

The EIS/R Process to Date. Many DEIS/R commenters have asserted that the proposed Amtrak 2010 schedule of passenger trains could negatively impact present and future Rhode Island freight rail service operations with associated adverse environmental and economic consequences.

Commenters also assert that clearance restrictions imposed by the installation of a catenary system as planned by Amtrak could effectively preclude any future opportunity to improve freight clearances in Rhode Island between Boston Switch in Central Falls (MP 190.4) and Davisville in North Kingstown (MP 168.0), a distance of some 22 miles of the Shore Line route, limiting freight rail growth prospects.



KEY FREIGHT RAIL LOCATION IN THE NORTHEAST CORRIDOR

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 3.1-1

A number of comments pertained to the impact of the Proposed Action on Rhode Island's plans to expand the Quonset Point/Davisville Intermodal Center and related proposals for construction of a dedicated freight track and improved vertical clearances from the Intermodal Center to Boston Switch. Specifically, concerns were expressed that the Proposed Action would impose physical limitations precluding subsequent analysis and construction of the freight rail improvements proposed by the State of Rhode Island. Prospective operational difficulties relating to the availability of timely, cost effective freight service to the Center were also identified. Absent cost effective, efficient service, it is argued, the Center's attractiveness to businesses making locational decisions, and, therefore, its future development, could be significantly limited.

The Quonset Point/Davisville Intermodal Center in North Kingston contains 1,300 acres of industrial land, of which nearly 800 acres are vacant and available for development. These 800 acres represent approximately 45 percent of Rhode Island's vacant prime industrial land. Nearly 500 acres at Quonset Point/Davisville Industrial Center directly abut the site's 26-mile internal rail network which is connected to the Shore Line route. The Shore Line route provides access to New England and the United States via Boston Switch located in Central Falls, 22 miles to the north.

Fifteen firms are located in Quonset Point/Davisville, employing in excess of 5,000 workers. These firms generate in excess of $148,000,000 in direct wages annually.

In May 1994, the Rhode Island Department of Transportation published a Notice of Intent in the *Federal Register* inviting comments on a proposed scope of work for a Draft Environmental Impact Statement (DEIS) to be prepared for this proposed Third Track Project. Scoping sessions for this project, formally known as the Northeast Corridor Third Track Project, were held in June 1994.

Present Freight Service Schedules. P&W now operates two local freight trains along the Shore Line Route within Rhode Island. Both locals originate and terminate at Valley Falls Yard which is located approximately 1 mile north of Boston Switch on the railroad's main line between Worcester and Central Falls. The trains operate on a 5-day-a-week (Monday through Friday) schedule. P&W receives and forwards most of its interline traffic, which has Rhode Island origin and destination points, with Conrail at Worcester Yard, approximately 37 miles north of Valley Falls Yard. At Davisville in North Kingstown, P&W interchanges traffic with the Seaview Railroad, which serves several customer locations within the former U.S. Navy Base at Quonset Point.

A brief description of the daily movements of these two local freight trains along the Shore Line is as follows:

PR-3: This local train leaves Valley Falls Yard at 7:15 AM and serves all customer locations along the Shore Line between MP 190.2 and MP 168.0 in Rhode Island except Pawtucket Yard including customers located on the Harbor Junction Branch Line and located on the Seaview Railroad at Davisville. Upon completion of its work, the train returns to Valley Falls Yard about 9 hours later. The train actually occupies either of the main line passenger tracks a minor portion of the total trip time as much of the car switching operations occur on separate trackage.

PR-2: This local train leaves Valley Falls Yard at 10:15 AM and crosses the NEC main line at Lawn Interlocking (MP 188.7) to serve Pawtucket Yard. Upon completion of its work, the train returns to Valley Falls yard approximately 2 hours later.

In addition to these two daily weekday local freight trains, P&W operates an occasional special freight train to handle "over dimension" or "high or wide" equipment which exceeds the normal vertical or horizontal clearance standards for Shore Line. These infrequent moves take place at nighttime hours so as to avoid interference with other railroad train operations.

Railroad Freight Service Volumes. These local freight trains provide service to 23 Rhode Island customers at 10 locations. In 1993, these customers generated 3,695 revenue carloads of freight business. Inbound commodity volumes dominate the market as only 215 carloads originate at these customer locations while the balance of 3,480 cars are inbound moves.

For the 1984 calendar year period, P&W handled 3,543 revenue carloads for locations along the Shore Line in Rhode Island covered by this analysis. Thus, the 1993 traffic volumes of 3,695 represents a modest increase of 152 cars (4.3 percent, or 0.43 percent annually) in carload business over the past 10-year period. Given the dramatic decline of railroad freight traffic volumes in Southern New England over the post-World War II period, this traffic increase indicates a notable stabilization of the Shore Line railroad traffic base within Rhode Island.

Present Railroad Freight Customers. Companies served by P&W's Rhode Island operations occupy 15 manufacturing, transportation, and agricultural standard industry classifications. These firms directly employ 5,167 workers, paying in excess of $148,900,000 in direct wages annually. In addition, jobs generated indirectly by these firms employ over 10,000 workers, paying $260,000,000 in annual wages.

3.1.1(e) Freight Services in Massachusetts

Conrail continues to operate freight trains along the Shore Line in Massachusetts as successor to the Penn Central and New Haven Railroads. Conrail Shore Line freight trains serve customer locations both along the NEC and at other locations east of the Shore Line such as Taunton, Quincy, Braintree, Brockton, Middleboro, Fall River, New Bedford, and the Cape Cod region.

Present Freight Service Schedules. Conrail now operates the following pattern of trains along the NEC in Massachusetts.

Readville Yard to Route 128 Industrial Park (MP 220.3-MP 217.4): Operates 5 days a week from Readville and return to serve customer locations between the Yard area and the Route 128 Industrial Park in Westwood.

Readville Yard to Canton Junction (MP 220.3-MP 213.8): Operates Tuesdays and Thursdays from Readville and return to serve customer locations along the Stoughton Branch Line.

Readville Yard to Attleboro (MP 220.3-MP 198.4): Operates 5 days a week from Readville to Attleboro and return to serve customer locations along the NEC.

Mansfield to South Attleboro (MP 204.2-MP 192.3): Operates 5 days a week from Middleboro Yard and return. This train enters the NEC at Attleboro from the New Bedford Secondary Track (MP 197.0) and first serves customer locations between Attleboro and South Attleboro, then operates from South Attleboro to Mansfield on the Framingham Branch where it meets another freight train from Framingham to exchange inbound and outbound cars, and finally returns to Middleboro Yard.

In contrast to the issue of NEC railroad freight services in Connecticut and Rhode Island, there was a notable lack of review comments asserting that the electrification project would adversely impact existing or future railroad freight services within Massachusetts. The freight service operator (Conrail) did not participate in the several public hearings held on the DEIS/R and has not requested the implementation of any mitigation measures for the Massachusetts portion of the NEC as a result of the electrification project.

Most of the NEC main line sidetrack and connecting branch line locations within Massachusetts provide track configurations which enable Conrail local freight trains to perform freight car pickup and delivery services which do not obstruct the main line passenger tracks and thus interfere with Amtrak intercity and commuter train schedules. The local freight trains are planned and operated in a disciplined manner so as to avoid conflict with peak period times within which commuter and intercity trains dominate main line passenger track capacity.

For the long-term future, the installation of the overhead catenary system has been designed to provide for possible future extended and new third and fourth track segments between Readville and Attleboro along the NEC. While the primary purpose of such added main line tracks is to accommodate a more frequent and faster mix of intercity and commuter train schedules, these added track installations will also provide for more capacity and flexibility for local freight train operations during the periods outside peak commuter train movements.

Finally, many of the customer locations involve areas remote from residential zones where nighttime switching operations would have little or no perceptible noise impacts if nighttime service became necessary.

3.1.2 Environmental Consequences

3.1.2(a) Operational Impacts on Freight Rail

As described in Sections 3.1.1(a) through 3.1.1(e), P&W and Conrail provide local rail freight service along the NEC in Connecticut, Rhode Island, and Massachusetts. Current service by P&W involves operation of four round-trip freight trains daily along portions of the NEC. Current operations involve the movement of 11,438 rail cars annually, 7,743 in Connecticut and 3,695 in Rhode Island. P&W projects the rail car demand of existing freight rail users to increase by 8.8 percent annually.

Environmental and economic consequences associated with increased passenger train movements along the NEC depend, in part, on the operational impacts of these additional passenger movements on freight operations and on freight rail prices in Connecticut and Rhode Island. Adverse consequences would result if rail freight price increases cause users of rail freight services to shift to other modes of transportation and/or to scale back company operations or reduce employment levels.

No significant operational impacts are anticipated for Conrail freight movements in Massachusetts. However, rail operation simulations performed by Amtrak for P&W's Connecticut and Rhode Island NEC operations indicate that absent measures to increase the capacity of the NEC, the increased number of intercity and commuter trains projected for 2010 would reduce the time available for P&W to perform currently scheduled daytime freight movements. Review of these simulations indicates that on the NR-2, SN-1, and PR-3 lines, with the increased passenger trains it would, on average, take P&W 20 percent or 1.5 to 2.0 hours longer at 1993 volume levels to provide service to existing clients. If freight demand increases to the point that a third round-trip train becomes necessary, the operating time available will be reduced by an additional 20 percent, or a total delay of 3.0 to 3.5 additional hours to provide NEC freight rail service. In addition, the model indicates that freight demand beyond what would be satisfied by a third local train would necessitate shifting some freight service to nighttime operations.

P&W estimates that these operating cost increases and service delays would result in rail freight price increases of between 11 percent and 43 percent. P&W also estimates that more narrow service windows, with accompanying service delays, would stifle potential future freight rail service expansion. Given the likelihood of service delays at current freight volume levels and the expectation that impacts would increase as volume levels increase, adjustments to price would be expected if no measures were available to mitigate these impacts.

To determine whether rail freight price increases would result in a shift of freight from rail to truck, and to assess the impacts of this shift, a survey was undertaken of current users of rail freight services. The nine firms surveyed generate 64 percent of all current P&W NEC rail car movements. According to P&W, these firms are expected to generate 84 percent of year 2010 rail car movements.

The survey collected information about the products transported by companies served by P&W; the volumes of material transported; the means of transport, specifically the existing transport mode split between truck and rail; the distances products are transported; the timing of movements; the relative shipping costs between rail and truck; and anticipated company responses if faced with 5 percent, 10 percent, and 25 percent rail freight price increases. Information was collected regarding past, current, and anticipated future conditions. Data was then analyzed to determine whether, and to what extent, characteristics unique to the firms served by P&W, or to the type, volume, or distance of the freight shipped, would impact company responses if faced with rail freight price increases. Survey results are summarized below. Results reveal that several characteristics of the Connecticut and Rhode Island firms served by P&W, and characteristics of the products and distances shipped, would tend to hasten a move away from rail to trucks in the face of relatively small increases in rail prices.

Specifically, the data reveals that because a small number of firms dominate the rail freight marketplace in Connecticut and Rhode Island, and because these firms move raw materials which compete with those of competitors largely on the basis of price, small variations in transport prices are especially relevant to the ability of these firms to compete. This concentration of rail freight activity in the hands of firms highly sensitive to price means that small price shifts could result in aggressive cost cutting measures, including shifts away from rail to truck. The impetus to undertake this shift is heightened when there is a narrow difference between rail and truck freight prices, a characteristic present in short haul NEC freight movements. Therefore, survey responses indicate that firms with these market characteristics are likely to move away from rail to truck, with corresponding environmental and economic consequences stemming from increased truck trips and vehicle miles of travel.

Products Shipped by Freight Rail. As noted in Sections 3.1.1(a) through 3.1.1(e), P&W traffic data and data from the survey indicate that stone, sand, and other forms of aggregate, the raw material for concrete, account for 44 percent of all rail car movements in the NEC; metals, 16 percent; chemical products, 15 percent; paper, 9 percent; plastic resins, 5 percent; with food, dry bulk, and construction materials accounting for the remaining 11 percent. In Connecticut, aggregate accounts for 68 percent of all NEC rail car movements; chemical products, 15 percent; metals, 8 percent; paper, 6 percent; with miscellaneous items accounting for the remaining 3 percent. In Rhode Island, movement of metals constitutes 32 percent of all NEC car movements, chemical products 16 percent, paper 15 percent, plastic resins 14 percent, wood products 13 percent; with food, dry bulk, and construction materials accounting for the remaining 10 percent.

Data collected from P&W and from firms which P&W projects will account for 84 percent of future freight rail activity in 2010, indicate that stone, sand, and other aggregate shipments will exceed 50 percent of the total volume of product shipped by rail along the NEC. In Connecticut, stone, sand, and aggregate are projected to account for 70 percent in 2010 of the total freight shipped by rail.

Freight Rail Product Price Characteristics. The high concentration of raw materials shipped by rail along the NEC results in a product mix highly sensitive to fluctuations in transport costs. According to the United States Department of Interior's Bureau of Mines, competition to sell crushed stone, sand, gravel, and other forms of aggregate is highly competitive, largely because of the abundance of these products. Because there are numerous sources of supply, buyers are free to shop for alternatives, making purchasing decisions largely on the basis of price. According to the Bureau of Mines, producers with operations closest to their markets have significant advantages over competitors, largely because the costs of transporting these products often equals or is considerably greater than the cost of production at processing plants.[3]

Freight Rail Users -- Connecticut and Rhode Island. As noted in Sections 3.1.1(a) through 3.1.1(e), survey data indicate a highly concentrated set of rail freight users in the NEC marketplace. As stated previously, if no new large volume users enter the freight rail marketplace, the nine firms surveyed are projected to generate 84 percent of all NEC freight car movements in Connecticut and Rhode Island by 2010. In Connecticut, one firm currently generates 65 percent of Connecticut NEC freight rail movements, with four firms currently generating 89 percent. Absent new entrants into the marketplace, this high degree of concentration is projected to continue with one Connecticut firm projected to generate 67 percent of all activity in 2010 and with four firms projected to generate 79 percent. In Rhode Island, one firm generates 30 percent of all current activity, with five firms generating 79 percent. By 2010, absent new entrants, five Rhode Island firms are projected to generate 68 percent of NEC freight rail movements. The reactions of just a few firms to rail freight price increases, therefore, will largely define the environmental and economic consequences resulting from a shift to truck freight movement.

Shipping Distances of Rail Freight Moving in the NEC -- Rail/Truck Price Competition. Comparison of rail and truck costs indicates that price advantages of rail decrease as product shipping distances decrease.[4] While rail costs less for the line haul portion of the trip, or that portion where a container already loaded on a flatcar is moved from point A to point B, getting the container to and loading it onto the flatcar results in associated intermodal transfer costs and railroad terminal costs. At shorter distances there are fewer miles for which these intermodal transfer and railroad terminal costs can be distributed, making shipment by truck more competitive. At longer distances, where rail costs can more broadly be distributed, shipping by rail is more competitive.

Reinforcing the competitive advantages of rail at longer distances is its ability to operate 24 hours per day which, even when offset by loading and offloading times, is significantly greater than the hours truckers are permitted to drive under Federal law. At shorter distances, where Federal driving restrictions are not a factor, this time and cost advantage disappears.

The data collected indicate that 55 percent of all rail cars currently moving in the NEC serve final destinations within 100 miles of the rail trip's origin. This figure approaches 70 percent in Connecticut, reflecting the high percentage of short haul freight movements of aggregate. In Rhode Island, 20 percent of all freight cars serve final destinations within 100 miles of the origin of the rail trip.

The data collected also indicate that rail car movements of less than 100 miles are expected to account for 60 percent of rail traffic generated by existing rail customers by 2010. In Connecticut, 75 percent of all future NEC movements are projected to serve user destinations within 100 miles. This is in contrast to Rhode Island where projected growth is expected to result in only 25 percent of all car movements serving user destinations within 100 miles.

Finally, survey results indicate that for the vast majority of current Connecticut and Rhode Island rail freight movements, the rail cars traveling more than 100 miles actually travel distances of approximately 1,000 miles or greater. This reflects the movement by rail of significant amounts of wood products from Southern and Western states and the movement of metal products from the Midwest. Calculation of the distance freight travels allows for a more accurate assessment of the vehicle miles traveled if price increases result in a shift of rail traffic to truck.

The high percentage of materials moved short distances in the NEC results in a small difference between the costs of moving products by rail when compared to moving them by truck. Survey results highlight this small difference. A survey of the firms that move product by rail distances of 100 miles or less showed that 75 percent estimated that rail costs are approximately 5 percent less expensive when compared to truck costs. The remaining 25 percent attributed more significant rail cost advantages to owning rail capital stock, including rail cars and trackage. Where rail and truck prices converge, users of these services have greater freedom to shift modes if price and other circumstances warrant.

Company Responses -- NEC Freight Rail Price Increases. Survey results cited above reveal a high concentration of users of NEC freight rail services. These users move products, which compete largely on the basis of price, short distances where the cost differences between rail and truck are relatively narrow.

All of the firms surveyed stated they were highly likely to pursue cost cutting measures in the face of freight rail price increases or operating cost price increases of as little as 5 percent. The measures most frequently identified include reducing raw material usage; where feasible, using product substitutes; moving materials by truck rather than by rail; and reevaluating future investment plans and hiring practices. At price increases above 10 percent, 75 percent of the firms surveyed predicted truck usage increases of greater than 25 percent, job losses, and/or reduced company growth rates. The remaining 25 percent noted that a mode shift from rail to truck would prove exceedingly difficult resulting in increased pressure to reevaluate hiring practices and plant investment decisions.

For the purpose of analyzing conservatively the environmental and economic consequences resulting from a diversion of rail freight traffic to truck, both 25 percent to 50 percent mode shifts are investigated. In addition, annual freight rail growth rates of 2 percent and 8.8 percent are applied. The 2 percent growth assumption reflects an assumed increase in rail demand over that demonstrated in the past decade. The 8.8 percent growth rate reflects P&W's projection of future freight rail car demand to be generated by its existing customers and does not reflect growth associated with substantial buildout of the Quonset Point/Davisville Intermodal Center. As noted in Section 3.1.1(d), buildout of the Intermodal Center is largely dependent on freight rail track and clearance improvements currently under review by the Rhode Island Department of Transportation (RIDOT) in accordance with the provisions of the National Environmental Policy Act (NEPA).

These assumptions are made to illustrate potential impacts. In fact, there are no guarantees that projected increases in freight rail demand will occur.

3.1.2(b) Truck Trips and Vehicle Miles of Travel Per Annum

Truck trip generation data resulting from a price-induced mode shift and corresponding vehicle miles of travel (VMT) data provide the framework for evaluating the environmental consequences associated with increased conflict between rail passenger and freight movements in the NEC. From this data, the air quality and energy consumption impacts potentially resulting from this conflict can be projected.

Truck Trips. The following tables indicate the number of truck trips that would be generated nationally, and in Connecticut and in Rhode Island, if rail prices increase. Calculations proceed from the following assumptions:

- one rail car carrying 100 tons of freight = 4 trucks carrying 25 tons of freight
- one rail car movement = 4 trucks carrying 25 tons of freight + 4 trucks returning with no freight
- annual freight rail growth rates of 2 percent-low and 8.8 percent-high
- 25 percent and 50 percent mode shifts of rail freight to truck associated with anticipated price increases

Tables also include truck trips generated by a 100 percent mode shift, presented in the unlikely event that P & W ceases service in the NEC.

Table 3.1-1 indicates the total number of additional truck trips that might be generated within the NEC if there are adverse effects on shippers in Connecticut and Rhode Island. The results indicate that a 25 percent mode shift would generate between 31,900 additional truck trips in 2010 at low growth rates and 95,600 at high growth rates. A 50 percent mode shift would generate between 63,800 additional 2010 truck trips at low growth rates and 191,200 at high growth rates.

TABLE 3.1-1 Truck Trips in Various Freight Rail Growth and Mode Shift Scenarios, Connecticut and Rhode Island Combined, Various Years

MODE SHIFT	100%		50%		25%	
Annual Freight Rail Growth	2.0%	8.8%	2.0%	8.8%	2.0%	8.8%
Year	**Truck Trips**					
1993 Base Case	91,160	91,160	45,580	45,580	22,790	22,790
1995	94,843	107,910	47,421	53,955	23,711	26,978
2000	104,714	164,515	52,357	82,258	26,179	41,129
2010	127,646	382,380	63,823	191,190	31,912	95,595

Source: DMJM/Harris, 1994

Table 3.1-2 shows additional Connecticut truck trips potentially generated. The results indicate that a 25 percent mode shift would generate between 21,600 additional truck trips in 2010 at low growth rates and 64,600 at high growth rates. A 50 percent mode shift would generate between 43,100 additional 2010 truck trips at low growth rates and 129,200 at high growth rates.

TABLE 3.1-2 Truck Trips in Various Freight Rail Growth and Mode Shift Scenarios, Connecticut, Various Years

MODE SHIFT	100%		50%		25%	
Annual Freight Rail Growth	2.0%	8.8%	2.0%	8.8%	2.0%	8.8%
Year	**Truck Trips**					
1993 Base Case	61,600	61,600	30,800	30,800	15,400	15,400
1995	64,089	72,919	32,044	36,459	16,022	18,230
2000	70,759	111,169	35,380	55,584	17,690	27,792
2010	86,255	258,388	43,127	129,194	21,564	64,597

Source: DMJM/Harris, 1994

Table 3.1-3 shows additional Rhode Island truck trips potentially generated. The results indicate that a 25 percent mode shift would generate between 10,400 additional truck trips in 2010 at low growth rates and 31,000 at high growth rates. A 50 percent mode shift would generate between 20,700 additional truck trips in 2010 at low growth rates and 62,000 at high growth rates.

TABLE 3.1-3 Truck Trips in Various Freight Rail Growth and Mode Shift Scenarios, Rhode Island, Various Years

MODE SHIFT	100%		50%		25%	
Annual Freight Rail Growth	2.0%	8.8%	2.0%	8.8%	2.0%	8.8%
Year	**Truck Trips**					
1993 Base Case	29,600	29,600	14,800	14,800	7,400	7,400
1995	30,796	35,039	15,398	17,519	7,699	8,760
2000	34,001	53,419	17,001	26,709	8,500	13,355
2010	41,447	124,160	20,724	62,080	10,362	31,040

Source: DMJM/Harris, 1994

Vehicle Miles of Travel. The vehicle miles of travel per annum associated with a possible shift of a portion of rail freight to truck is calculated for the national highway system, for Connecticut, Rhode Island, and for Massachusetts by multiplying trip distance data by the above cited truck trip generation data. Tables outlining VMT growth under growth scenarios of 2 percent and 8.8 percent per annum, with assumed mode shifts of 50 percent and 25 percent, are presented.

The calculation of national VMT increases reflects survey data indicating that 55 percent of all NEC rail car trips serve end user destinations less than 100 miles from the point of origin, with the remaining 45 percent part of long-haul rail movements averaging 1,000 miles. Table 3.1-4 shows national VMT increases generated at each growth and mode shift assumption.

If rail price increases or operational charges result in a 50 percent shift from rail to truck in 2010 national VMT increases could range from between 32,270,000 at low growth rates to 96,556,000 at high growth rates. A 25 percent shift in 2010 could result in VMT increases of between 16,110,000 at low growth rates to 48,278,000 at high growth rates.

The calculation of VMT increases in Connecticut reflects survey data indicating that 70 percent of all rail freight trips serve destination points within 40 miles of points of origin. The remaining 30 percent travel distances of 50 miles or less before reaching the state's borders with New York, Massachusetts, or Rhode Island, whereupon the vehicle miles traveled are ascribed to calculations of miles traveled within the neighboring state. Table 3.1-5 shows Connecticut VMT increases at each growth and mode shift assumption.

TABLE 3.1-4 National Vehicle Miles Traveled in Various Freight Rail Growth and Mode Shift Scenarios, 2010

ANNUAL FREIGHT RAIL GROWTH		2.0%	8.8%
Year	Mode Shift	Vehicle Miles Traveled	
2010	25%	16,109,500	48,278,000
	50%	32,269,500	96,556,000
	100%	64,539,000	193,112,000

Source: DMJM/Harris, 1994

TABLE 3.1-5 Vehicle Miles Traveled in Various Freight Rail Growth and Mode Shift Scenarios in Connecticut, 2010

ANNUAL FREIGHT RAIL GROWTH		2.0%	8.8%
Year	Mode Shift	Vehicle Miles Traveled	
2010	25%	928,800	2,777,800
	50%	1,857,600	5,555,600
	100%	3,715,200	11,111,200

Source: DMJM/Harris, 1994

If rail price increases or operational charges result in a 50 percent shift from rail to truck in 2010 Connecticut VMT increases could range from between 1,860,000 at low growth rates to 5,556,000 at high growth rates. A 25 percent shift could result in Connecticut VMT increases of between 929,000 at low growth rates to 2,780,000 at high growth rates.

The calculation of VMT increases in Rhode Island reflects survey data indicating that 80 percent of all rail freight trips serving interstate destination points travel distances 35 miles or less before reaching the state's borders with Connecticut or Massachusetts. The remaining 20 percent travel distances of 20 miles or less within Rhode Island. Table 3.1-6 shows Rhode Island VMT increases at each growth and mode shift assumption.

If rail price incrêases or operational changes result in a 50 percent shift from rail to truck in 2010 Rhode Island VMT increases could range from between 666,000 at low growth rates to 1,984,000 at high growth rates. A 25 percent shift could result in VMT increases of between 333,000 at low growth rates to 992,000 at high growth rates.

TABLE 3.1-6 Vehicle Miles Traveled in Various Freight Rail Growth and Mode Shift Scenarios in Rhode Island, 2010

ANNUAL FREIGHT RAIL GROWTH		2.0%	8.8%
Year	Mode Shift	Vehicle Miles Traveled	
2010	25%	332,800	992,000
	50%	665,600	1,984,000
	100%	1,331,200	3,968,000

Source: DMJM/Harris, 1994

Although P&W does not move freight on the NEC in Massachusetts, and, though a mode shift from freight rail to truck is not projected for Conrail's Massachusetts movements, diversion to truck of Connecticut and Rhode Island freight moved by P&W would result in VMT increases in Massachusetts. This occurs as trucks substituting for rail cars run from Connecticut and Rhode Island to intermodal facilities used by P&W in Worcester, MA. The calculation of VMT increases in Massachusetts reflects survey results indicating that 75 percent of Connecticut's and Rhode Island's NEC product shipped out of state moves through Worcester, and given that it is 15 miles from Connecticut's border and 17 miles from Rhode Island's border to Worcester's facilities. Table 3.1-7 shows Massachusetts VMT increases at each growth and mode shift assumption.

If rail price increases or operational charges result in a 50 percent shift of freight from rail to truck in 2010 Massachusetts VMT increases could range from between 348,000 at low growth rates to 1,044,000 at high growth rates. A 25 percent shift in 2010 could result in Massachusetts VMT increases of between 174,000 at low growth rates to 522,000 at high growth rates.

TABLE 3.1-7 Vehicle Miles Traveled in Various Freight Rail Growth and Mode Shift Scenarios in Massachusetts, 2010

ANNUAL FREIGHT RAIL GROWTH		2.0%	8.8%
Year	Mode Shift	Vehicle Miles Traveled	
2010	25%	174,192	521,808
	50%	348,384	1,043,616
	100%	696,768	2,087,232

Source: DMJM/Harris, 1994

Air Quality. The air quality implications in 2010 of the modal shifts are measured in the increase/decrease of emissions over the levels estimated for the Proposed Action. The results of the analysis are summarized below:

25 Percent Shift

- +17 kg/day of volatile organic compounds (VOC)
- +143 kg/day of oxides of nitrogen (NO_x)
- +94 kg/day of carbon monoxide (CO)

50 Percent Shift

- +33 kg/day of VOC
- +285 kg/day of NO_x
- +188 kg of CO

As noted in Tables 4.10-4 through 4.10-6 of Volume I of the FEIS/R, the Proposed Action, assuming no shifts to trucking, would result in reduced emissions for all three pollutants from the emissions levels of the no-build condition. The increases in emissions associated with shifts to trucking could reduce the projected benefits to air qualilty associated with the Proposed Action.

Energy Consumption. Table 3.1-8 shows the projected number of vehicle miles traveled within the states of Connecticut, Rhode Island, and Massachusetts as a result of shifts from rail. The vehicles assumed are transfer-trailer trucks. The fuel efficiency of these vehicles is based on national data for 1991, the last year for which data is compiled. Using the 5.65 miles per gallon figure from the national data, the number of gallons of diesel fuel consumed is calculated. It can be seen that the full range of incremental fuel consumption is between 8 and 48 million gallons per year depending on freight rail growth rate and modal shift assumptions. Based on 141,000 British thermal units (Btu) per gallon of diesel fuel, this can be converted to the total number of Btu consumed. This ranges from 1,100 to 6,800 billion Btu per year.

This increased energy use by trucks would be partially offset by a decrease in energy use by freight rail. As freight cars are eliminated from trains, the energy consumption of the locomotives would decrease. However, insufficient information was available regarding the energy consumption of freight rail and the manner in which freight rail operations would change as a result of the shift to trucks to be able to reasonably estimate the decrease in freight rail energy consumption. Therefore, it has conservatively been assumed that freight rail energy consumption would remain the same. Therefore, the incremental energy use projected in Table 3.1-8 reflects the total energy impacts estimated as a result of shifts from freight to truck rail.

Economic Consequences. Economic consequences ranging from layoffs and plant closings in Connecticut and Rhode Island, to a $900,000 loss of current operating revenue,[5] to an inability to attract new NEC freight rail users, have been predicted by the P&W, and shippers to accompany cost increases that might from increased NEC passenger rail operations if measures are not taken to increase the capacity of the NEC. Survey results indicate that firms are likely to pursue a variety of steps to reduce costs in the face of increased freight rail costs or operating cost increases associated with changes in freight rail delivery schedules.

As noted above, 100 percent of the firms surveyed responded that cost increases of 5 percent would result in cost cutting measures including: taking steps to reduce raw material usage; where feasible, using product substitutes, exploring moving materials by truck rather than rail; and reevaluating future investment plans and hiring practices. At price increases above 10 percent, 75 percent of the firms surveyed predicted a minimum of 25 percent increases in truck usage, job losses, and/or reduced company growth rates. The remaining 25 percent noted that a mode shift from rail to truck would prove exceedingly difficult resulting in increased pressure at low rail price increases to reevaluate hiring practices and investment decisions.

TABLE 3.1-8 Energy Impacts in Connecticut, Rhode Island, and Massachusetts of Modal Shift from Freight Rail to Truck in the Year 2010

FREIGHT RAIL GROWTH RATE	25 PERCENT MODAL SHIFT	
	2.0%	**8.8%**
Additional vehicle miles traveled per year	1,435,800	4,291,600
Additional fuel (diesel) consumed per year (gallons)[1]	8,112,270	24,247,540
Additional energy consumed (billions Btu/yr)[2]	1,144	3,420
	50 PERCENT MODAL SHIFT	
	2.0%	**8.8%**
Additional vehicle miles traveled per year	2,871,600	8,583,200
Additional fuel (diesel) consumed per year (gallons)	16,224,540	38,495,080
Additional energy consumed (billions Btu/yr)	2,288	6,838

Notes: [1]Based on 5.65 miles/gallon in 1991, as reported in *National Transportation Statistics, Annual Report*, September 1993, Bureau of Transportation Statistics, Department of Transportation.
[2]Based on 141,000 Btu per gallon.

Source: Roy F. Weston, Inc., 1994

Given the large number of factors that impact company growth rates, hiring practices, and investment decisions, it is not possible to isolate freight rail prices from other factors to establish a direct causal relationship between freight rail prices and job gains or losses. It is possible, however, to determine what the impact on wages would be if rail price issues or operational charges resulted in a 1 percent job loss.

As summarized in Sections 3.1.1(a) through 3.1.1(e), 43 firms are served by P&W along the NEC, generating 70,000 direct and indirect jobs and $1,800,000,000 in direct and indirect wages.

Analysis of average wage rates in the industries receiving P&W service in Connecticut and Rhode Island and application of job creation and wage rate multipliers for these states published by the Unites States Department of Commerce's Bureau of Economic Analysis allows for quantification of lost wages, measured in 1991 dollars, associated with each job that would be lost or job opportunity foregone because of anticipated rail price increases.

In Connecticut, companies served by P&W occupy 17 manufacturing, transportation, and mining standard industrial classifications. Connecticut Department of Economic Development figures indicate that these firms employ over 15,800 workers. Application of Bureau of Labor Statistics seasonably adjusted earnings data indicates $27,900 in annual average industry earnings,[5] resulting in total direct earnings of $442,000,000 annually.

In addition, application of Direct Effect Employment Multipliers for these Connecticut industries[7] reveals that each job directly generates 2.5 additional indirect jobs, accounting for 39,500 indirect jobs in 1993. Application of Direct Effect Earnings Multipliers[8] for these Connecticut industries reveals that each job directly created generates indirect wages 2.2 times that of average annual industry earnings. Each direct job, therefore, generates $61,400 in indirect wages, or a total of $972,000,000 in indirect wages annually.

In sum, any job lost in Connecticut or any job creation opportunity foregone because of increases in rail prices or operational charges would result in an accompanying loss of 2.5 jobs with a cumulative wage impact of $89,250 as measured in 1991 dollars. A 1 percent increase in job loss or percentage decrease in job creation experienced by Connecticut shippers, directly attributable to increasing rail prices would result in the loss of 158 direct jobs with 1991 wage value of $4,400,000, and a loss of 395 indirect jobs, with an associated wage value of $9,700,000. This 1 percent impact would result in a cumulative loss of 553 direct and indirect jobs paying $14,100,000 in annual wages.

In Rhode Island, companies served by P&W occupy 15 manufacturing, transportation, and agricultural standard industry classifications. According to Rhode Island Port Authority and Economic Development Corporation figures, these firms employ over 5,100 workers. Port Authority and Economic Development Corporation data also indicate that employees of these firms earn $28,800 annually,[9] with total annual direct earnings of $148,900,000.

In addition, application of Direct Effect Employment Multipliers for these Rhode Island industries reveals that each job directly created generates 2.0 additional indirect jobs,[10] accounting for in excess of 10,200 jobs in 1993. Application of Direct Effect Earnings Multipliers for these Rhode Island industries[11] reveals that each job directly created generates indirect wages 1.75 times that of average annual industry earnings. Each direct job, therefore, generates $50,550 in indirect wages, with a total of $260,700,000 in indirect wages generated annually.

In sum, any job lost in Rhode Island or any job creation opportunity foregone because of increases in rail prices or operational charges would result in an accompanying loss of 2.0 jobs with a cumulative wage impact of $79,300 measured in 1991 dollars. A 1 percent increase in job loss or a 1 percent decrease in job creation experienced by Rhode Island shippers, directly attributable to increasing rail prices, therefore, would result in the loss of 51 direct jobs with a 1991 wage value of $1,470,000, and a loss of 102 indirect jobs with an associated 1991 wage value of $2,575,000. This 1 percent impact would result in a cumulative loss of 153 direct and indirect jobs paying $4,045,000 in annual wages.

The cumulative impacts of a 1 percent increase in job loss or 1 percent decrease in job creation directly attributable to rail price increases or operational charges is 706 direct and indirect jobs with an associated 1991 wage value of $18,045,000 annually.

Capacity Improvements as Mitigation. The Northeast Corridor Transportation Plan (NECTP), released by the Federal Railroad Administration (FRA) in July 1994, incorporates into the NECIP plan a number of capacity improvements, primarily the reinstallation of previously existing side tracks, to accommodate the anticipated increased demand for access to the NEC main line by its intercity, commuter, and freight rail users. Simulations conducted for FRA indicate that with these capacity improvements, existing and projected intercity passenger and commuter schedules can be accommodated without any significant degradation to the freight service presently provided. If such improvements are built, the economic impact on freight rail shippers should be minimal.

Quonset Point Redevelopment. The State of Rhode Island proposes the development of a major port facility at the former U.S. Navy base in Quonset Point, RI. A major element of this proposed development is the provision of rail service using large dimension (double-stack container and tri-level automobile rack) rail cars. This service would use the NEC between Davisville and Central Falls, RI, where the P&W branches off the NEC. Presently, the clearances under 32 bridges over the NEC in this area are inadequate to accommodate these taller cars. RIDOT and the Federal Highway Administration (FHWA) have initiated a review of alternatives, including the preparation of an environmental impact statement (with FRA as a cooperating agency) to provide the necessary clearances and capacity for the additional traffic expected by the state. Amtrak has incorporated a number of design changes into its plan in this area to accommodate potential future construction of a parallel track should that be the alternative selected by RIDOT and FHWA.

Conclusion. The increase in passenger train traffic projected for 2010, absent increases to NEC capacity, could result in increased truck traffic, heightened annual VMT, and elevated freight rail prices in the NEC in Connecticut and Rhode Island, with corresponding economic consequences, absent measures to mitigate operational conflicts between passenger and freight service. Increases in passenger train traffic are not a result of the Proposed Action per se but of the NECIP program as a whole and state efforts to increase commuter service. As such, the potential impacts discussed above would also hold true under the No-Build Alternative FF-125 and FRA-150 scenarios. To address the potential for impact of the Proposed Action on other users of the NEC mail line, including freight service, Section 5.1.1(i) of Volume I of the FEIS/R includes a number of measures in the preferred alternative to mitigate potential impact. A simulation conducted for FRA concludes that with these measures, the year 2010 freight service can be adequately accommodated on the upgraded and electrified Corridor.[12]

3.2 MOVEABLE BRIDGES

Increased train traffic in 2010 would require more frequent and longer closures of moveable bridges during the daylight hours of the warm weather months when recreational boating is at its peak volume, with a potential for reducing marine access to waterways both upstream and downstream of the five moveable railroad bridges along coastal Connecticut between Old Saybrook and Stenington. Marina interests in areas affected by the bridge closures fear an economic impact to themselves, believing that boaters would relocate to other marinas not affected by the bridge closures. This report addresses this issue, analyzes the marine environment, and suggests a number of mitigation options, where appropriate.

3.2.1 Affected Environment

Records for the year 1992 from the State of Connecticut Department of Motor Vehicles show approximately 100,877 vessels registered in the entire state. Of that total, 89 percent are less than 26 feet in length while the remaining 11 percent range from 26 to 100 feet. Shoreline communities south of Interstate 95 account for roughly one-third of all boat registrations; the remaining two-thirds are registered in inland towns (registration in inland towns likely denotes the residence of the boat owner and not the boating season location of the boat).

The boating industry, while not the largest industry in the state, makes a large and significant contribution to the Connecticut economy. As estimated by one marine association, the total economic impact of this industry is approximately $1.6 billion,[13] with the State of Connecticut receiving approximately $62 million annually in taxes collected on the sale of boats, equipment, services, registration fees, and boating fuel.[14]

3.2.1(a) Moveable Bridge and Marine Environment

There are five moveable bridges between New Haven and Rhode Island:

- The Connecticut River Bridge, linking Old Saybrook and Old Lyme
- The Niantic River Bridge, linking East Lyme and Waterford

- The Shaw's Cove Bridge in New London
- The Thames River Bridge, linking New London and Groton
- The Mystic River Bridge, linking Groton and Stonington

Each is discussed in detail below, with the information summarized in Table 3.2-1. The locations of the five bridges are indicated in Figures 3.2-1.

Connecticut River Bridge. The first structure across the Connecticut River (going inland from Long Island Sound) is Amtrak's Connecticut River Moveable Bridge, located at MP 106.89 along the NEC. Built in 1907, it is a bascule bridge with a total length of approximately 1,581 feet from east abutment to west abutment. The specifications of the bridge in the closed position are 19 feet of vertical clearance at mean high water (MHW) and 139 feet of horizontal clearance. The bridge was last rehabilitated in the period 1980/82 as part of NECIP and will require renovation or complete replacement within the next 10 to 15 years. The Connecticut River Bridge is determined eligible for listing on The National Register of Historic Places (National Register).

The Connecticut River extends from Long Island Sound into Canada. A 15-foot-deep navigable channel is maintained by the U.S. Army Corps of Engineers (USACE) from the Sound to Hartford, CT, a distance of approximately 52 miles.[14]

The main width between bridge abutments at the moveable span is 139 feet. However, smaller boats that require little vertical clearance and that draw little water may pass elsewhere beneath the bridge, although most boats operate within the defined channel. When the bridge is in the open position vertical clearance is unlimited; however, in the closed position at MHW, only a vessel with a vertical dimension of up to 18 feet can pass safely under the bridge (leaving 1 foot for vertical clearance or tolerance). The tide fluctuation in the immediate area averages from 2 to 4.5 feet while the current averages 1 to 3 knots. There are no pre-existing nautical dangers surrounding the Connecticut River Moveable Bridge at this time that could endanger maritime traffic.[15]

Niantic River Bridge. The Niantic River Bridge is located at MP 116.7 on the NEC and is the first structure across the river moving inland from Long Island Sound. It was built in 1906 as a bascule-style bridge and is determined eligible for listing on the National Register. The bridge spans approximately 292 feet from east abutment to west abutment; its key marine specifications in the closed position are 11 feet of vertical clearance at MHW, and 45 feet of horizontal clearance.[16] The Niantic River Bridge was originally slated for replacement under NECIP in the early 1980s. However, due to budget cutbacks a new bridge was not constructed. Its replacement is included in NECTP.

The Niantic River flows from a point approximately 3.6 miles inland to Niantic Bay on Long Island Sound. The railroad bridge lies at the mouth of the river, and a second bridge -- the CT Route 156 highway bridge -- lies approximately 600 feet upstream. The highway bridge has approximately 30 feet of vertical clearance and over 100 feet of horizontal clearance. USACE maintains an 8-foot-deep navigation channel at mean low water (MLW) from Niantic Bay to the highway bridge, and beyond the highway bridge a 6-foot-deep channel for another 1.3 miles. The channel is approximately 100 feet wide, narrowing to 45 feet at the railroad bridge and to 65 feet at the highway bridge.

The 45 feet of horizontal clearance is located at the moveable span portion of the railroad bridge. Boats with a vertical clearance of no more than 10 feet can pass safely beneath the bridge when it is in the closed position at MHW. This factor limits the majority of maritime traffic to the main channel at the moveable span portion of the bridge. There is on average a current of 1 to 4.5 knots that moves diagonally through the bridge, and the tide fluctuation ranges from 2 to 4 feet. These conditions have the effect of limiting maritime movement under the bridge to one vessel in one direction at a time.

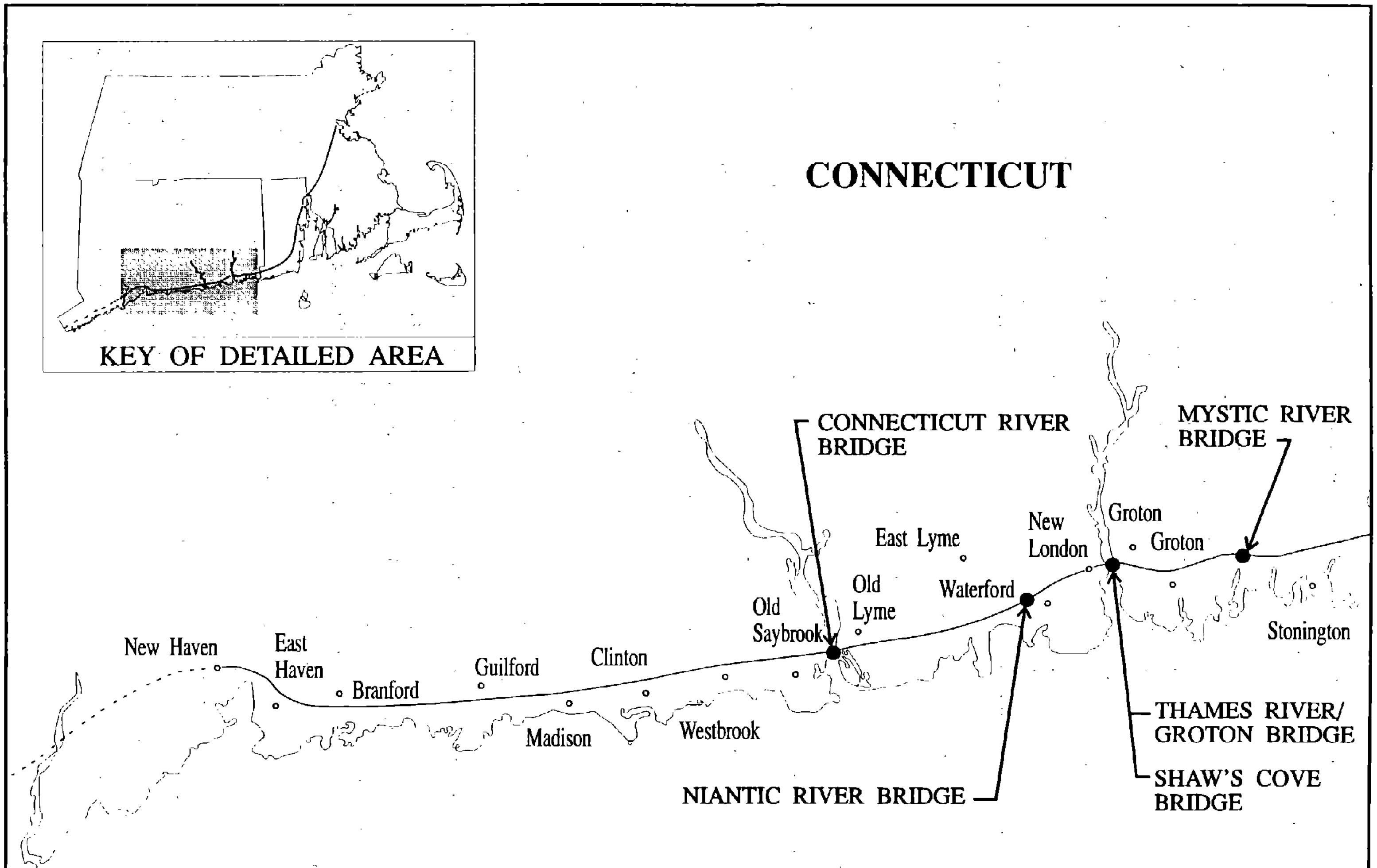
TABLE 3.2-1 Moveable Bridge Summary

MOVEABLE BRIDGE/ MUNICIPALITY/ MILEPOST	BRIDGE TYPE	CLEARANCE IN CLOSED POSITION		YEAR BUILT	NOTES
		Vertical (ft)	Horizontal (ft)		
Connecticut River| Old Saybrook/ Old Lyme, CT/ MP 106.89	Bascule	19	139	1907	Bridge rehabilitated from 1980/82 as part of NECIP
Niantic River| East Lyme/ Waterford, CT/ MP 116.74	Bascule	11	45	1906	Scheduled to be replaced as part of NECIP
Shaw's Cove| New London, CT/ MP 122.6	Swing	6	(2) 35-foot-wide channels	1984	Replaced as part of NECIP
Thames River| New London/ Groton, CT/ MP 124.09	Bascule	30	151	1919	Bridge rehabilitated from 1980/82. Proposed for replacement as part of the NECIP.
Mystic River| Groton/ Stonington, CT/ MP 132.2	Swing	4	(2) 65-foot-wide channels	1984	Replaced as part of NECIP

Source: Nautical Chart 12372. *Watch Hill to New Haven Harbour*. Edition 27. National Oceanic and Atmospheric Administration, March 1, 1993.

A vessel south of the railroad bridge is exposed to the open waters of Fisher Island Sound, particularly so if there is a delay in the bridge opening. This factor would have an adverse effect on the commercial maritime traffic that operates on the Niantic River, due to having no convenient site to discharge passengers if the bridge is closed or delayed from opening for long periods of time. There are no pre-existing nautical hazards surrounding the Niantic River Bridge.

Shaw's Cove Bridge. The Shaw's Cove Bridge is situated on the Thames River, and is located at MP 122.6 on the NEC. This bridge was constructed as part of NECIP in 1984 as a swing bridge to replace an older, deteriorating structure. The specifications for the bridge in the closed position are 6 feet of vertical clearance at MHW, with a horizontal clearance of 35 feet in both channels that are created by the center span of the swing leaf. The bridge is approximately 634 feet from east abutment to west abutment.[17] The bridge was completely replaced in 1982/83 and was opened for train traffic in 1984. Prior to its replacement, the original bridge was photographed and measured following Historic American Engineering Record (HAER) standards.



CONNECTICUT MOVEABLE BRIDGES

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 3.2-1

Shaw's Cove is a small inlet off the Thames River approximately 3.5 miles upriver from Long Island Sound. The railroad bridge forms the entrance of the cove which has an area of approximately 13 acres and an average depth of 15 feet at low water. Due to vertical constraints, only boats with a vertical height of less than 5 feet can pass safely under the bridge when it is closed at MHW. The tidal fluctuation at Shaw's Cove ranges from 1 to 2 feet, and the current averages 1 to 2 knots. There are no pre-existing nautical hazards surrounding the Shaw's Cove Bridge.

Thames River Bridge. The (Groton) Thames River Bridge is located at MP 124.1 on the NEC. The bascule-style bridge was built in 1919, and has a length from east abutment to west abutment of approximately 1,394 feet.[18] The primary marine specifications of the bridge in the closed position are 30 feet of vertical clearance at MHW, with 151 feet of horizontal clearance. The bridge was rehabilitated in the period 1980/82 but will likely require another major rehabilitation or moveable span replacement in 10 to 15 years. This replacement is included in NECTP. The Thames River Bridge is also eligible for listing on the National Register.

The Thames River extends north from Long Island Sound about 16 miles and then branches into the Yantic and Shetucket Rivers. USACE established a navigable channel the length of the river, ranging in depth from 38 feet south of the railroad bridge to 20 to 25 feet north of the bridge. The railroad bridge, approximately 4 miles north of Long Island Sound, is the first structure across the river going inland from Long Island Sound.

When the railroad bridge is in the closed position, boats with a vertical clearance of up to 29 feet can pass safely under the bridge at MHW. The 151-foot horizontal clearance at the bridge allows simultaneous passage of north and south moving maritime traffic. The tidal fluctuation at the railroad bridge averages 2 to 4 feet, and there is a current that averages 1 to 3 knots. There are no pre-existing nautical dangers surrounding the Thames River Bridge.

Mystic River Bridge. The Mystic River Bridge is located at MP 132.2 on the NEC. The bridge was constructed as part of NECIP in 1984 as a swing style bridge. Bridge specifications in the closed position are 4 feet of vertical clearance at MHW, and 65 feet of horizontal clearance in each of the two channels. The bridge spans approximately 998.6 feet between east and west abutments.[19]

The Mystic River runs approximately 6 miles from an inland point to Fishers Island Sound. The railroad bridge is about 2.4 miles upstream from the river mouth, and the CT Route 1 highway bridge is about 0.4 mile upstream of the railroad bridge. The key marine dimensions of this bridge are 4 feet of vertical clearance with 65 feet of horizontal clearance. Established by USACE in 1957, the navigable channel is 15 feet deep (MLW) from the sound to the highway bridge, and continues north at a depth of 12 feet for a distance of approximately 0.8 mile.

Due to vertical constraints, only boats with a vertical clearance of no more than 3 feet -- generally only the smaller skiffs -- can pass safely under the railroad bridge while it is in the closed position at MHW. When the bridge is in the open position vertical clearance is unlimited. As this is a swing bridge, the simultaneous passage of vessels heading north and south can occur. The tidal fluctuation surrounding the railroad bridge ranges from 1 to 3 feet, and the current averages 1 to 3 knots. There are no pre-existing nautical dangers surrounding the Mystic River Bridge.

3.2.1(b) Railroad Operations at the Moveable Bridges

For this analysis FRA 1993 data of train times at midspan for each of the five moveable bridges are used. (See Table 3.2-2 for a summary of this information.) These data are contained in Appendix 3A. Appendix 3C contains tables showing the results of calculations employed to define the open and closure periods for maritime traffic at these five moveable bridge locations.

Connecticut River Bridge. Currently, 22 Amtrak intercity trains cross the Connecticut River Bridge on a usual weekday, 11 in each direction. Of these 22, two are Amtrak's Montrealer which runs daily from Washington, DC, to Montreal, Canada. These trains cross at approximately 1-hour intervals from early morning to midnight. Two local freight trains operated by P&W also cross the bridge daily during daylight hours. No through freight or commuter service is provided on this section of the NEC Shore Line.

The Connecticut River is a highly traveled river, indicated by the fact that the railroad bridge was opened 3,087 times during the 1993 calendar year. Commercial activity, consisting mainly of barges and tugs, accounts for almost all the openings in the winter months. In the warm weather months, the number of commercial vessels drops off slightly and recreational boats become the major users of the river at the bridge site.

Based upon the 1993 Amtrak Public Timetable and the P&W freight schedule, it is possible to estimate the scheduled time each train will cross the Connecticut River Bridge. With this information, it is also possible to identify the time period the bridge channel would normally be closed to maritime traffic in order to assure a safe operation of a train across the bridge at peak periods. This process involves the following assumptions:

- The demonstration day is a warm weather normal weekday.
- The moveable bridge is usually in the open position to accommodate maritime traffic navigation.
- The trains operate on schedule.
- The bridge will begin to close 7 minutes prior to the scheduled train crossing over the moveable span.
- The bridge will require a 3-minute period to return to the full open position after the train clears the moveable span.
- The bridge will not open for maritime traffic if the window for vessel passage is less than 10 minutes according to the railroad schedule of train operations over the bridge.

Given these assumptions, a pictorial graph was prepared which displays the respective time periods that the bridge would be open for vessel passage and the time periods that the bridge would be closed to maritime traffic in order to accommodate train crossings. Appendix 3B contains these graphs for 1993.

Niantic River Bridge. Currently, 22 Amtrak intercity trains cross the Niantic River Bridge on a usual weekday, 11 in each direction. Two of these trains are Amtrak's Montrealer. These trains cross at approximately 1-hour intervals from early morning to midnight. Two local freight trains operated by P&W also cross the bridge daily during daylight hours. No through freight or commuter service is provided on this section of the NEC Shore Line.

A number of small and medium-sized marinas, boat yards, and charter fishing docks are located upstream of the railroad bridge on both the east and west banks. In addition, state-owned public launching ramps are maintained at Mago Point, Waterford, and Smith Cove, East Lyme. Privately owned pleasure craft and charter fishing boats account for the large majority of traffic on the river. Recreational boating is predominant in the summer months, but the fishing boats are recorded passing the railroad bridge throughout the year.

During the 1993 calendar year, the number of Niantic River Bridge openings amounted to 3,026. Utilizing the same assumptions and procedures described for the Connecticut River Bridge, Appendix 3B has been prepared to display the bridge open and closure periods for 1993.

Shaw's Cove Bridge. Currently, 22 Amtrak intercity trains cross the Shaw's Cove Bridge on a usual weekday, 11 in each direction. Two of these trains are Amtrak's Montrealer. These trains cross at approximately 1-hour intervals from early morning to midnight. Two local freight trains operated by P&W also cross the bridge daily during daylight hours. No through freight or commuter service is provided on this section of the NEC Shore Line.

During the 1993 calendar year, the total number of bridge openings was 2,116. As for the Connecticut River Bridge and Niantic River Bridge analysis, Appendix 3B has been prepared to show the railroad bridge open and closure periods for 1993.

Thames River Bridge. Currently, 20 Amtrak intercity trains cross the Thames River (Groton) Bridge on a weekday, 10 in each direction. These trains cross at approximately 1-hour intervals from early morning to midnight. Two local freight trains operated by P&W also cross the bridge daily during daylight hours. No through freight or commuter service is provided on this section of the NEC Shore Line.

The Thames is a heavily traveled river throughout the year. During the calendar year 1993, the bridge was opened a total of 2,129 times, to varied traffic. The river is a National Defense Waterway, and the U.S. Navy submarine base and the U.S. Coast Guard Academy are both located upstream of the bridge; their vessels must pass the bridge to reach the open sea. Commercial establishments, as far north of the bridge as Norwich, use the river for delivery and shipment of goods and materials. Recreational craft are predominant on the river in the summertime.

The Thames River Bridge open and closure periods have been calculated in a manner identical to the calculations for the Connecticut River, Niantic River, and Shaw's Cove bridges. The result of the process is shown in Appendix 3B.

Mystic River Bridge. Currently, 20 Amtrak intercity trains cross the Mystic River Bridge on a normal weekday, 10 in each direction. These are the only trains now scheduled to operate over this structure. P&W currently operates infrequent special trains to handle over-dimension equipment. These moves are conducted during the nighttime hours to avoid interference with passenger trains along this line segment. Special moves over this bridge have not exceeded four such moves per year over the last 5 years.

Marinas and private docking spaces line the river's edge between the railroad bridge and a highway bridge to the north. North of the highway bridge are more docking facilities and the Mystic Seaport Museum. The seaport has docking spaces to accommodate 50 visiting boats, and these spaces are normally full during the summer months. The seaport museum also operates a popular tour boat which makes one run per day on the Mystic River beginning in May and extending well into October. At a capacity of approximately 100 persons per trip, the boat is sufficiently large to require a bridge opening for passage.

The majority of the vessels using the river are private recreational boats, although there are a few charter fishing and pleasure boats.

During the 1993 calendar year, the Mystic River Bridge was opened 3,013 times to permit passage of maritime traffic. The open and closure periods for the typical 1993 weekday are shown in Appendix 3B.

The railroad movements across all five moveable bridges are summarized in Table 3.2-2.

TABLE 3.2-2. Railroad Movements, Typical Weekday, 1993

BRIDGE	RAILROAD MOVEMENTS ACROSS BRIDGE		
	AMTRAK (intercity)	SHORE LINE EAST (commuter)	P&W RR (freight)
Connecticut River	22	0	2
Niantic River	22	0	2
Shaw's Cove	22	0	2
Thames River	20	0	2
Mystic River	20	0	0

Seasonal Variation. In the case of all five of the moveable bridges located between New Haven and Boston, the monthly data for 1993 disclose a very wide seasonal variation in the number of bridge openings. Such variation is shown in Table 3.2-3 and Figure 3.2-2. Any present conflict between railroad and marine transportation modes is limited to the warm weather months during the daylight hours.

3.2.1(c) Marine Industry and Traffic

The economic analysis began with a data-gathering effort aimed at marinas and marine-related businesses. While the economic base of the communities in which these businesses are located are clearly subject to impacts, it was felt that a good understanding of the marine industry in these communities was necessary first. Impacts to marinas and marine-related businesses, if severe enough, could possibly affect other businesses and the local economy in fairly short order.

During Spring 1994, telephone surveys were conducted with representatives of a large group of marinas and marine-related businesses in the areas surrounding the five moveable bridges. The original list of marinas and marine-related businesses was obtained from a current commercial publication.[20] Each business contacted by telephone was subsequently requested to name the marina or marine-related business physically located on either side. In this manner, the study team attempted to identify all such businesses both upstream and downstream of the moveable bridges within a reasonable distance.

The telephone survey requested facility as well as economic data. Facility data requests ranged from numbers of slips, moorings, and winter/storage to distance from the railroad bridge in question. Economic data requests focused on the rental costs of slips, moorings, etc., as well as the aggregate dollar volume from related businesses, e.g., restaurants located on the premises, gas sales, repair volume.

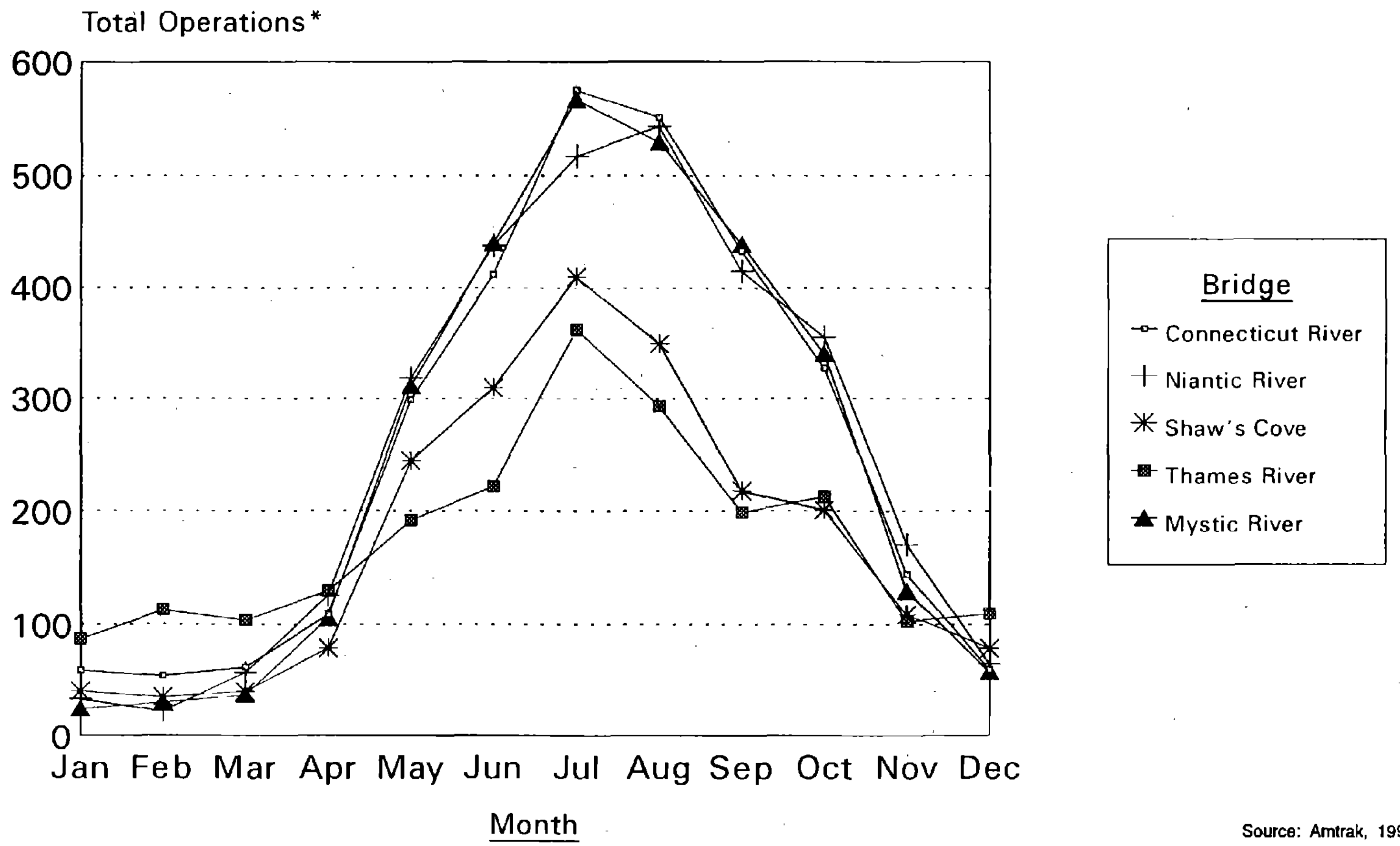
A similar set of questions was addressed to all marine-related businesses contacted and care was taken to note that all data would be treated confidentially. As expected, some businesses, citing the competitive business climate in coastal Connecticut, declined to respond fully to economic data requests. The number of

TABLE 3.2-3 Moveable Bridge Operations,[1] 1993

BRIDGE	MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Connecticut River	59	54	62	109	299	412	575	551	433	328	145	60
Niantic River	30	22	57	122	319	415	515	526	328	455	171	66
Shaw's Cove	40	35	40	79	245	310	410	350	218	201	109	79
Thames River	87	113	104	130	192	222	363	293	199	213	103	110
Mystic River	24	30	37	106	312	440	567	529	439	341	130	58

Notes: [1]One operation includes one raise/lower cycle

Source: Amtrak, 1994



Source: Amtrak, 1994

* one operation includes one raise/lower cycle

1993 CONNECTICUT MOVEABLE BRIDGE SUMMARY

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 3.2-2

businesses providing these key data, however, yield sample sizes sufficiently large to enable projections to be made from the accumulated data base.

The individuals contacted also provided a wealth of information on the competitive nature of the marine industry along coastal Connecticut, and offered their views on potential impacts associated with increased railroad traffic across the moveable bridges. These views are included in the analyses below. The results of these surveys are discussed by individual bridge below and summarized in Table 3.2-9.

Field interviews were conducted on Tuesday, May 17, 1994, with four harbormasters located at four of the five moveable bridges. The harbormasters confirmed much of the data being provided by the marina owners/managers and provided considerable information themselves, particularly relating to the marine environment in and around the bridges, and in the difficulty in maintaining clear distances and course headings in less than ideal weather conditions while waiting for a railroad bridge to open.

Recent counts of marine traffic through the moveable bridges were difficult to obtain. The 1993 bridge logs maintained by the bridge tenders were reviewed and found to contain incomplete specific data regarding the movements of vessels. Log entries ranged from "many boats passing" and "several boats" to specific numbers in only a few cases. As the peak marine traffic period occurs during the summer months, actual field counts could not be taken for inclusion in this study, given the timetable of this FEIS/R.

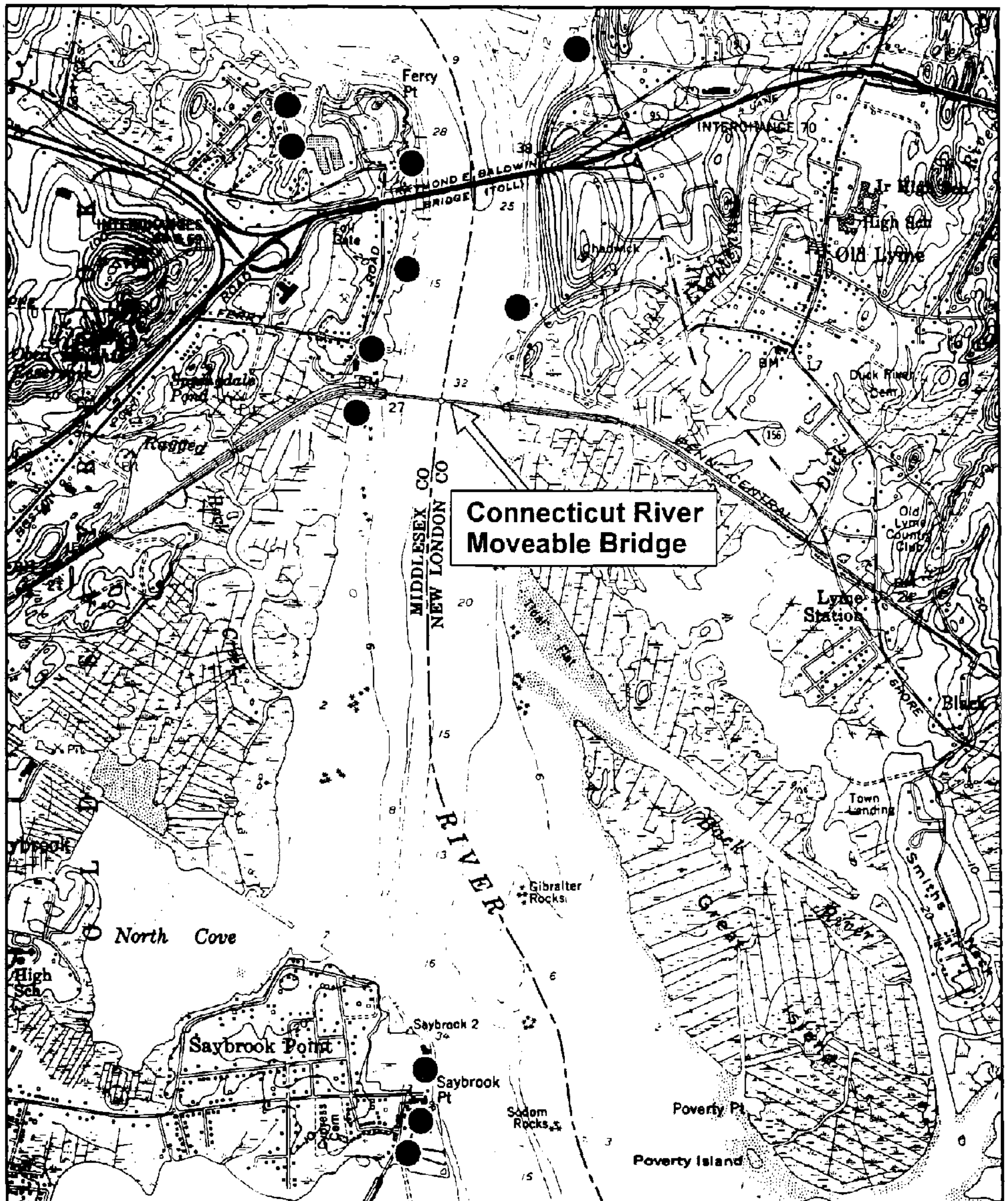
The traffic data tabulated for each bridge below are drawn from a number of environmental documents prepared for the moveable bridges in the period 1976/78. While clearly reflecting conditions over 15 years ago, the data are of some use in defining the magnitude of marine traffic at a given point in time and in defining the relative volumes of marine traffic among the five bridges. These data are also useful in comparisons with the 1993 bridge opening data. Such comparisons are noted below.

A means of estimating the "theoretical" volume of boats which could pass through each bridge in 1993 is developed and presented below. This volume is calculated by totaling the marine windows, or periods (in minutes) when the railroad bridge is in the up position, for the 12-hour period from 7 AM to 7 PM, and then multiplying the total minutes by two, which depicts a passage of two boats per minute *per direction* through the bridge.[21] The factor of two boats per minute per direction was deemed by the four harbormasters to be reasonable.

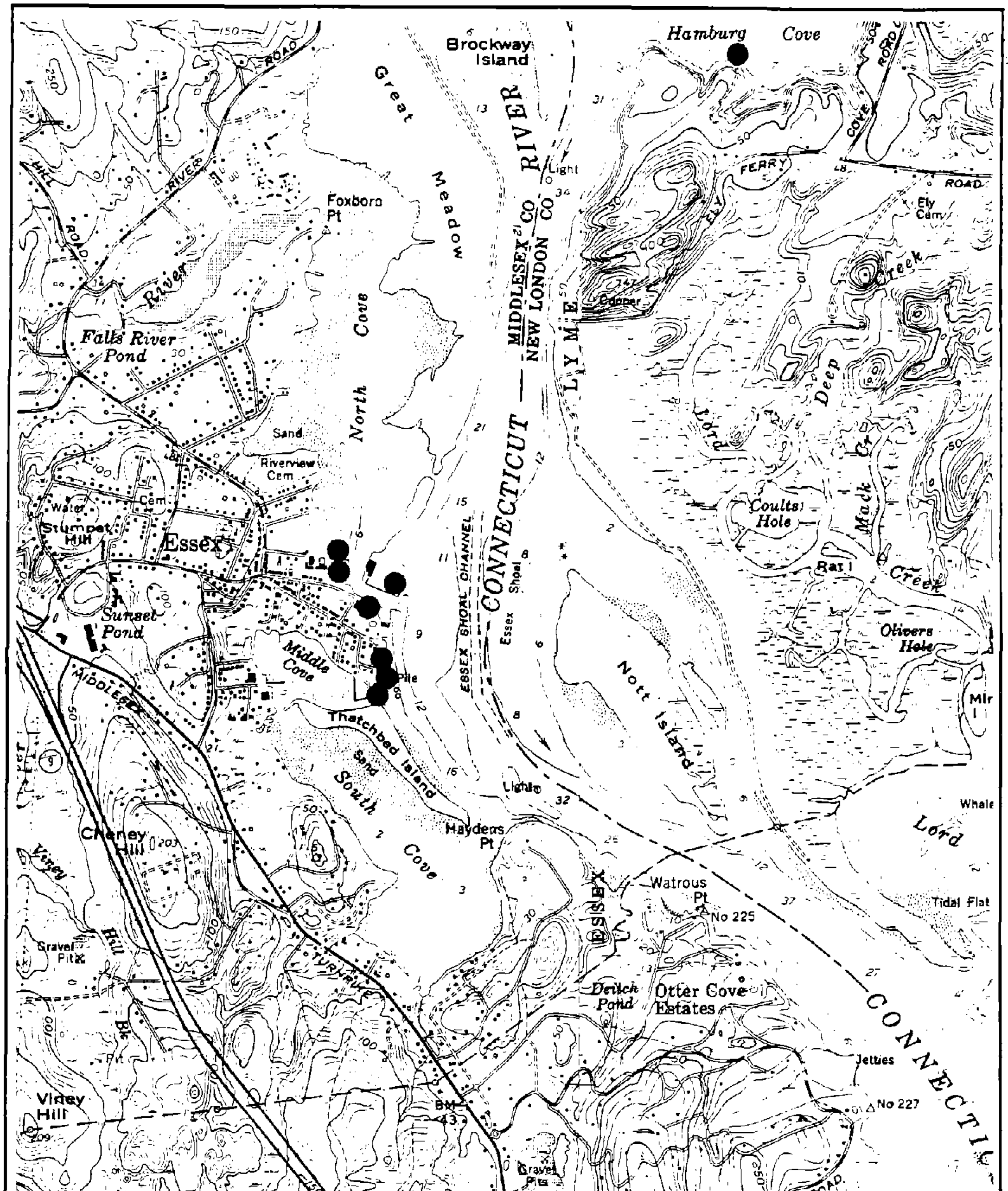
The volume thus derived is the estimated volume of boats which *require the vertical clearance provided by the bridge in its open position*. Not all boats require a bridge opening; therefore, the volume derived by this methodology is not the full volume of boats able to pass under the moveable bridge in question.

Connecticut River Bridge.
Marinas and Marine-Related Businesses: There are approximately 31 marine-related businesses, i.e., marinas, yacht clubs, marine service shops, located along the shoreline of the Connecticut River (see Figure 3.2-3). Of the 31 businesses, 29 are located upriver (north) of the Connecticut River Bridge. The projected total facility counts at the 29 businesses, based on a sample size of 20 businesses, are as follows: 2,609 slips, 372 moorings/racks, and 2,911 winter/storage spaces. The average slip, mooring, and storage occupancy rate at each of the businesses located north of the moveable railroad bridge is 95 percent a year.

Based on economic data provided by 14 businesses, total annual revenues for the 29 businesses located upriver of the bridge are projected at $15.8 million. Employment in the peak summer period is projected at 218 employees for the 29 businesses.



MARINAS AND MARINE-RELATED BUSINESSES FOR CONNECTICUT MOVEABLE BRIDGE	Figure 3.2-3
Northeast Corridor Improvement Project Electrification - New Haven CT to Boston MA	



MARINAS AND MARINE-RELATED BUSINESSES FOR CONNECTICUT MOVEABLE BRIDGE

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 3.2-4

Presently, six of the 20 marine-related businesses surveyed are planning to expand their operations in some capacity, i.e., slips, moorings, or winter/storage.

The two marine-related businesses located downriver of the Connecticut River Bridge have 200 slips and 200 winter/storage spaces, with an occupancy rate of all facilities at about 100 percent. The total annual revenues of the two businesses is estimated at $1.1 million. One of the two marine operations is planning to expand its site in some capacity.

Marine Traffic: Marine traffic for the period 1977/78 is tabulated in Table 3.2-4. Also tabulated in this table are the bridge openings for 1977/78 and 1993. In comparing the bridge openings, the data reveal marked declines in bridge openings for the months November through April and an increase of 23 percent in bridge openings for the month of July, a peak boating month. The remaining months for 1993 show slightly increased levels of bridge openings over the comparable months in 1977/78.

TABLE 3.2-4 Marine Traffic and Bridge Openings at Connecticut River Bridge, 1977/78 and 1993

MONTH	NUMBER OF COMMERCIAL VESSELS	NUMBER OF OPENINGS	NUMBER OF OPENINGS, 1993	% CHANGE, 1977/78 - 1993
August 1977	92	502	551	10
September	104	404	433	7
October	96	318	328	3
November	125	182	145	-20
December	136	158	60	-62
January 1978	126	127	59	-54
February	125	123	54	-56
March	135	132	62	-53
April	135	206	109	-47
May	81	262	299	14
June	74	405	412	2
July	79	469	575	23

Sources: Federal Railroad Administration, 1979; Amtrak, 1993

Between 7 AM and 7 PM, the 1993 marine window totals 576 minutes in a typical weekday. At two boats per minute in each direction, the bridge has an estimated capacity of 1,152 boats (requiring bridge openings) per direction per day.

Niantic River Bridge.
Marinas and Marine-Related Businesses: There are eight marine-related businesses located on the Niantic

River, all located north (upstream) of the railroad bridge (see Figure 3.2-5). Six of the eight businesses were surveyed and the results of these surveys, projected to the eight businesses, are as follows: 787 slips, 376 moorings, and 1,387 winter/storage spaces. Occupancy rates are approximately 98 percent. Based on economic data provided by five businesses, the projected total annual revenue of the eight is $4.5 million.

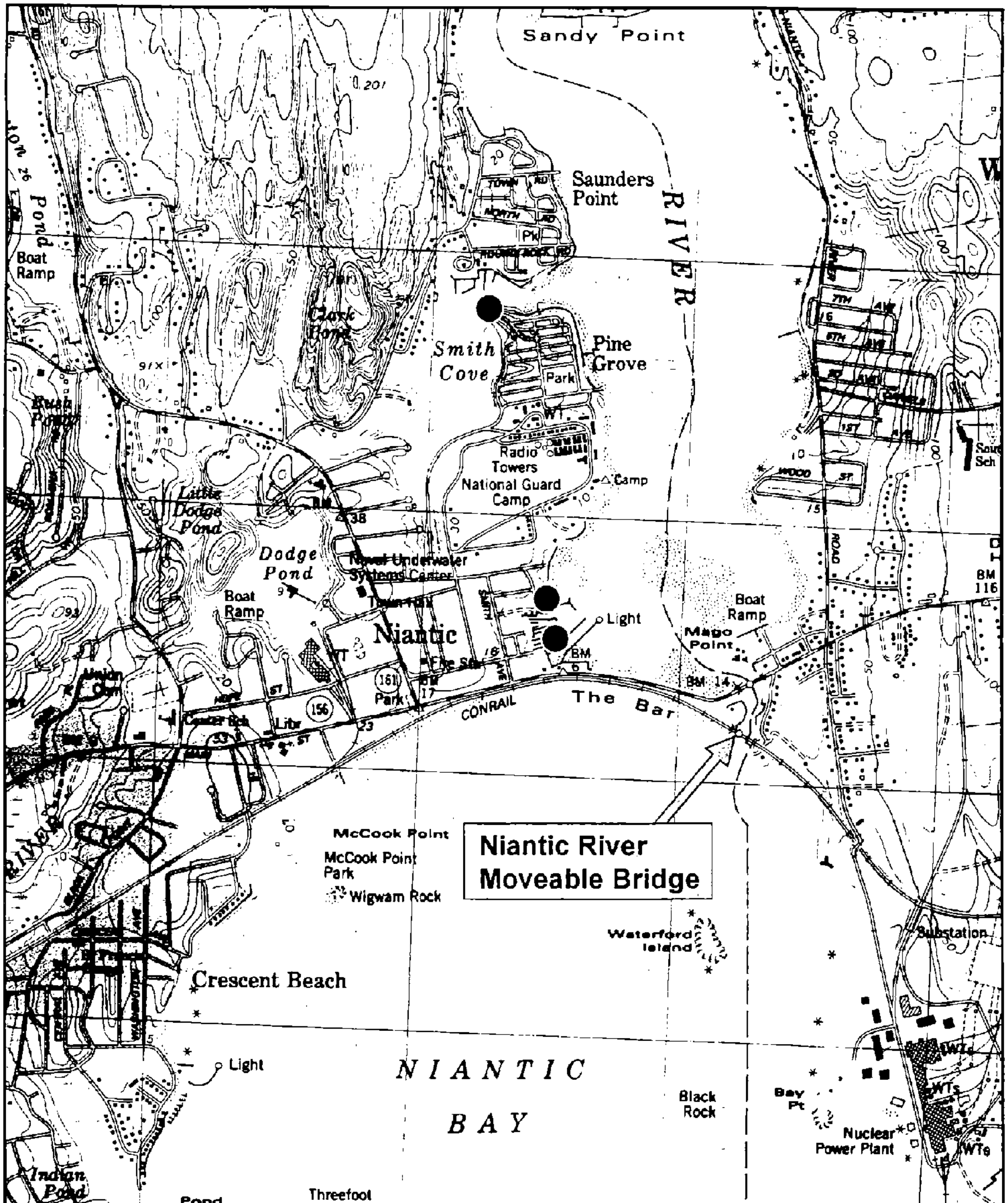
Employment is projected at 67 during the peak summer period. Presently, none of the six operations surveyed has any plans to expand operations.

Marine Traffic: Marine traffic for the period 1976/77 is tabulated in Table 3.2-5. The bridge opening data for the periods 1976/77 and 1993 are also tabulated here. Bridge openings in July and August 1993 increased by 21 percent and 26 percent, respectively, over the 1976 data. The most marked changes occurred in the off-peak boating period October through February, where both increases and decreases in openings are noted.

TABLE 3.2-5 Marine Traffic and Bridge Openings at Niantic River Bridge, 1976/77 and 1993

MONTH	NUMBER OF VESSELS	NUMBER OF OPENINGS	NUMBER OF OPENINGS, 1993	% CHANGE, 1976/77 - 1993
May 1976	743	325	319	-2
June	1211	404	415	3
July	1713	426	515	21
August	1950	418	526	26
September	1426	346	328	-5
October	852	271	455	68
November	176	136	171	26
December	51	49	66	35
January 1977	39	38	30	-21
February	41	39	22	-44
March	72	62	57	-8
April	188	121	122	1

Sources: Federal Railroad Administration, 1979; Amtrak, 1994



MARINAS AND MARINE-RELATED BUSINESSES FOR NIANTIC RIVER MOVEABLE BRIDGE

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 3.2-5

Between 7 AM and 7 PM, the 1993 marine window totals 559 minutes in a typical weekday. As noted above, tidal and current conditions at the bridge permit boat movements in only one direction at a time. At two boats per minute, the bridge has an estimated capacity of 1,118 boats (requiring bridge openings) per day.

Shaw's Cove Bridge.

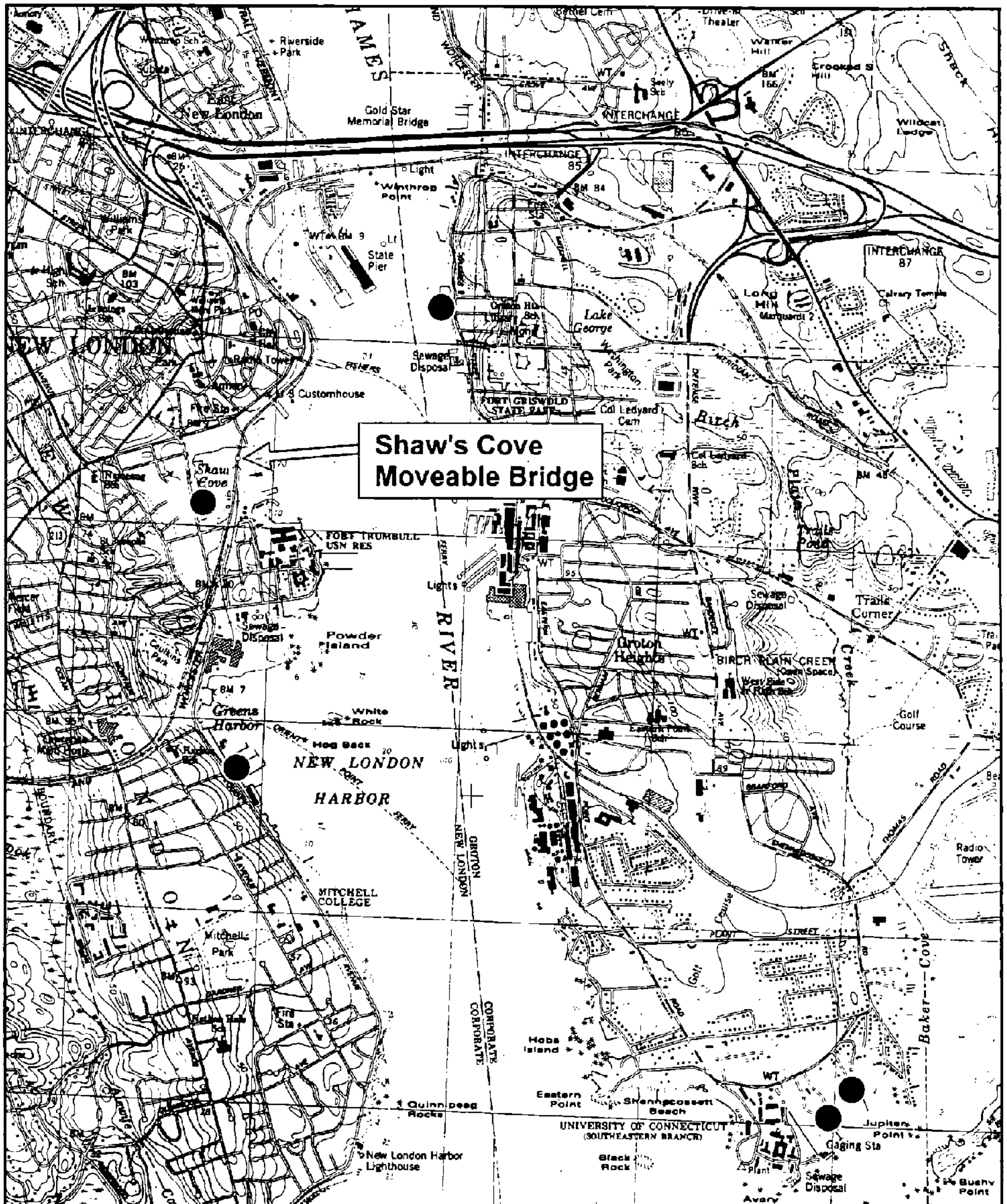
Marinas and Marine-Related Businesses: There is one marina located behind the Shaw's Cove Bridge, with 286 slips and 350 winter/storage facility spaces (see Figure 3.2-6). Given issues of confidentiality, occupancy and economic data for this one marina are not published in this report.

Marine Traffic: Marine traffic for the period 1976/77 and bridge openings for the periods 1976/77 and 1993 are tabulated in Table 3.2-6. With the exception of 1 month, April, 1993 openings are higher than the comparable months in 1976/77, and considerably higher for most months. Data for 5 months in 1993 reveal increases in openings exceeding 100 percent, including an apparent 900 percent increase (four to 40 openings) in openings for the month of January. Data for January 1977 (four openings for four boats) reflect the fact that the moveable bridges remain closed for long periods in the off-peak boating months, particularly in the colder winter months, opening only upon demand.

TABLE 3.2-6 Marine Traffic and Bridge Openings at Shaw's Cove Bridge, 1976/77 and 1993

MONTH	NUMBER OF VESSELS	NUMBER OF OPENINGS	NUMBER OF OPENINGS, 1993	% CHANGE, 1976/77 - 1993
May 1976	344	180	245	36
June	378	151	310	105
July	526	188	410	118
August	551	190	350	84
September	368	147	218	48
October	226	119	201	69
November	95	73	109	49
December	33	30	79	163
January 1977	4	4	40	900
February	12	12	35	192
March	48	37	40	8
April	122	82	79	-4

Sources: Federal Railroad Administration, 1981; Amtrak, 1994



MARINAS AND MARINE-RELATED BUSINESSES FOR SHAW'S COVE MOVEABLE BRIDGE

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 3.2-6

Between 7 AM and 7 PM, the 1993 marine window totals 554 minutes in a typical weekday. At two boats per minute in each direction, the bridge has an estimated capacity of 1,108 boats (those requiring bridge openings) per direction per day.

Thames River (Groton) Bridge.

Marinas and Marine-Related Businesses: There are eight marine-related businesses located along the shoreline of the Thames River in the study area (see Figure 3.2-7). Of the eight, four are located north or upstream of the Groton/Thames River Bridge. Marine facilities, based on survey data provided by two businesses, are projected to be 544 slips, 16 moorings, and 288 winter/storage spaces. The average occupancy percentage is projected at 93 percent. The total annual revenue of the four upstream businesses is projected to be $1.7 million, based on economic data provided by two of the four businesses. The peak summer period employment at these facilities is projected at 44.

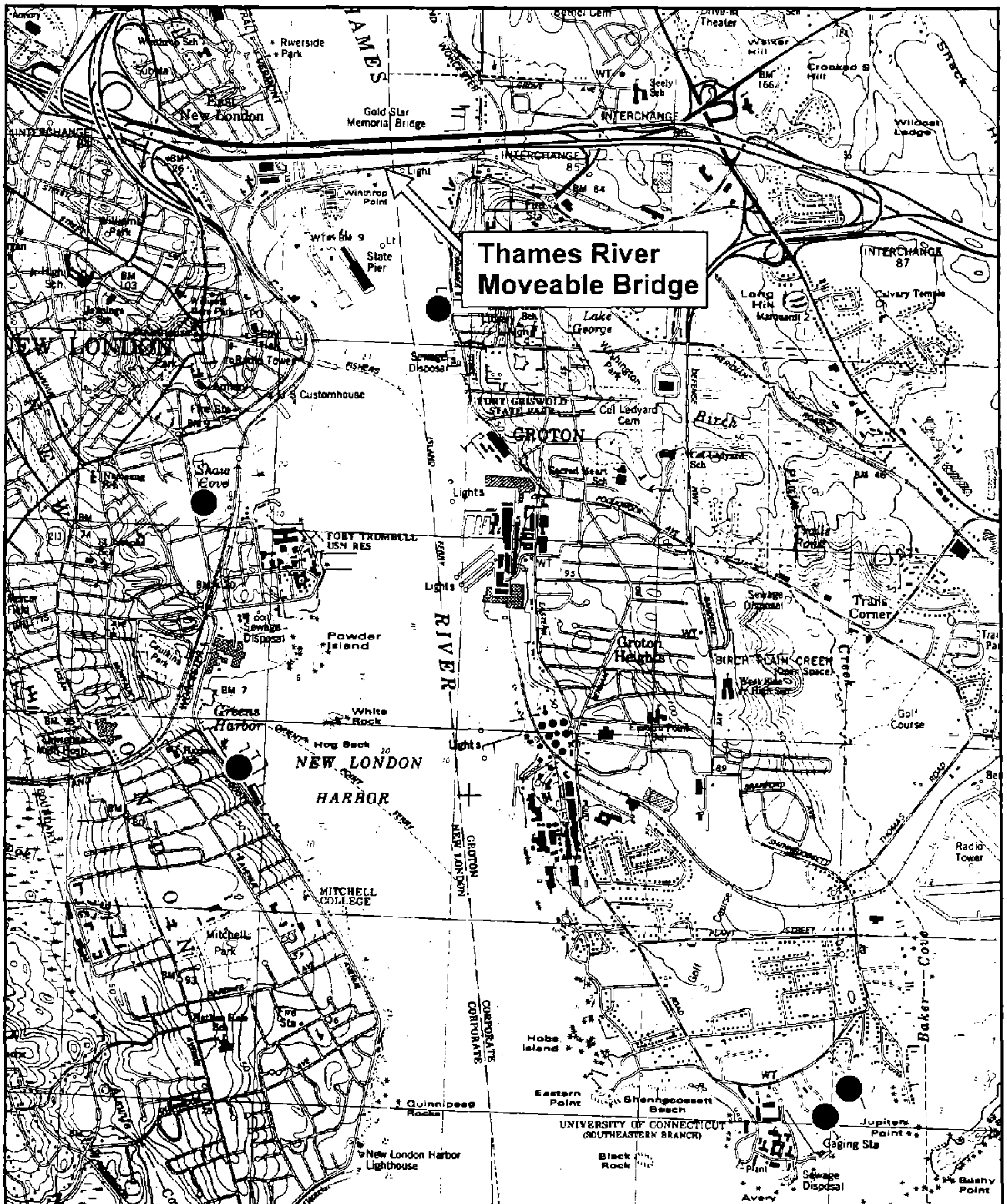
Presently, one of the two upstream businesses surveyed is planning on expanding its operation in some capacity. The remaining four marine-related operations along the shoreline of the Thames River are located south (downstream) of the railroad bridge. Based on a sampling of three of the four businesses, the projected totals of marine facilities are 345 slips, 120 moorings, and 153 winter/storage spaces. The projected occupancy is 85 percent.

Two of the downstream businesses provided economic data. Based on these data, total annual revenues are estimated at $1.1 million for the four businesses. Employment is projected at 27 during the peak summer period. At the present date none of the three downstream businesses surveyed is planning on expanding its operations.

Marine Traffic: An important generator of marine traffic in the Thames River is the U.S. Navy. The U.S. Naval Submarine Base at New London is located on the east bank of the Thames River above Groton, CT. The New London Naval Base was created in 1868 when the City of New London gave the Navy approximately 112 acres of farmland. The base now consists of 1,326 acres of land and over 1,750 buildings.

The Naval Submarine Base at New London is responsible for maintaining facilities to support both afloat and ashore forces. The base supports the submarines of Submarine Group Two, Submarine Development Squadron Twelve, and Submarine Squadron Two. The submarines and squadrons are located on "Lower Base," which stretches along the Thames River and is the site of the original base. Shark Boulevard, once a state highway, divides the Lower Base from the "Upper Base," which extends up and away from the road on higher ground. This section contains administration buildings, Naval Submarine School buildings, the Naval Hospital Groton, recreational facilities, and barracks. Counting dependents, over 40,000 people use the Navy Submarine Base at New London.

Because of national security considerations, specific information on the amount and nature of U.S. Navy movements are not presented here. Most naval movements under the Thames River Bridge do require the bridge to be opened. Given the strategic importance of the Naval Submarine Base, the Thames River is designated a National Defense Waterway. Also located north of the bridge is the U.S. Coast Guard Academy, a facility which generates some marine traffic in vessels of all sizes.



MARINAS AND MARINE-RELATED BUSINESSES FOR THAMES RIVER MOVEABLE BRIDGE

Figure 3.2-7

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Marine traffic for the period 1976/77 is tabulated in Table 3.2-7. Bridge opening data for the periods 1976/77 and 1993 are also contained in this table. The bridge opening data indicate that there were fewer bridge openings for 9 months in 1993 when compared to the same months in 1976/77. For only 3 months -- July, August, and October -- did 1993 openings exceed 1976/77 figures. Two of the 3 months, July and August, are peak boating months, so a rough conclusion can be drawn that peak-period seasonal boating volumes were higher in 1993 than in 1976/77, while there appears to be net decline in off-peak seasonal boating volumes. Between 7 AM and 7 PM, the 1993 marine window totals 573 minutes in a typical weekday. At two boats per minute in each direction, the bridge has an estimated capacity of 1,146 boats (those requiring bridge openings) per direction per day.

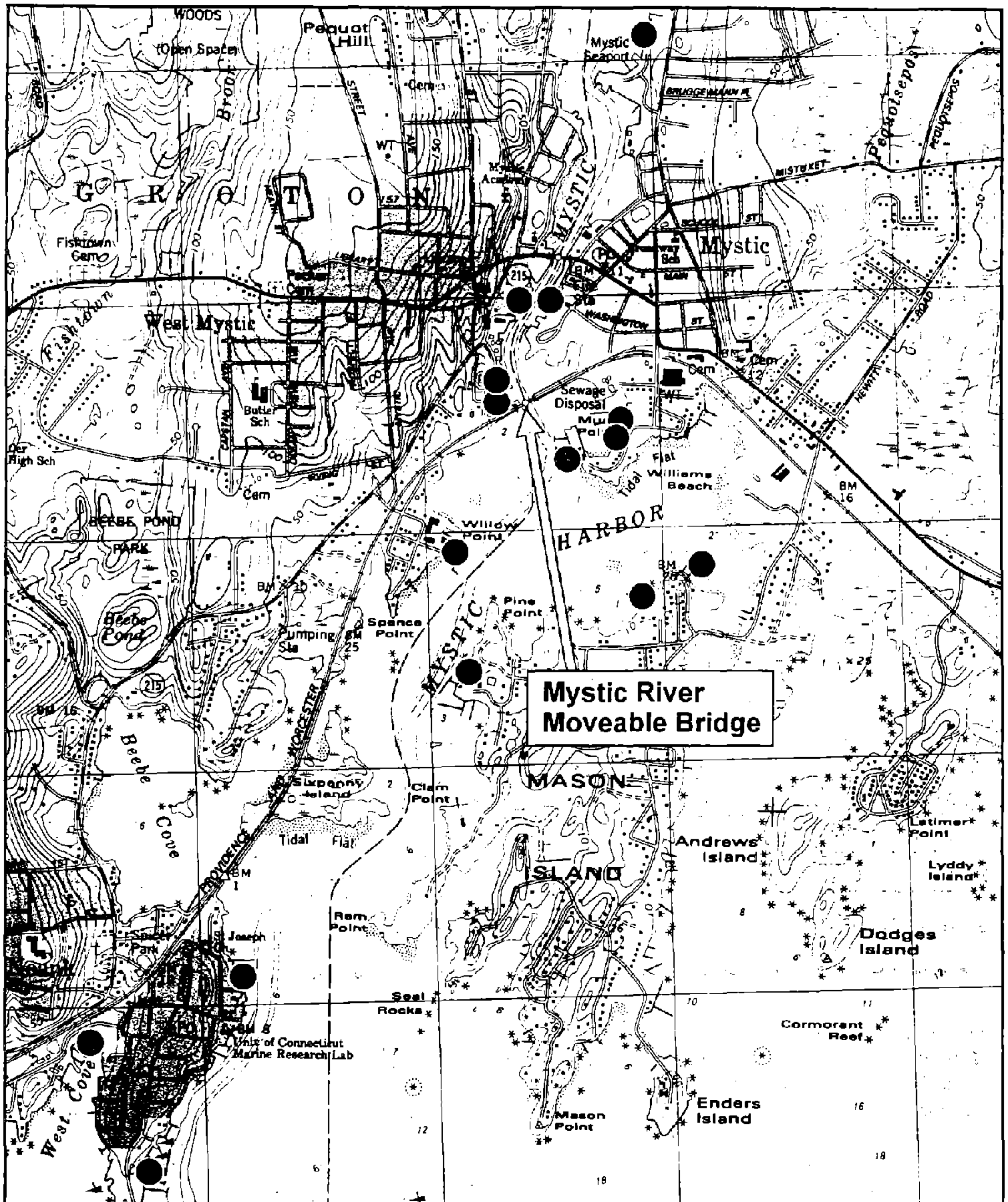
TABLE 3.2-7 Marine Traffic and Bridge Openings at Thames River Bridge, 1976/77 and 1993

MONTH	NUMBER OF VESSELS	NUMBER OF OPENINGS	NUMBER OF OPENINGS, 1993	% CHANGE, 1976/77 - 1993
May 1976	415	201	192	-4
June	415	346	222	-36
July	482	254	363	43
August	435	240	293	22
September	390	207	199	-4
October	298	174	213	22
November	234	150	103	-31
December	248	138	110	-20
January 1977	228	141	87	-38
February	281	169	113	-33
March	164	107	104	-3
April	238	159	130	-18

Sources: Federal Railroad Administration, 1979; Amtrak, 1994

Mystic River Bridge.
Marinas and Marine-Related Businesses: There are 16 marine-related facilities located along the shoreline of the Mystic River (see Figure 3.2-8). Seven of the 16 marinas situated on the river are located north (upstream) of the railroad bridge. All seven businesses were contacted and provided data on their marine facilities. The totals are 388 slips and 765 winter/storage spaces. The average occupancy rate is 87 percent. The total annual revenues of the seven upstream businesses are $2.2 million. The upstream businesses employ 86 people during the peak summer period.

Two of the seven marine-related businesses have expansion plans at the present.



MARINAS AND MARINE-RELATED BUSINESSES FOR MYSTIC RIVER MOVEABLE BRIDGE

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 3.2-8

Nine businesses are located south (downstream) of the Mystic River Bridge. Eight of the nine provided facility data. An average of these data, applied to the ninth business, yields the following totals for all nine businesses: 1,613 slips, 327 moorings, and 1,693 winter/storage spaces. Occupancy rates average 91 percent. From a sample size of five businesses, the total annual revenues of the nine businesses are projected at $5.6 million. Employment is projected at 132 during the peak summer period.

At present two of the eight marine related businesses surveyed are planning expansion in their operations in some capacity.

Marine Traffic: Marine traffic for the period 1976/77 is tabulated in Table 3.2-8. The bridge opening data in this table indicate moderate increases in openings for the key boating months of July and August 1993 over figures for July and August 1976 (13 percent and 5 percent, respectively). Comparisons of the remaining months indicate both increases and decreases from earlier levels.

Between 7 AM and 7 PM, the 1993 marine window totals 571 minutes in a typical weekday. At two boats per minute in each direction, the bridge has an estimated capacity of 1,142 boats (those requiring bridge openings) per direction per day.

TABLE 3.2-8 Marine Traffic and Bridge Openings at Mystic River Bridge, 1976/77 and 1993

MONTH	NUMBER OF VESSELS SELECTED MONTHS	NUMBER OF OPENINGS	NUMBER OF OPENINGS, 1993	% CHANGE, 1976/77 - 1993
May 1976	--	319	312	-2
June	--	401	440	10
July	--	500	567	13
August	1,463	506	529	5
September	1,210	390	439	13
October	685	316	341	8
November	--	193	130	-33
December	81	81	58	-28
January 1977	5	5	24	380
February	17	16	30	88
March	82	82	37	-55
April	245	218	106	-51

Sources: Federal Railroad Administration, 1979; Amtrak, 1994

Summary. Marina facilities and total annual revenues for the marinas and marine-related facilities at the five moveable bridges are summarized in Table 3.2-9. Marine traffic for all five moveable bridges in the period 1976/78 is summarized in Table 3.2-10.

TABLE 3.2-9 Facility and Economic Data of Marine-Related Businesses at the Five Moveable Bridges

BRIDGE	LOCATION	NO.	PROJECTIONS					
			SLIPS	MOORINGS	TOTAL	WINTER STORAGE	EMPLOYEES, PEAK SUMMER	ANNUAL REVENUES ($m)
Connecticut River[1]	Upstream	29	2,609	372	2,981	2,911	218	15.8
	Downstream	2	200	0	200	200	19	1.1
Total		31	2,809	372	3,181	3,111	237	16.9
Niantic River[2]	Upstream	8	787	376	1,163	1,387	67	4.5
	Downstream	0	0	0	0	0	0	0
Total		8	787	376	1,163	1,387	67	4.5
Shaw's Cove[3]	Upstream	1	286	0	286	350	12	-
Thames River[4]	Upstream	4	544	16	560	288	44	1.7
	Downstream	4	345	120	465	153	27	1.1
Total		8	889	136	1,025	441	71	2.8
Mystic River[5]	Upstream	7	388	0	388	765	86	2.2
	Downstream	9	1,613	327	1,940	1,693	132	5.6
Total		16	2,001	327	2,328	2,458	218	7.8

Notes: [1]Facility projections based on the following sample sizes: 21/29 upstream; 2/2 downstream. Economic projections are based on the following sample sizes: 14/29 upstream; 2/2 downstream.
[2]Facility projections based on the following sample sizes: 6/8 upstream; [N.A.] downstream. Economic projections are based on the following sample sizes: 5/8 upstream; [N.A.] downstream.
[3]Economic data suppressed to protect confidentiality of marina owner.
[4]Facility projections based on the following sample sizes: 2/4 upstream; 3/4 downstream. Economic projections are based on the following sample sizes: 2/4 upstream; 2/4 downstream.
[5]Facility projections based on the following sample sizes: 7/7 upstream; 8/9 downstream. Economic projections are based on the following sample sizes: 4/7 upstream; 5/9 downstream.

Source: DMJM/Harris, 1994

TABLE 3.2-10 Marine Traffic Summary, 1976/78[1]

BRIDGE	TOTAL NO. OF OPENINGS	TOTAL NO. OF BOATS
Connecticut River Bridge	3,288	1,308[2]
Niantic River Bridge	2,635	8,461
Shaw's Cove Bridge	1,213	2,707
Thames River Bridge	2,286	3,828
Mystic River Bridge	3,027	3,788[3]

Notes: [1]The above data were tabulated during the following time periods: CT River Bridge, 1977-78; Niantic River Bridge, 1976/77; Shaw's Cove Bridge, 1976/77; Thames (Groton) River Bridge, 1976-77; and Mystic River Bridge, 1976/77.
[2]Commercial craft
[3]Selected months

Source: Various FRA environmental documents on the five moveable bridges

3.2.1(d) Regulatory Setting

The NEC Shore Line route within eastern Connecticut was originally constructed as separate segments early in the second half of the nineteenth century. The final link was the first moveable bridge over the Thames River which opened in 1889. At the time of construction of the railroad, moveable bridges were required to maintain the rights of maritime traffic operating over navigable watercourses. Initially, the "rules of the road" required the railroad to open the bridges on demand for passage of vessels as long as railroad operational safety was not affected. Over time, with the increase in speed and frequency of railroad trains, it was deemed to be in the public interest to create special regulations to govern the opening of the moveable bridges so as to develop reasonable solutions to the potential conflicts between railroad and marine traffic demands. The U.S. Coast Guard has responsibility for the promulgation and enforcement of such regulations.

For the five moveable bridges along the NEC route north of New Haven, such regulations are now in effect. Such regulations are reproduced for each of the five bridge locations with the pertinent citation and effective date.

Connecticut River Bridge.
Section 117.205 Connecticut River:

(a) The draws of the Amtrak Old Saybrook - Old Lyme Bridge, mile 3.4 and the Conrail Middletown Bridge, mile 32.0, shall open on signal:

(1) For commercial vessels except as described below:

(i) Amtrak Bridge, Mile 3.4, when a westbound train scheduled to cross the bridge without stopping has passed Old Lyme and Blackhall Station, or an eastbound train has passed Saybrook Junction Station, and is in motion toward the bridge, the draw shall be opened as soon as the train has crossed the bridge.

(2) For all other vessels which cannot pass the closed bridges the draws shall be opened as soon as practicable, but in no case shall the delay be more than 20 minutes from the time of request.

(b) All openings of the draws shall afford full horizontal and vertical clearance, regardless of the size or requirements of the passing vessel.

[CGD3 85-42, 50 CFR 26711, June 28, 1985]

Niantic River Bridge.
Section 117.215 Niantic River:

(a) The draw of the Amtrak bridge, mile 0.0 at Niantic, shall open on signal; except that, from April 1 through October 31 from 8 PM to 4 AM and from November 1 through March 31 from 6 pm to 6 am, the draw shall open on signal if at least one hour notice is given. When a train scheduled to cross the bridge without stopping has entered the drawbridge block, a delay in opening the draw may occur until the train has cleared the block.

(b) The draw of the S156 bridge, mile 0.1 at Niantic, shall open on signal; except that, from 7 AM to 8 AM and from 4 PM to 5 PM Monday through Friday except holidays, the draw shall open only for the passage of commercial vessels.

[CGD 82-025, 49 FR 17452, Apr. 24, 1984; 49 FR 37381, Sept.24, 1984]

It is to be noted that the regulation for the Niantic Railroad River Bridge is coupled with the regulation of the Connecticut State Highway Moveable Bridge over the Niantic River which is located 0.1 mile north (upstream) of the railroad bridge.

Shaw's Cove Bridge.
Section 117.223 Shaw Cove:

The draw of the Amtrak bridge, mile 0.0 at New London, shall open on signal from December 1 through March 31 from 8 AM to 5 PM Monday through Friday. From December 1 through March 31 from 5 PM to 8 AM and on Saturdays and Sundays, the draw shall open on signal if at least eight hours notice is given. From April 1 through November 30 from 5 AM to 10 PM the draw shall open on signal; and from 10 PM to 5 AM, the draw shall open on signal if at least one hour notice is given. A delay of up to 10 minutes may be expected if a train is approaching so closely that it may not be safely stopped. When a vessel is in an emergency that may endanger life or property, the draw shall open as soon as possible.

[CGD 82-025, 49 FR 17452, Apr. 24, 1984; 49 FR 43459, Oct. 29, 1984]

Thames River Bridge.
Section 117.224 Thames River:

The draw of the Amtrak bridge, mile 3.0 in New London, shall open --

(a) Immediately on signal for vessels owned or operated by the United States Government, state and local vessels used for public safety, vessels in an emergency, and commercial vessels; except, when a train scheduled to cross the bridge without stopping has passed the Midway, Groton, or New London station and is in motion toward the bridge, the draw shall not be opened for the passage of any vessel until the train has crossed the bridge; and

(b) As soon as practicable for all other vessels but no later than 20 minutes after the signal to open is given.

[CGD 82-025, 49 FR 43459, Oct. 29, 1984]

Mystic River Bridge.
Section 117.211 Mystic River:

(a) The draw of the Amtrak railroad bridge, mile 2.4 at Mystic, shall operate as follows:
(1) From April 1 to October 31, the draw shall open on signal.
(2) From November 1 to March 31, the draw shall open on signal if at least eight hours notice is given.
(3) Public vessels of the United States, state and local vessels used for public safety, vessels in an emergency, and commercial vessels shall be passed immediately at any time; however, the opening may be delayed up to eight minutes to allow trains, which have entered the drawbridge block and are scheduled to cross the bridge without stopping to clear the block.
(4) All other vessels shall be passed as soon as practicable but no later than 20 minutes after the signal to open is given.

(b) The draw of the U.S. 1 bridge, mile 2.8 at Mystic, shall open on signal, with a maximum delay of 20 minutes, except:
(1) From May 1 through October 31 from 7:15 AM to 7:15 PM, the draw need only open hourly at quarter past the hour.

(2) From November 1 through April 30 from 7:15 PM to 5:15 AM, the draw shall open on signal upon eight hours notice.

[CGD 82-025, 49 FR 43458, Oct. 29, 1984, as amended by CGD3 84-31, 50 FR 26710, June 28, 1985]

As in the case of the Niantic River Railroad Bridge, it is to be noted that the regulation of the railroad is coupled with the regulation of the State Highway Moveable Bridge which is located north (upstream) of the railroad bridge. The distance between these bridges is 1.4 miles.

3.2.1(e) Summary of the Affected Environment

While there are inevitable conflicts in the current daily interaction of marine and railroad traffic at the five moveable bridges, it appears by all accounts that marine traffic has adapted well to the present level of railroad activity across the bridges. In the daylight hours of the peak boating season the bridges remain in the up position for the most part. In the winter months or other off-season boating months, the bridges generally remain closed, opening upon signal.

There are conflicts, however, and there are a number of concerns on the part of mariners which frequently arise in any discussion of moveable bridge issues. One, mariners frequently cite the unreliable train schedules at present, which affect their ability to avoid nuisance delays at the bridges. Two, mariners also cite the seemingly arbitrary and capricious behavior of the bridge tenders, who are Amtrak employees. From the perspectives of the mariners, the bridge tenders tend to give priority to train passages and not to mariners, causing delays in excess of those allowed by the U.S. Coast Guard regulations. Amtrak is aware of these concerns and recently began periodic meetings with groups of mariners, boating industry representatives, and state and local government officials to air and to resolve such disputes.

3.2.2 Environmental Consequences

This section explores the potential effects of projected 2010 railroad traffic on the ability of marine traffic to pass through the five moveable bridges identified in Section 3.2.1(a). The analysis follows expressions of public concern that projected increases in daily rail service with accompanying bridge closures would unduly restrict maritime activities. Such restrictions, it is argued, would affect the regional economy by inconveniencing boat owners and harming marinas and other marine-related businesses located upstream of these bridges. This section assesses the likelihood that projected 2010 railroad traffic would restrict maritime movements beyond that encountered in 1993 and outlines a series of impact scenarios possible in the event that more frequent restrictions occur.

In this analysis of the moveable bridges, there are no evaluation criteria which one can use to conclude directly that impacts have crossed a particular threshold. In the absence of such criteria a number of measures are put forth to qualitatively assess potential impacts. The impact criterion put forth is the effect on marine movements through the individual moveable bridges. Two means of assessing this criterion are as follows:

- Change in measured/theoretical capacity for boat passages through the moveable bridges
- Number and total duration of projected delays over 20 minutes

3.2.2(a) Projected 2010 Boat Registrations

Boat registrations in Connecticut for the period 1986/93 are illustrated in Table 3.2-11. In the late 1980s, fueled by the national economy's strong growth and a general surge in the popularity of recreational boating, boating registrations increased at a significant rate, with 1988 levels almost 10 percent above 1987 levels. The effects of the economic slowdown beginning in the late 1980s and the effect of the so-called 10 percent luxury boat tax are also clearly reflected in these data.[23] By 1989, the explosive growth of the two prior years has dropped from 6.1 percent in 1987 and 9.6 percent in 1988 to 3.6 percent, followed by 2.1 percent growth in 1990. There was negligible growth in 1992 and a slight decline in boat registrations for 1993 (-1.2 percent).

These data do indicate the sensitivity of recreational boating to the general state of the economy. Recreational boating is an expensive recreational activity, for the most part, and in times of recession, many individuals and families cut back on expenses, boating being one such area that is targeted for cuts. With the national and regional economy now indicating signs of growth, local marinas are experiencing a resurgence in slip bookings and boat sales, as noted in a recent article in *The New Haven Register*.[24]

TABLE 3.2-11 Boat Registrations in Connecticut, 1986/93

YEAR	NUMBER OF BOATS	PERCENT CHANGE
1986	81,485	--
1987	86,444	+6.1%
1988	94,819	+9.6%
1989	98,254	+3.6%
1990	100,366	+2.14%
1991	100,800	+.43%
1992	100,877	+.07%
1993	99,619	-1.2%

Source: State of Connecticut, 1994

Despite negative growth in 1993, there is an increase of approximately 18,000 boat registrations between 1986 and 1993. Over this 7-year period, this growth implies an average annual increase of 2.9 percent. Projecting this same growth over the 17-year period 1993-2010 yields approximately 162,000 boat registrations in Connecticut. While a number of coastal Connecticut communities have been particularly hard hit by the cutbacks in national defense spending, and thus are experiencing some economic difficulties still, the attractiveness of coastal Connecticut (and of the inland waterways of Connecticut as well) and the continued popularity of recreational boating make such a projection reasonable. Therefore, while there will be periods of strong growth and also periods of stagnant or even declining growth, the general trend is assumed to be positive growth in boat activity.

The marina owners gave further indication of continued growth in recreational boating and related activities. Of 49 marinas surveyed for this study, 12 or roughly 25 percent are planning some form of physical expansion.

3.2.2(b) Projected 2010 Railroad Operations at Moveable Bridges

To analyze possible future rail usage of bridges, FRA/Amtrak simulated 2010 rail operations over the NEC. This simulation used an optimum schedule from a rail perspective, without consideration of bridge operations, and, consequently, can be viewed as a Worst Case Scenario. These data are detailed in Appendix 3A and summarized in Table 3.2-12.

The projected increase in Amtrak intercity service is shown in Table 3.2-12. Shore Line East commuter rail service is scheduled to extend beyond Old Saybrook to New London by 2010 and would affect three bridges -- the Connecticut River, Niantic River, and Shaw's Cove bridges. Freight rail service is also expected to grow slightly, doubling the number of freight rail trains across four bridges from 1993 levels.

The effects of these train movements on bridge closures and marine windows are presented graphically in Appendix 3B. The available marine windows are tabulated in Appendix 3C.

TABLE 3.2-12 Railroad Movements, Typical Weekday, 2010

BRIDGE	RAILROAD MOVEMENTS ACROSS BRIDGE			
	AMTRAK (intercity)	SHORE LINE EAST (commuter)	P&W RR (freight)	TOTAL
Connecticut River	54	10	4	68
Niantic River	54	10	4	68
Shaw's Cove	54	10	4	68
Thames River	52	0	4	56
Mystic River	52	0	2	54

Sources: FRA, *Draft Master Plan*, Appendix H, 1993
ConnDOT, Fax transmittal dated May 6, 1993 to DMJM/Harris
P&W, P&W letters dated December 14, 1992 and February 8, 1994 to DMJM/Harris

Analysis of train movement impacts on bridge closures and marine windows in 1993 and in 2010 indicates that all five bridges would be closed more frequently and for longer periods in 2010 than in 1993 (see Appendix 3B). This means that in 2010 fewer marine movements could be accommodated each weekday than was the case in 1993.

At the Connecticut River Bridge, the 2010 marine window between 7 AM and 7 PM totals 317 minutes in a typical weekday, down from windows of 576 minutes in 1993. At two boats per minute in each direction the bridge in 2010 would have an estimated capacity of 634 boats per direction per day, a 45 percent decline from 1,152 in 1993.

At the Niantic River Bridge, the 2010 marine window between 7 AM and 7 PM totals 316 minutes in a typical weekday, down from windows of 559 minutes in 1993. At two boats per minute, the bridge has a 2010 estimated capacity of 632 boats per day, a 43 percent decline from 1,118 in 1993.

At the Shaw's Cove Bridge, bridge capacity was projected at levels 49 percent below 1993 levels. At the Thames River Bridge, 39 percent fewer marine movements could be accommodated in 2010 with a decline by 32 percent of potential 2010 movements at the Mystic River Bridge. Table 3.2-13 outlines the reduction from 1993 levels of bridge capacity that could accompany prospective 2010 rail activity.

TABLE 3.2-13 Total Marine Windows and Estimated Boat Passage Volumes, 7 AM to 7 PM, Typical Weekday, 1993 and 2010

BRIDGE	TOTAL MARINE WINDOWS (7AM to 7PM) (min)		ESTIMATED BOAT PASSAGES, EACH DIRECTION[1]	
	1993	2010	1993	2010
Connecticut River	576	317	1,152	634
Niantic River	559	316	1,118[1]	632[1]
Shaw's Cove	554	284	1,108	568
Thames River	573	350	1,146	700
Mystic River	571	387	1,142	774

Notes: [1]Each direction with the exception of Niantic River, where open water conditions frequently permit only single-lane movement through the bridge. Passages are those requiring a bridge opening only.
[2]As boat passages are derived from the total marine windows, the percent decrease applies to the changes in both marine windows and boat passages.

Source: DMJM/Harris from FRA data, 1994

Impacts associated with this reduced 2010 capacity would be exacerbated if the frequency and duration of bridge closures which would accompany peak rail travel periods were to overlap with peak marine travel periods. Analysis indicates that this overlap of peak rail and marine traffic demand would occur.

The frequency and longer duration of bridge closures would be most pronounced in the morning and afternoon peak travel periods, reflecting projected daily intercity demand for travel as well as the introduction of Shore Line East commuter traffic. The harbormasters note that there are similar peaking patterns in marine traffic as well, although apparently less pronounced than in journey to work commuter patterns. The longest single bridge closure period and the available marine windows for two key boating periods -- 7 to 10 AM and 5 to 8 PM -- are presented in Table 3.2-14.

In the morning period the longest projected continuous bridge closing occurs at the Niantic River Bridge, where the bridge is in the down position for 60 minutes. The 3-hour morning marine window is 68 minutes, particularly critical for a bridge passage where open water conditions frequently permit marine traffic in a single direction only. Using an estimated passage volume of two boats per minute, in this instance in a single direction, 136 boats with a vertical clearance of more than 10 feet can pass through this bridge. From Table 3.2-9, a total of 1,163 slips and moorings are estimated to be located upstream of the Niantic River Bridge.

TABLE 3.2-14 Projected Impact of Bridge Closures in Key Morning and Afternoon Periods of Marine Traffic, Typical Weekday, 2010

BRIDGE	MORNING PERIOD (7 - 10 AM)			AFTERNOON PERIOD (5 - 8 PM)		
	LONGEST SINGLE BRIDGE CLOSURE (min)	TOTAL AVAILABLE MARINE WINDOWS		LONGEST SINGLE BRIDGE CLOSURE (min)	TOTAL AVAILABLE MARINE WINDOWS	
		(min)	Percent of Period		(min)	Percent of Period
Connecticut River	30	81	45.0	48	80	44.4
Niantic River	60[1]	68	37.8	74[2]	49	27.2
Shaw's Cove	32[3]	84	46.7	123	43	23.9
Thames River	41	70[4]	33.8	39	103[5]	57.2
Mystic River	54	88[6]	48.9	48	79[7]	43.9

Notes: [1]Closure period begins at 6:21 AM. Total bridge closure is from 6:21 AM - 8 AM (1 hour 39 minutes).

[2]Closure period extends to 8:08 PM. Total bridge closure is from 6:46 PM - 8:08 PM (1 hour 22 minutes).

[3]Closure period extends to 10:16 AM. Total bridge closure is from 9:28 AM - 10:16 AM (48 minutes).

[4]Window begins at 6:46 AM and extends to 10:13 AM. Total marine window between 6:46 AM and 10:13 AM is 1 hour 37 minutes.

[5]Window begins at 4:48 PM and extends to 8:09 PM. Total marine window between 4:48 PM and 8:09 PM is 2 hours 4 minutes.

[6]Window begins at 6:39 AM and extends to 10:20 AM. Total marine window between 6:39 AM and 10:20 AM is 2 hours 20 minutes.

[7]Window begins at 4:46 PM and extends to 8:16 PM. Total marine window between 4:46 PM and 8:16 PM is 1 hour 49 minutes.

Source: DMJM/Harris from FRA data, 1994

In the afternoon period the greatest impacts appear at the Shaw's Cove Bridge, located west of the New London rail station. The bridge is projected to close from 5:47 PM to 7:50 PM, a period of 2 hours and 3 minutes, during which time four Shore Line East commuter trains and seven Amtrak trains cross the bridge. The total marine window available to the mariners within Shaw's Cove is 43 minutes in the period 5 PM to 8 PM. As the bridge has only a 6-foot vertical clearance at MHW, a bridge opening is required for all but smaller boats. Within the 43-minute marine window, approximately 86 boats in each direction can pass through the bridge opening. While 86 boats reflects approximately 30 percent of the total boats estimated to be moored in Shaw's Cove, a 2+ hour bridge closing in a peak boating period could likely affect a mariner's choice of marina facilities; consequently, economic impacts would likely be felt by marinas and marine-related businesses in Shaw's Cove.

Impacts could appear at all five bridges. Congestion may even appear at the Connecticut River Bridge, given the volume of slips and moorings (roughly 3,000) estimated to be located upstream of the bridge. While the vertical clearance at this bridge is 19 feet at MHW, all but the smaller sailboats require bridge openings. With marine windows of 81 and 80 minutes, respectively, for the morning and evening peak boating periods, a theoretical volume of 160 boats in each direction can pass through the bridge, *if* one "lane" of boat traffic in each direction is assumed. With a horizontal clearance of 139 feet between bridge abutments, there is some likelihood that boats will pass in parallel heading in the same direction. Channel widths are of constant concern to mariners, and the larger boats will likely choose the main channel rather than venture into the shallower waters outside the main channel.

Table 3.2-14 projects the impacts at each moveable bridge. Existing Coast Guard regulations in effect at the bridges specifically state in a number of instances that [maritime] delays should not exceed 20 minutes. One measure of impacts in 2010, therefore, is the time in minutes where delay is anticipated to exceed 20 minutes. Table 3.2-15 presents these data in tabular form.

TABLE 3.2-15 Projected Maritime Delays at Bridges in Excess of 20 Minutes, 4 AM - 12 Midnight, Typical Weekday, 2010

BRIDGE	AVERAGE DAILY OPENINGS, MAY-OCT	VESSEL DELAYS IN EXCESS OF 20 MINUTES (4 AM - 12 Midnight)		
		PERIODS	TOTAL DELAY (min)	TOTAL EXCESS TIME OVER 20 MINUTES (min)
Connecticut River	14.22	9	379	228
Niantic River	14.06	8	408	213
Shaw's Cove	9.43	9	373	199
Thames River	8.05	7	244	104
Mystic River	14.22	5	190	90

Source: DMJM/Harris from FRA data, 1994

Three bridges -- the Connecticut River Bridge, the Niantic River Bridge, and the Shaw's Cove Bridge -- are projected to have total maritime delays of over 200 minutes on a typical weekday in 2010. The Thames River and the Mystic River bridges are projected to have delays of approximately 100 minutes, roughly half that of the other three bridges. As indicated in Table 3.2-12, the number of Amtrak intercity and freight trains across the latter two bridges differs only slightly from the volumes over the other three bridges. What is apparent from Tables 3.2-12 and 3.2-14, however, is the influence of the 10 Shore Line East commuter trains across the Connecticut River, Niantic River, and Shaw's Cove bridges. These commuter trains clearly would have an impact and raise a number of issues vis-a-vis Connecticut commuters and Connecticut boaters.

The data in Appendix 3B also indicate how many Shore Line East and Amtrak trains combine to create the long bridge closings in key marine traffic periods. As noted above, four Shore Line East commuter trains and seven Amtrak trains contribute to the over 2-hour bridge closing at the Shaw's Cove Bridge, and commuter trains contribute significantly to delays at the Connecticut River, Niantic River, and Shaw's Cove bridges. During the 1-hour and 39-minute bridge closing which occurs between 6:21 AM and 8:00 AM at the Niantic River Bridge, three Shore Line East and five Amtrak trains cross during this period. Clearly, Shore Line East movements contribute substantially to the impacts at the bridges.

In summary, the total marine windows and estimated boat passage volumes available at the projected 2010 train schedule would result in decreased marine windows and reduced volumes of boats which could pass through the bridges. At today's level of boating activity, significant impacts to mariners would be likely if these projected schedules were in effect today; in 2010, with projected increases in boat activity, the impacts will be even greater.

While impacts to mariners are primarily in the areas of convenience and free choice/movement, the steps mariners may take to reduce the impacts to themselves directly will likely have impacts, both beneficial and negative, on the marinas and marine-related businesses in the areas surrounding the moveable bridges. A number of likely scenarios are possible and these are explored below.

3.2.2(c) Impact Scenarios

As noted in Section 3.2.2(a), boat registrations in Connecticut have increased at an annual rate of 2.9 percent since 1986. This trend is expected to continue, even in the face of declining marine windows and reduced bridge throughput capacities. While survey results indicate that the reduced marine windows are likely to impact choices of where boats are moored within the state, the businesses surveyed did not predict a significant exodus of marine activity to either New York or Rhode Island. This suggests that the economic impacts associated with increased rail activity would be more localized in nature, reflecting locational decisions within communities or between neighboring communities. Survey data do not indicate that the Proposed Action would diminish the attractiveness of Connecticut's shoreline to maritime commerce or recreational boating activity with corresponding regional economic consequences. Instead, the results suggest the greater likelihood of the following probable scenarios.

Scenario #1: Relocation out of Area. Scenario #1 assumes that a boat owner would relocate out of the waterway area impacted by the moveable bridge, e.g., from the Connecticut River to inland waterways or to a marina in an adjacent coastal area not impacted by railroad bridges. The economic multiplier effects of the expenditures of this boat owner are thus removed from the area surrounding the moveable bridge, directly affecting the local economy.

This is a plausible scenario, and some boat owners may pursue such an action. The factors that affect a boat owner's selection of a boat location are numerous, and several at least relate to proximity to the boat owner's residence and other convenience factors. The perceived inconvenience of dealing with moveable bridge issues would be weighed by an individual against these factors and a decision to remain or relocate would ultimately be reached.

Given the projected growth in boating activity, however, it is also possible that a new boat owner will "replace" the relocated boat owner and moor his/her boat in the moveable bridge area, e.g., a powerboat replaces a sailboat. In this instance, the economic impacts would be neutral.

Scenario #2: Relocation *within* an Area. This scenario, cited frequently by marina owners, assumes that the owners of larger boats will be drawn to marinas located downstream of the moveable bridges. Sensing this interest, marina owners downstream may be able to charge higher fees for mooring larger boats, possibly displacing the owners of smaller boats in the process. Marinas upstream may then be viewed as location alternatives by the owners of the smaller boats. The boats remain within the moveable bridge area, but are simply relocated. Owners of marinas and marine-related businesses downstream of the bridges may see some increase in business revenue; owners of marinas and marine-related businesses upstream of the moveable bridges may see a decrease in business revenue.

In effect, this is what is happening today, according to the harbormasters and a number of marina owners. The larger boats do locate at marinas not impacted by the moveable bridges, paying a premium for such locations in some instances (which could be viewed as a moveable bridge penalty). Smaller boat owners and those owners not willing to pay premium prices are drawn to alternate locations, even those located upstream of the moveable bridges. The projected bridge closings in 2010 could exacerbate these conditions.

It is impossible at this level of analysis to determine which likely scenario would be followed by the majority of boat owners; thus it is impossible to quantify, in specific dollar terms, the impact that more frequent and lengthy future bridge closings would have on the marine industry and, consequently, the local economies along coastal Connecticut. It is possible to assert, however, that to some extent future impacts would likely occur to a number of local businesses along the Connecticut coast. It seems appropriate that mitigation measures be evaluated and implemented as service frequencies increase and impacts begin to surface.

The above scenarios address recreational boating. To a considerable degree, military and commercial boat traffic through the bridges can be scheduled to coincide with the available marine windows. Impacts to these boat traffic classes, therefore, are considered minimal. Military and commercial traffic will, however, benefit from the mitigation measures discussed below.

3.2.2(d) Mitigation Measures

As noted above, the role of resolving conflicts between railroad and marine traffic demands is assigned to the U.S. Coast Guard. Any train schedule that implies an alteration in the current regulations at the five moveable bridges would first have to be approved by the Coast Guard. Consequently, the Coast Guard will play a key role in deciding which mitigation measures are appropriate and effective. A number of exploratory meetings and discussions with the Coast Guard have been held to date on issues surrounding moveable bridges and Coast Guard permits, and such discussions will continue as the design of the Proposed Action proceeds.

Mention should be made here of a number of elements of NECIP which affect and will affect conditions at the five moveable bridges. Important parts of NECIP are the signal and bridge upgrade programs. The Niantic River bridge is slated for replacement through NECIP, and several other moveable bridges have already been rehabbed through this program. Installation of a signal system capable of handling high speed trains is also being programmed. Both bridge rehabilitations and signal installations increase the efficiency and reliability of the systems and should play a key role in eliminating delays due to malfunctioning equipment or outdated signals.

In addition to elements already programmed in NECIP, there are mitigation measures which could be considered for implementation as service frequencies increase. These range from expensive, such as increasing vertical clearances at the moveable bridges, to less costly measures such as utilizing marine expediters. These measures are detailed below.

Service Frequencies and/or Schedule Adjustment. Impacts can be reduced by adjusting train frequencies and/or arrival/departure times to create more frequent marine windows and to eliminate bridge closings for long and continuous periods. Since impacts to mariners are seasonal impacts limited primarily to the warm weather months, adjustments to the Amtrak spring/summer timetable and not the fall/winter timetable may be in order. A reduction in train frequencies could be matched with longer trains on the remaining scheduled runs to continue to service the intercity travel demand. It is very possible that relatively minor adjustments in projected future train schedules would reduce impacts significantly.

Elimination of Weekend and Holiday Service on the Shore Line East. As indicated by the data in Appendices 3B and 3C, there are less frequent bridge closings and more time in the marine windows on a typical Saturday than on a typical weekday. This is due primarily to reduced Amtrak train frequencies on weekends. However, Shore Line East service is presently intended by ConnDOT to run on Saturdays, Sundays, and holidays at substantial frequencies. A measure to be further explored is the elimination of or significant reduction in the weekend/holiday schedules and frequencies of the Shore Line East in the spring and summer periods. Such a measure would create additional and more lengthy marine windows.

Vertical Clearance Increase. Consideration could be given to revising the grade and profile of these bridges during the next rehabilitation of these bridges to increase the vertical clearance. As four of the five bridges have been rehabilitated in the past 10 to 15 years, it is unlikely that these bridges would be in need of significant rehabilitation for another 15 to 25 years. However, the Niantic River and Thames River bridges are scheduled for replacement in the near future and some attention could be given to increasing the vertical clearance at this bridge.

Equipment Upgrades and Maintenance. One means of maximizing the available marine windows is to upgrade the motor mechanisms of the moveable bridges with two purposes: to speed up the opening and closing of the bridges and to increase the reliability of the mechanisms. Reliability is crucial to Amtrak and Shore Line East operations and of considerable interest to mariners as well.

Use of Marine Expediters. A marine expediter could be utilized during the peak months of maritime traffic to maximize the available marine windows. The role of the expediter would be to organize the marine traffic waiting for a bridge opening, with the goal of increasing the number of boats which can pass through the available windows. For instance, when marine traffic in only one direction is present, the expediter could organize this traffic into two parallel streams of traffic. Such an expediter has been used at one moveable bridge, the Niantic River Bridge, with success in the past. To function as intended the expediter would require a boat and good communications equipment. Given the needs of the various bridges, it may be possible to have one or two "roving" expediters, working at different bridges at different days of the week or during specific times of the day.

3.2.2(e) Summary

The projected train frequencies for Amtrak intercity service and the proposed extension of Shore Line East commuter rail service from Old Saybrook to New London are likely to impact maritime operations at the five moveable railroad bridges in Connecticut. The impacts are in two areas: reduced marine windows at the bridges and bridge closings of greater duration. It should be stressed that these impacts are seasonal in nature, limited primarily to the warmer months when recreational boating is at its peak. This is not to dismiss the significance of these impacts, however, as the marine industry in coastal Connecticut is a significant contributor to a number of local economies. The increased frequency of intercity (Amtrak) trains is not the direct result of the extension of electrification per se but of the cumulative impacts of NECIP as a whole. As such, the Proposed Action as well as the No-Build Alternative FF-125 and FRA-150 scenario, would have equivalent impacts on these bridges.

The U.S. Coast Guard, whose role it is to resolve conflicts between railroad and maritime traffic, would be a key player in any discussions regarding impacts to mariners at the moveable bridges.

Endnotes

1. *Regional Multipliers: A User Handbook for the Regional Input-Output Modelling System*, United States Department of Commerce, Bureau of Economic Analysis. May, 1992.

2. *Employment and Earnings*, United States Department of Labor, Bureau of Labor Statistics. Washington, January, 1994.

3. *Industrial Sand and Gravel - 1991*, United States Department of Interior, Bureau of Mines (Washington, DC, November 1992). *Cement - 1991*, United States Department of Interior, Bureau of Mines (Washington, DC, April 1993). *Mineral Industry Survey - 1992*, United States Department of Interior, Bureau of Mines (Washington, DC, February 1993).

4. *Railroad Industry Perspectives: A Summary of Railroad Industry Major Concerns and Trends*, American Association of State Highway and Transportation Officials. Washington, 1990.

5. Comments of Providence & Worcester Railroad Company on Draft Environmental Impact Statement/Report DEIS - Northeast Corridor Improvement Project - Electrification - New Haven, CT to Boston, MA, Providence & Worcester Railroad Company, undated.

6. *Employment and Earnings*, United States Department of Labor, Bureau of Labor Statistics. Washington, January, 1994.

7. *Regional Multipliers: A User Handbook for the Regional Input-Output Modelling System*, United States Department of Commerce, Bureau of Economic Analysis. May, 1992.

8. Ibid.

9. *Rhode Island Third Rail Economic Information*, Rhode Island Port Authority and Economic Development Corporation. June, 1994.

10. *Regional Multipliers: User Handbook for the Regional Input-Output Modelling System*, United States Department of Commerce, Bureau of Economic Analysis. May, 1992.

11. Ibid.

12. *Analysis of the Providence and Worcester Year 2010 Local Freight Service For the Environmental Impact Statement*, D&Z Transportation Services, September 1994.

13. *Connecticut's Boating Business*, a publication (undated) of the Connecticut Marine Trades Association, Essex, CT.

14. Ibid.

15. *Rehabilitation of Connecticut River Bridge (4F).* Northeast Corridor Improvement Project. Federal Railroad Administration, April 1, 1979.

16. Nautical data for the five bridges are drawn from Nautical Chart 12372, *Watch Hill to New Haven Harbour*, Edition 27. National Oceanic and Atmospheric Administration, March 1, 1993.

17. *Replacement of Niantic River Bridge,* Final Environmental Impact Statement 4(f) Statement. Federal Railroad Administration, May, 24, 1979.

18. *Replacement of Shaw's Cove Bridge and Approaches New London, CT.* Final Environmental Impact Statement 4(f) Statement. Federal Railroad Administration, September 16, 1981.

19. *Rehabilitation of Groton Bridge New London/Groton, CT.* Finding Of No Significant Impact. Federal Railroad Administration, December 12, 1979.

20. *Replacement Of Mystic River Bridge And Approaches.* Draft Environmental Impact Statement, 4(f) Statement. Federal Railroad Administration, August 21, 1979.

21. *Waterway Guide,* Northern 1994. Volume 47, No. 4. Argus, Inc. 1994

22. The Niantic River Bridge is an exception. Marine conditions exist frequently which permit a boat passage in only one direction. Thus, the theoretical volume at this bridge denotes passage in one direction only.

23. The tax was included in the Federal Omnibus Budget Reconciliation Act. The act added an additional 10 percent tax on every dollar above $100,000 on boats costing $100,000 or more; hence, the sobriquet "luxury boat tax." The implementation of the tax began on January 1, 1991; it was subsequently repealed on August 1, 1993. A number of marina owners cited this tax as contributing to the decline in high-priced boat sales documented in the early 1990s.

24. *Economic Tide Lifts Marinas,* The New Haven Register, Dave Altimari, May 7, 1994.

Appendix 3A

TABLE 3A-1 Existing Train Operations At Moveable Bridges, 1993

TRAIN	CONNECTICUT RIVER	NIANTIC RIVER	SHAW'S COVE	THAMES RIVER	MYSTIC RIVER
67	12:35a	12:26a	12:18a	12:12a	12:06a
61	5:06a	4:55a	4:46a		
66	6:00a	6:10a	6:15a	6:22a	6:31a
151	**7:56a**	**7:47a**	**7:42a**	**7:34a**	**7:26a**
169	9:33a	9:24a	9:18a	9:10a	9:03a
12	9:40a	9:49a	9:55a	10:02a	10:10a
153	11:00a	10:50a	10:43a	10:39a	10:31a
171	11:38a	11:29a	11:22a	11:13a	11:07a
190	12:14p	12:23p	12:30p	12:34p	12:42p
173	1:43p	1:35p	1:26p	1:18p	1:11p
170	2:18p	2:26p	2:31p	2:38p	2:46p
154	2:57p	3:05p	3:11p	3:15p	3:23p
175	3:38p	3:30p	3:22p	3:15p	3:06p
172	4:29p	4:38p	4:44p	4:51p	4:59p
177	5:53p	5:45p	5:38p	5:32p	5:25p
174	5:59p	6:07p	6:12p	6:18p	6:27p
179	**6:39p**	**6:30p**	**6:25p**	**6:17p**	**6:07p**
156	7:10p	7:19p	7:24p	7:29p	7:36p
176	8:33p	8:43p	8:49p	8:55p	9:03p
193	9:22p	9:12p	9:03p	8:55p	8:47p
178	9:57p	10:06p	10:12p	10:19p	10:28p
162	10:43p	10:51p	10:57p	11:04p	11:12p
60	11:20p	11:27p	11:34p		
77	12:02a	11:56p	11:47p	11:41p	11:35p

Key: 9:00 Trains operate 7 days per week
9:00 Trains operate Monday through Friday

Source: Federal Railroad Administration, 1994

TABLE 3A-2 Projected Train Operations at Moveable Bridges, 2010[1]

CONNECTICUT RIVER	NIANTIC RIVER	SHAW'S COVE	THAMES RIVER	MYSTIC RIVER
4:32a	4:26a	4:22a		
5:00a	5:06a	5:09a	5:16a	5:23a
5:49a	5:57a	6:02a		
6:29a	6:28a	6:22a		
6:37a	6:37a	6:43a		
6:56a	6:50a	6:47a	6:43a	3:63a
7:19a	7:09a	7:03a		
7:23a	**7:28a**	7:30a	7:23a	7:14a
7:38a	7:33a	**7:31a**	**7:35a**	**7:42a**
7:39a	**7:44a**	**7:47a**	7:49a	7:43a
8:03a	7:57a	7:54a	**7:54a**	**8:01a**
8:24a	*8:29a*	**8:30a**	**8:23a**	**8:16a**
8:39a	**8:33a**	*8:32a*	*8:36a*	*8:43a*
9:03a	**8:57a**	**8:54a**	**8:50a**	**8:43a**
9:28a	9:29a	9:25a	9:18a	9:12a
9:35a	**9:34a**	**9:37a**	**9:40a**	9:39a
10:00a	9:54a	9:50a	9:46a	**9:47a**
10:04a	10:10a	10:03a	10:20a	10:27a
10:31a	10:13a	10:13a	10:44a	**10:38a**
10:58a	10:37a	10:40a	**10:45a**	10:50a
11:19a	**10:52a**	**10:49a**		
11:32a	11:32a	11:28a	11:20a	11:13a
11:37a	**11:37a**	**11:40a**	**11:44a**	11:39a
11:53a	11:53a	11:50a	11:45a	**11:51a**
11:59a	11:58a	12:02p	12:08p	12:16p
12:24p	12:29p	12:32p	12:36p	**12:39p**
12:59p	**12:53p**	**12:50p**	**12:45p**	12:43p
1:02p	1:10p	1:16p		
1:28p	1:30p	1:26p	1:19p	1:12p

TABLE 3A-2 Projected Train Operations at Moveable Bridges, 2010[1] (continued)

CONNECTICUT RIVER	NIANTIC RIVER	SHAW'S COVE	THAMES RIVER	MYSTIC RIVER
1:36p	**1:33p**	**1:36p**	**1:40p**	1:39p
1:49p	1:53p	1:50p	1:46p	**1:46p**
1:59p	1:55p	1:54p	2:05p	2:12p
2:10p	2:00p	1:59p		
2:26p	2:32p	2:35p	2:39p	2:39p
2:33p	2:53p	2:50p		
2:59p	2:53p	3:05p	2:46p	2:45p
3:24p	**3:29p**	**3:31p**	3:23p	3:17p
3:40p	3:36p	3:32p	**3:36p**	3:39p
3:49p	3:53p	3:50p	3:45p	**3:43p**
3:59p	3:56p	3:58p	4:05p	4:12p
4:24p	4:29p	4:32p	4:36p	**4:39p**
4:58p	**4:53p**	**4:50p**	**4:45p**	4:43p
5:24p	**5:29p**	5:28p	5:21p	5:14p
5:38p	5:32p	**5:32p**	**5:36p**	**5:42p**
6:01p	5:58p	5:54p	5:50p	5:43p
6:03p	6:06p	6:10p	6:18p	6:23p
6:03p	6:13p	6:18p		
6:26p	6:32p	6:35p	6:39p	*6:37p*
6:59p	*6:53p*	*6:48p*	*6:43p*	6:45p
6:59p	6:59p	6:52p	*7:16p*	7:10p
7:03p	*7:06p*	*7:09p*		
7:05p	7:12p	7:17p		
7:30p	7:28p	7:25p	7:17p	*7:22p*
7:34p	7:35p	7:38p	7:42p	*7:37p*
7:51p	7:43p	7:38p		
7:57p	*7:52p*	*7:47p*	*7:44p*	7:48p
7:59p	8:05p	8:08p	8:16p	8:23p
8:26p	8:33p	8:36p	8:40p	**8:38p**

TABLE 3A-2 Projected Train Operations at Moveable Bridges, 2010[1] (continued)

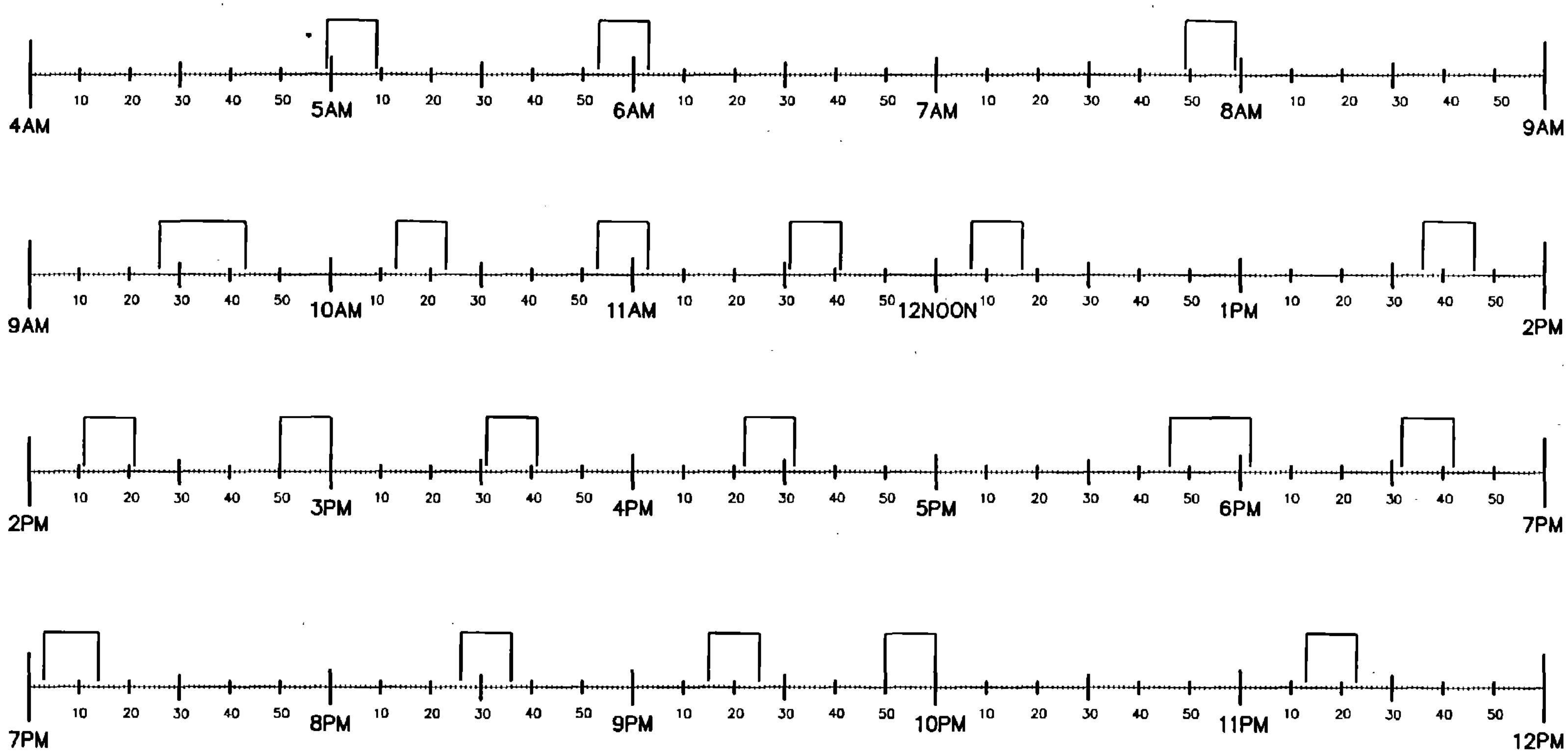
CONNECTICUT RIVER	NIANTIC RIVER	SHAW'S COVE	THAMES RIVER	MYSTIC RIVER
<u>8:58p</u>	**<u>8:52p</u>**	**<u>8:48p</u>**	**<u>8:45p</u>**	8:46p
9:24p	*9:28p*	*9:24p*	*9:17p*	*9:10p*
9:32p	9:29p	9:32p	9:35p	9:39p
9:50p	9:55p	9:49p	9:45p	9:42p
9:55p	9:55p	9:58p		
9:59p	10:01p	10:08p	10:06p	10:12p
10:28p	10:34p	10:38p	10:41p	10:47p

Note: [1]Trains at midspan -- does not include freight

Key:
- 9:00 Trains operate 7 days per week
- **9:00** Trains operate only Monday through Friday
- **<u>9:00</u>** Trains do not operate on Sunday
- *9:00* Trains do not operate on Saturday

Source: Federal Railroad Administration, 1994

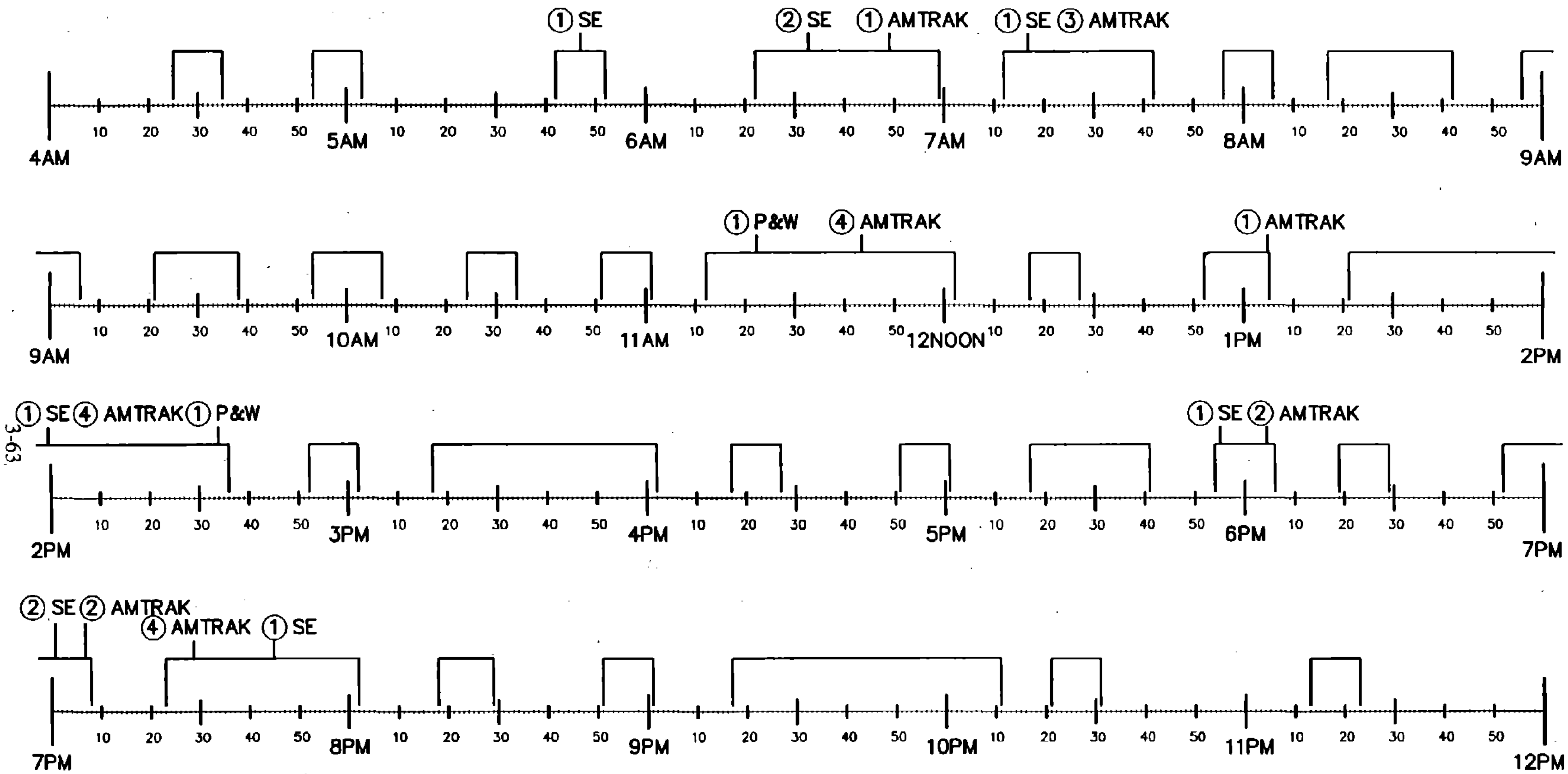
Appendix 3B



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

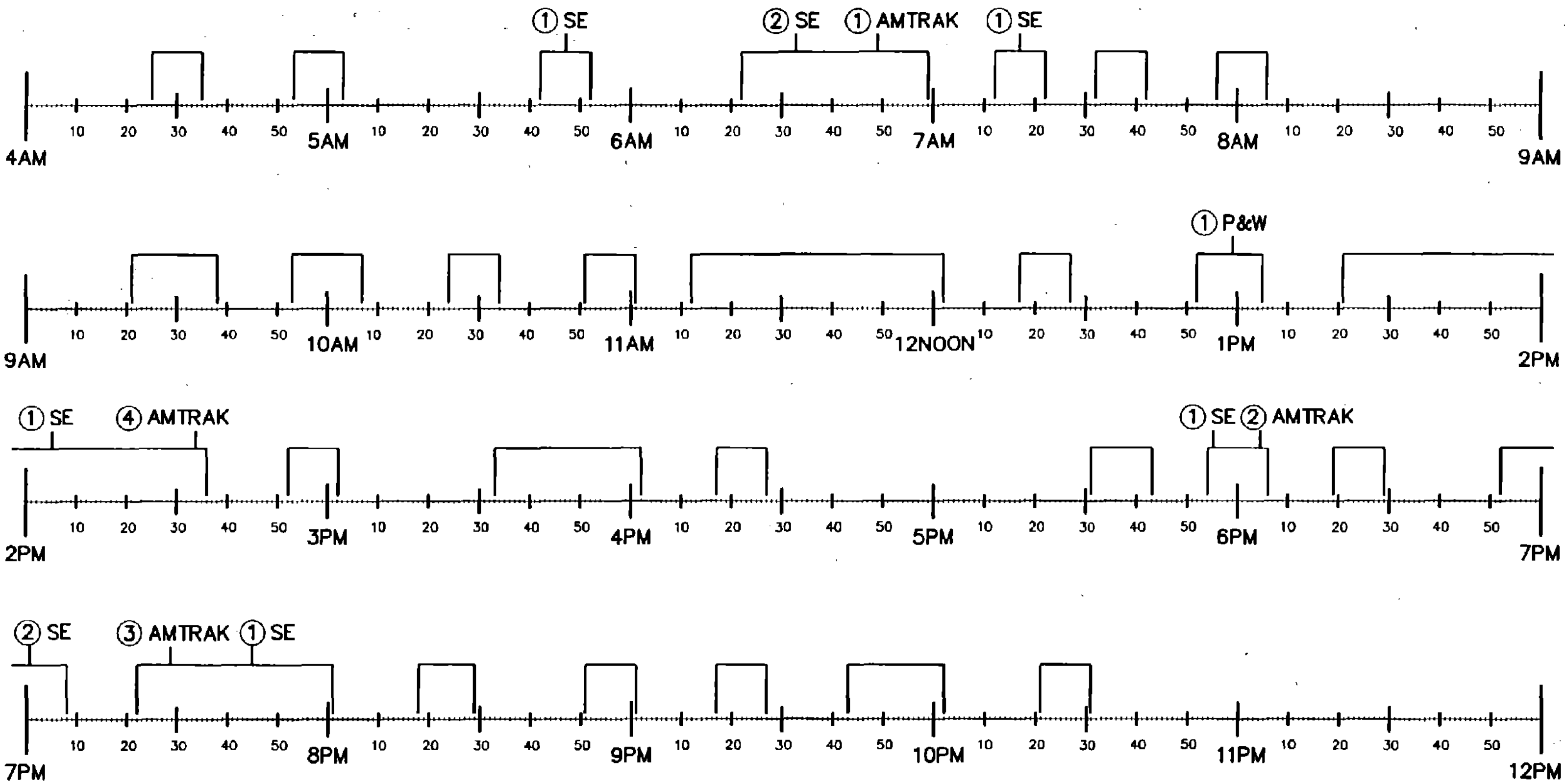
CONNECTICUT RIVER MOVEABLE BRIDGE [M.P. 106.9]
1993 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

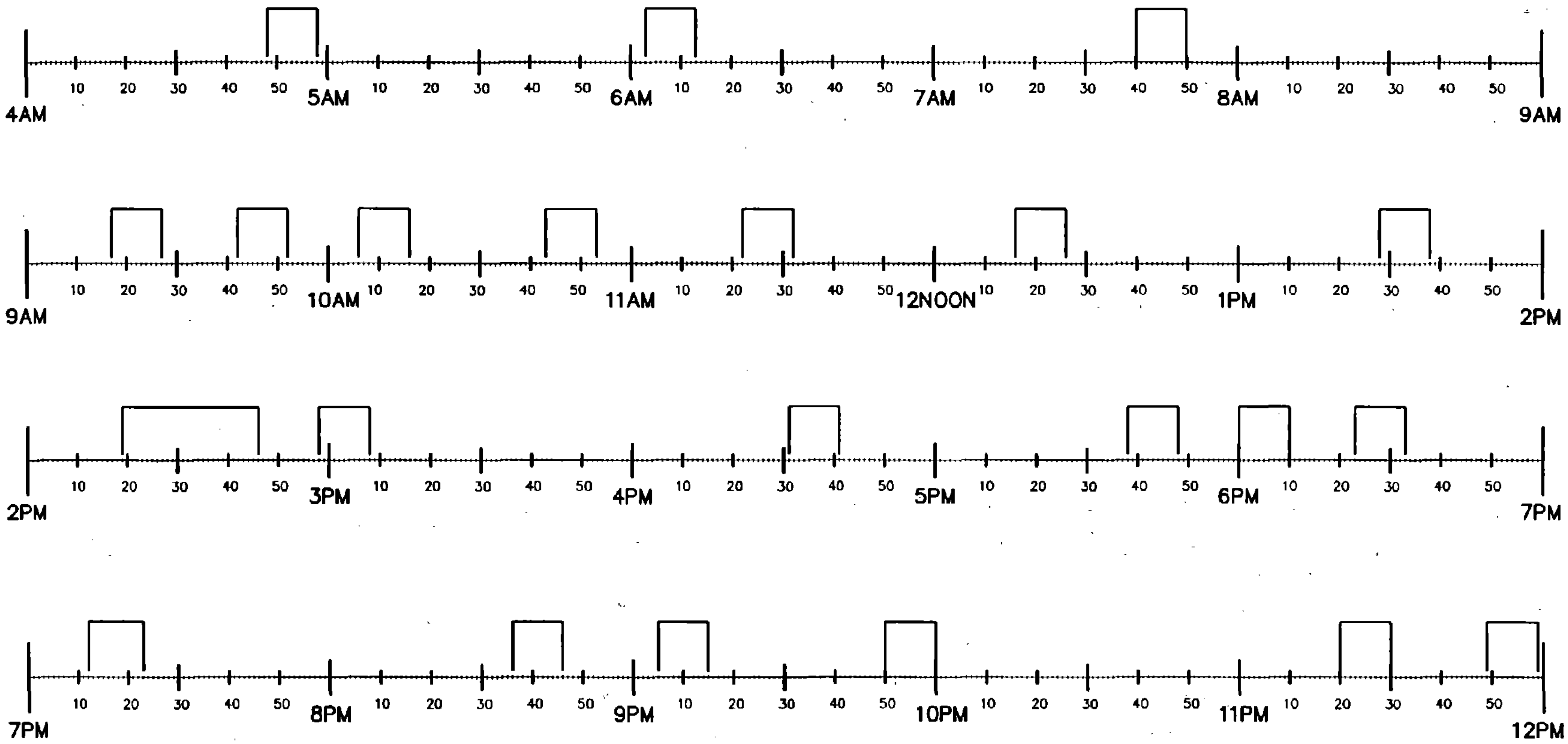
CONNECTICUT RIVER MOVEABLE BRIDGE [M.P. 106.9]
2010 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

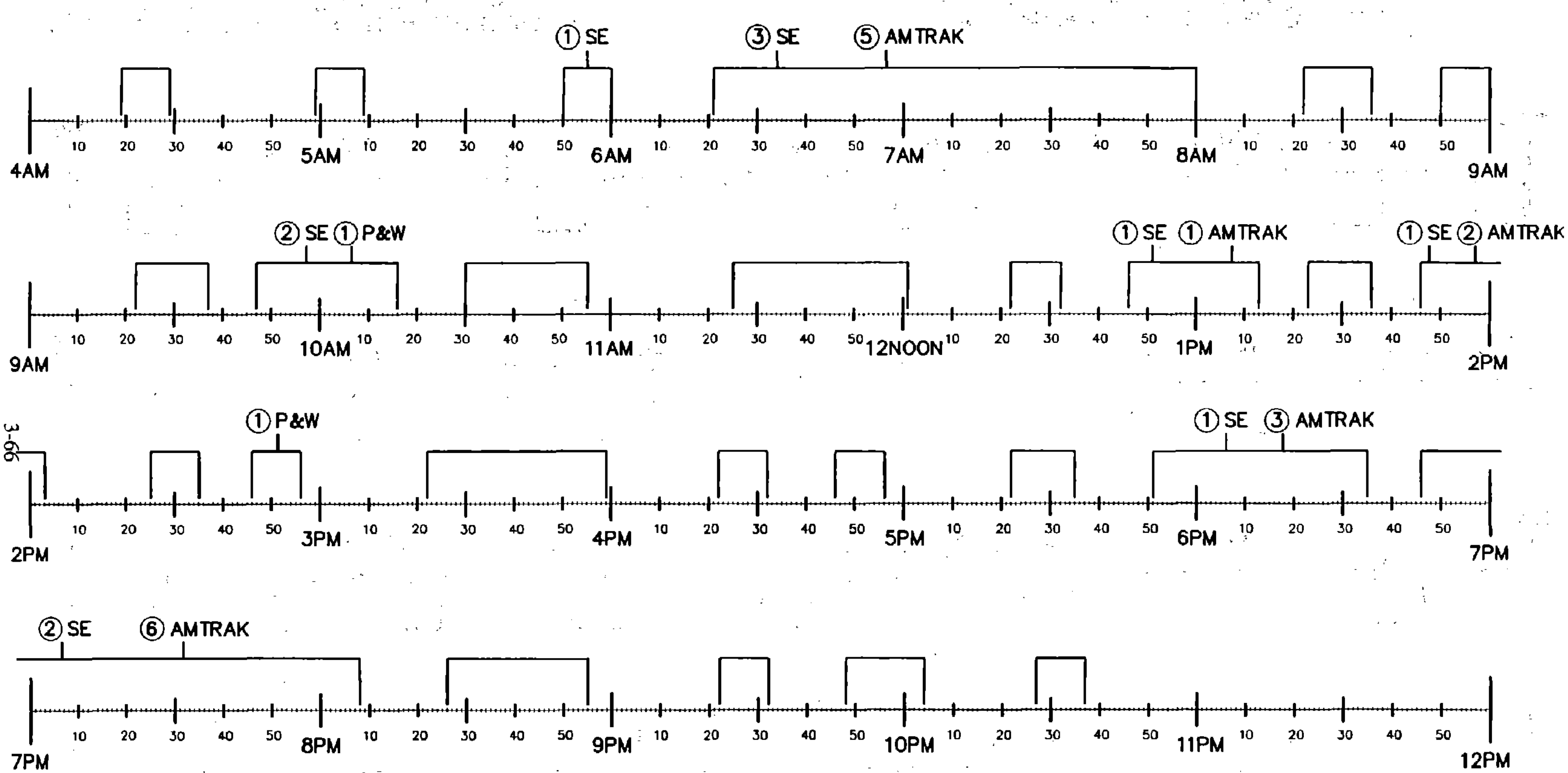
CONNECTICUT RIVER MOVEABLE BRIDGE [M.P. 106.9]
2010 SATURDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

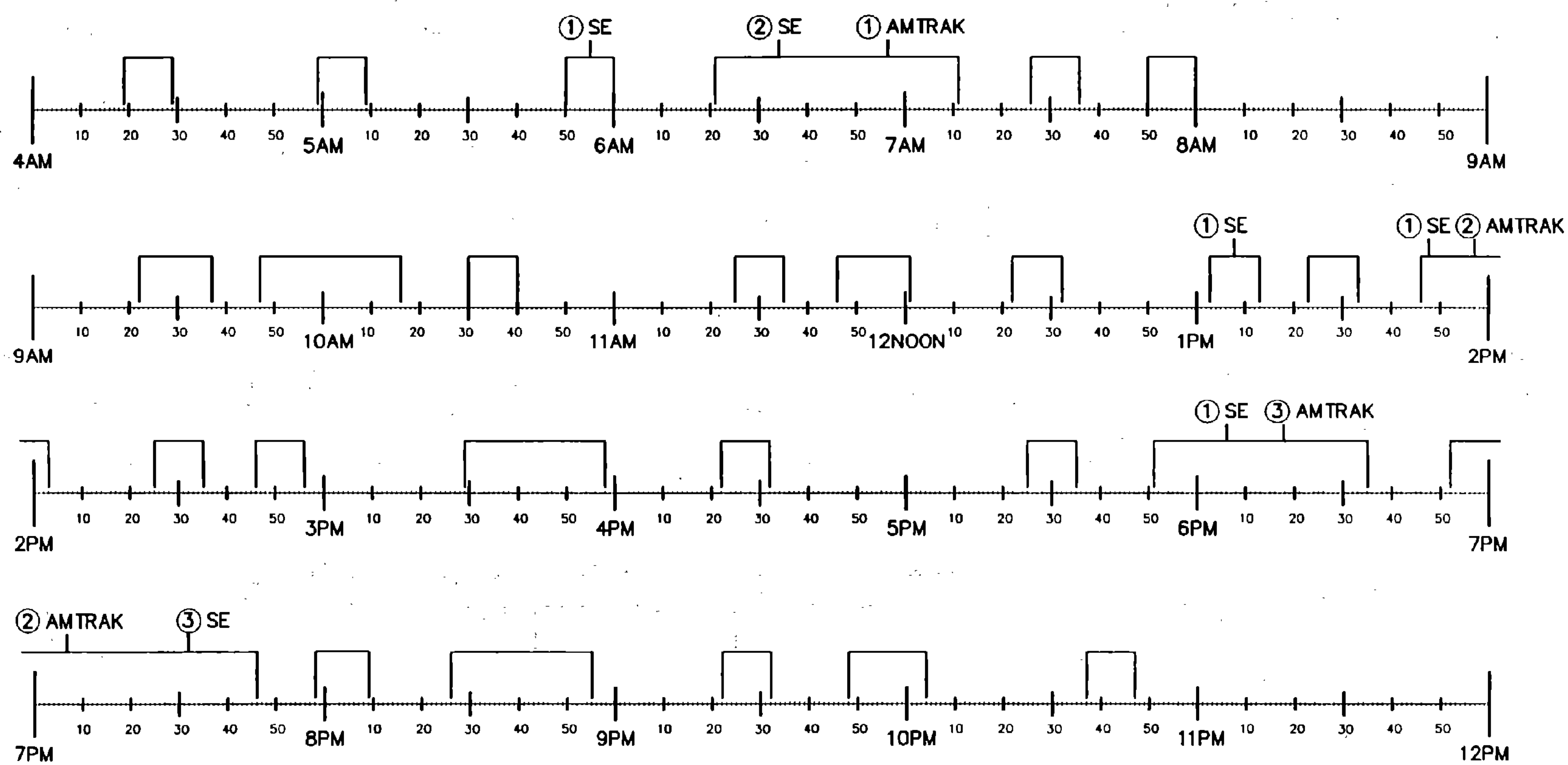
NIANTIC RIVER MOVEABLE BRIDGE [M.P. 116.7]
1993 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

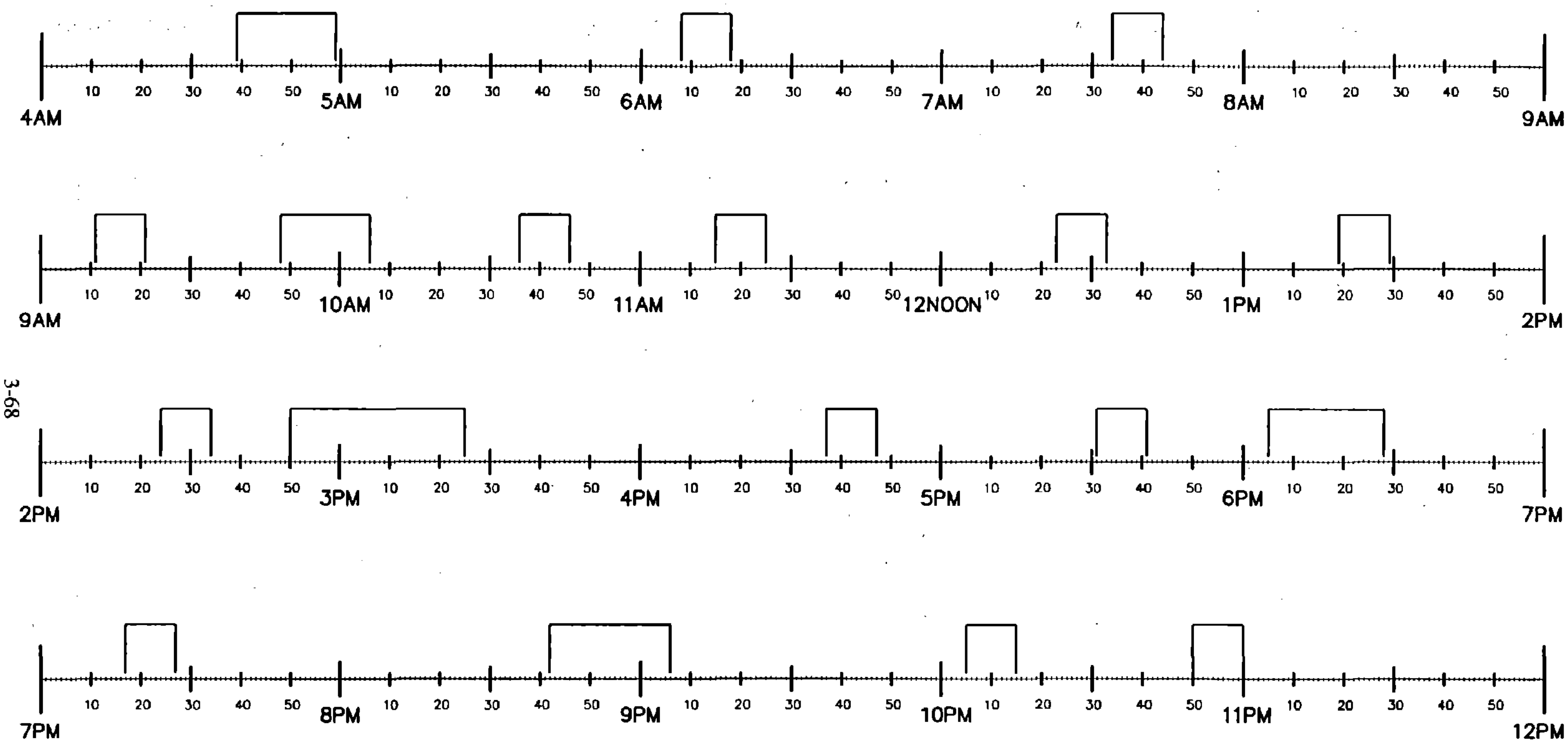
NIANTIC RIVER MOVEABLE BRIDGE [M.P. 116.7]
2010 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

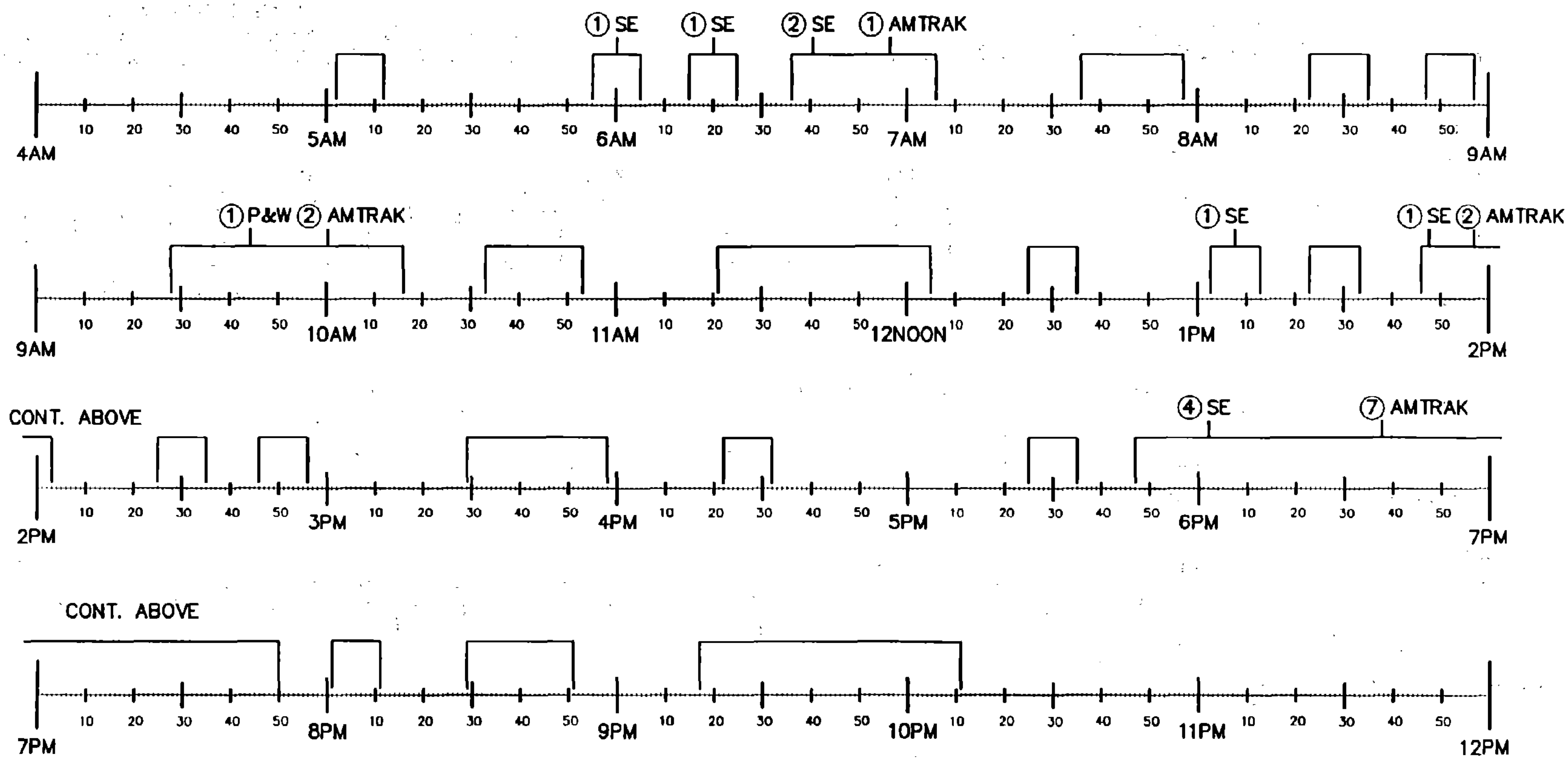
NIANTIC RIVER MOVEABLE BRIDGE [M.P. 116.7]
2010 SATURDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

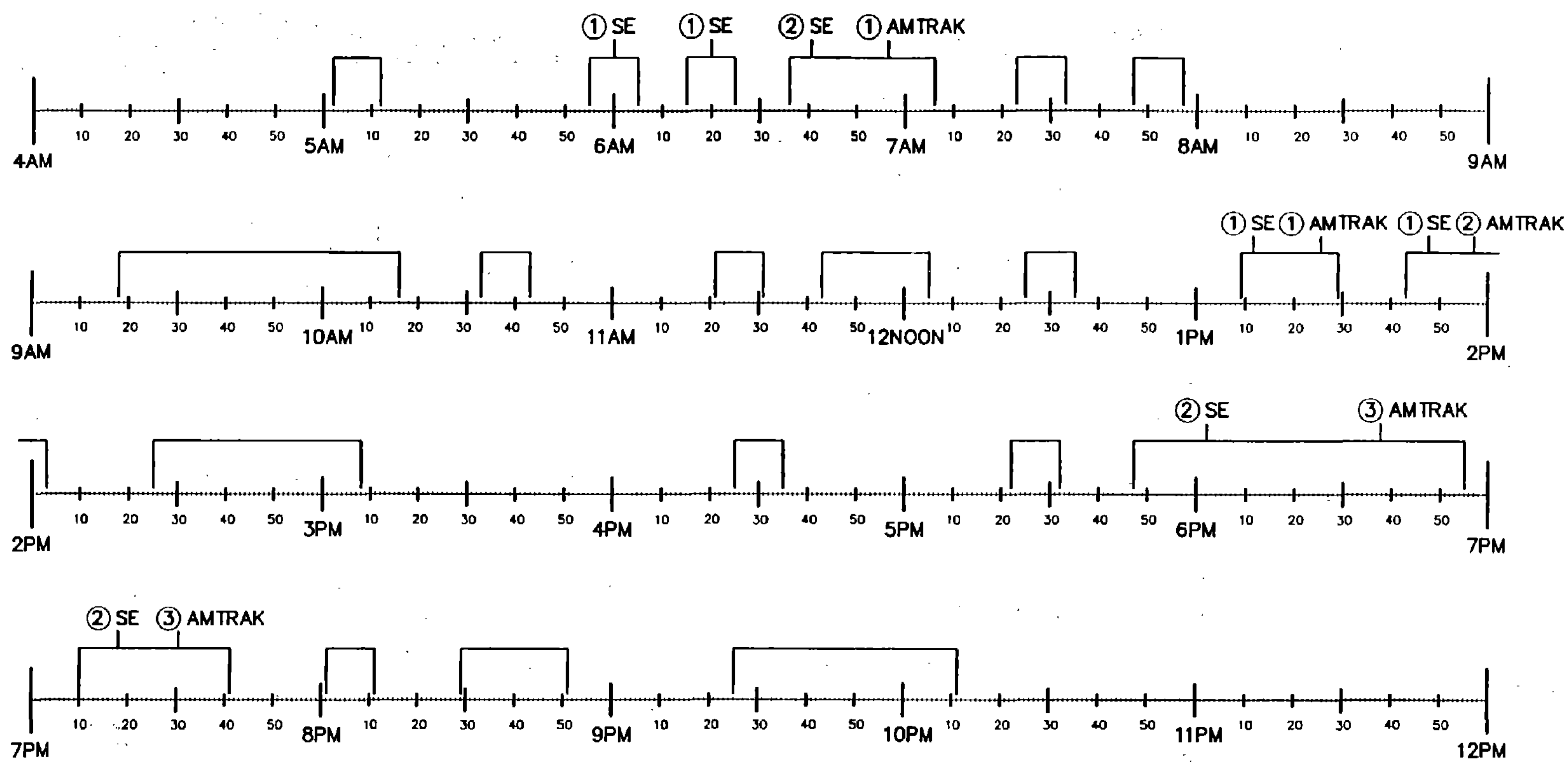
SHAWS COVE MOVEABLE BRIDGE [M.P. 122.6]
1993 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

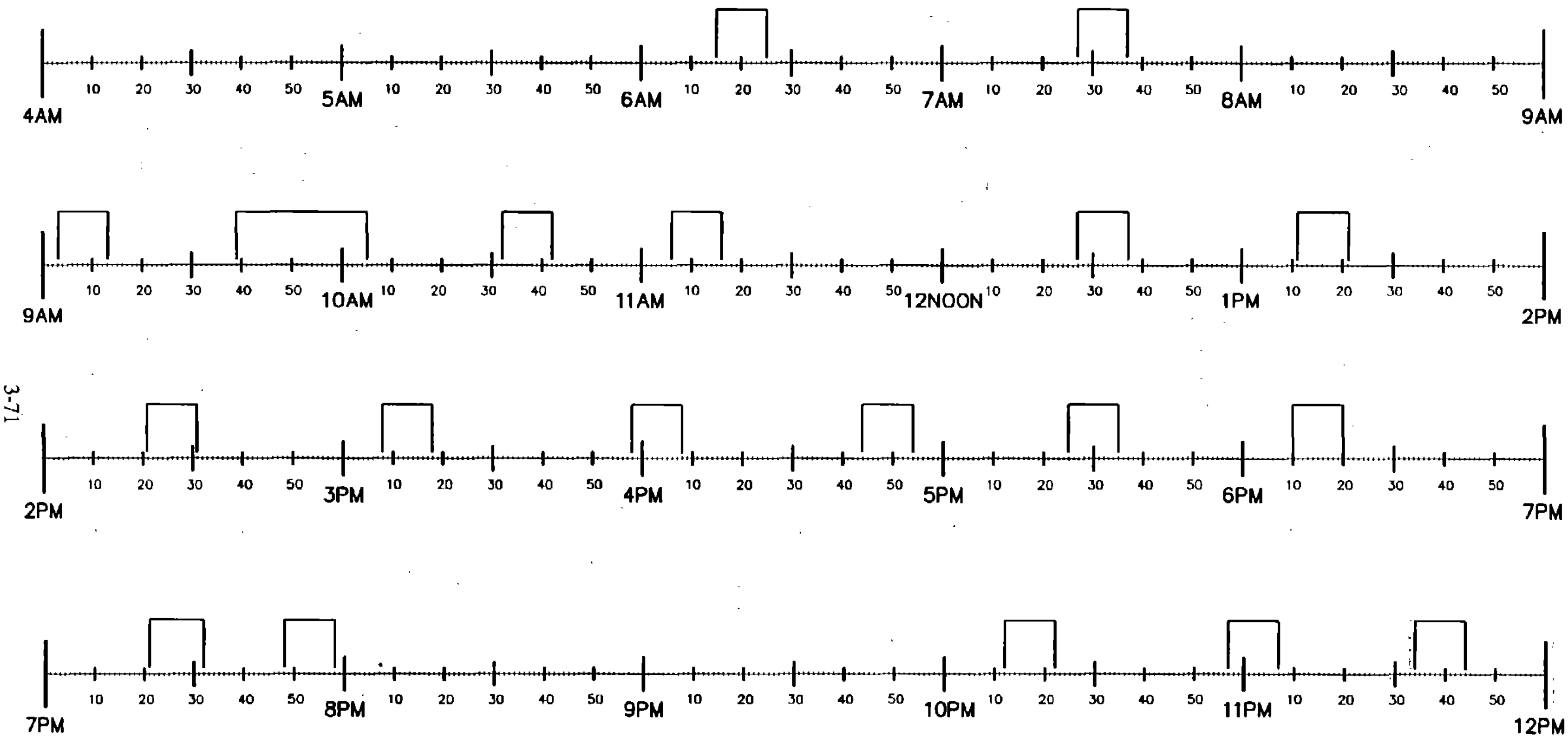
SHAWS COVE MOVEABLE BRIDGE [M.P. 122.6]
2010 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

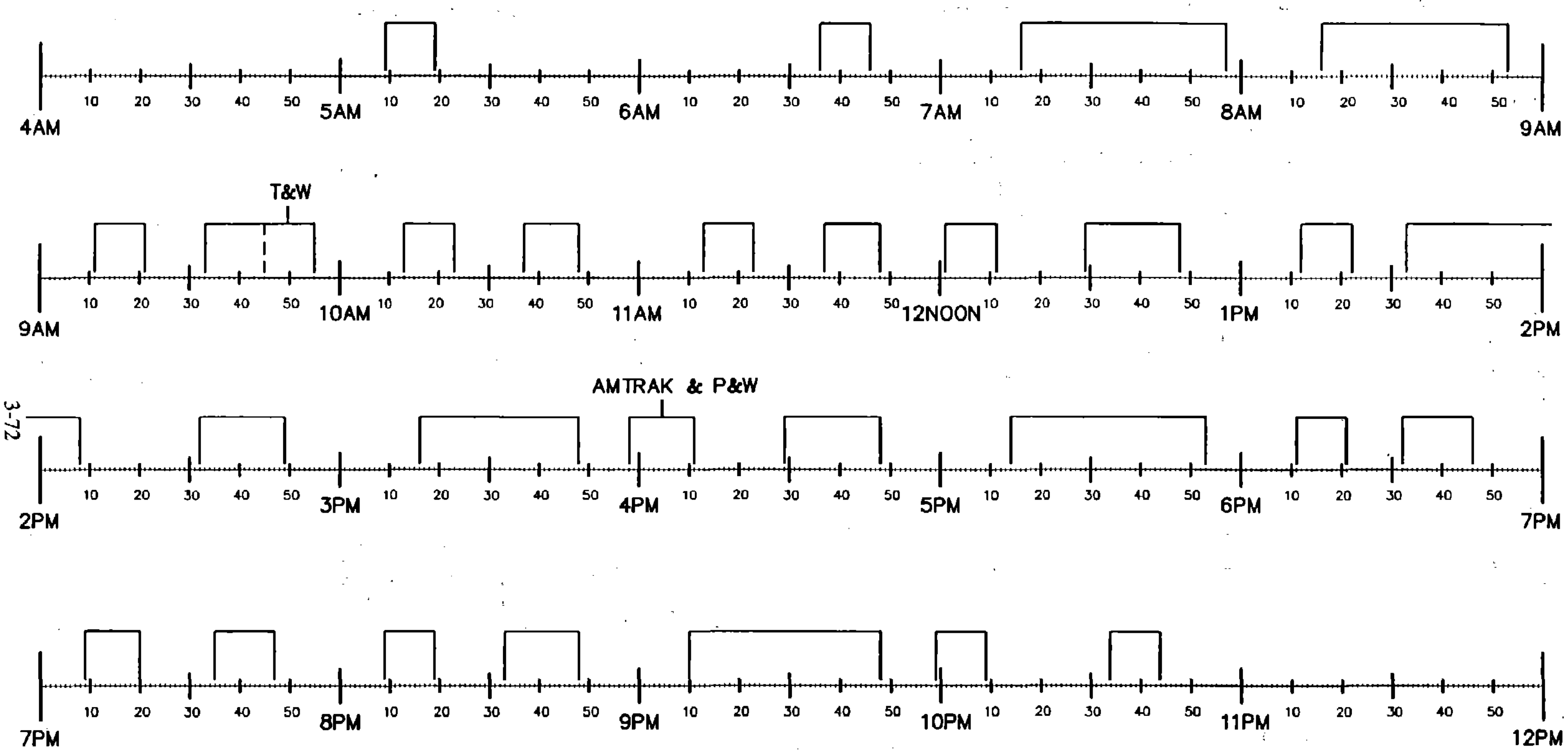
SHAWS COVE MOVEABLE BRIDGE [M.P. 122.6]
2010 SATURDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

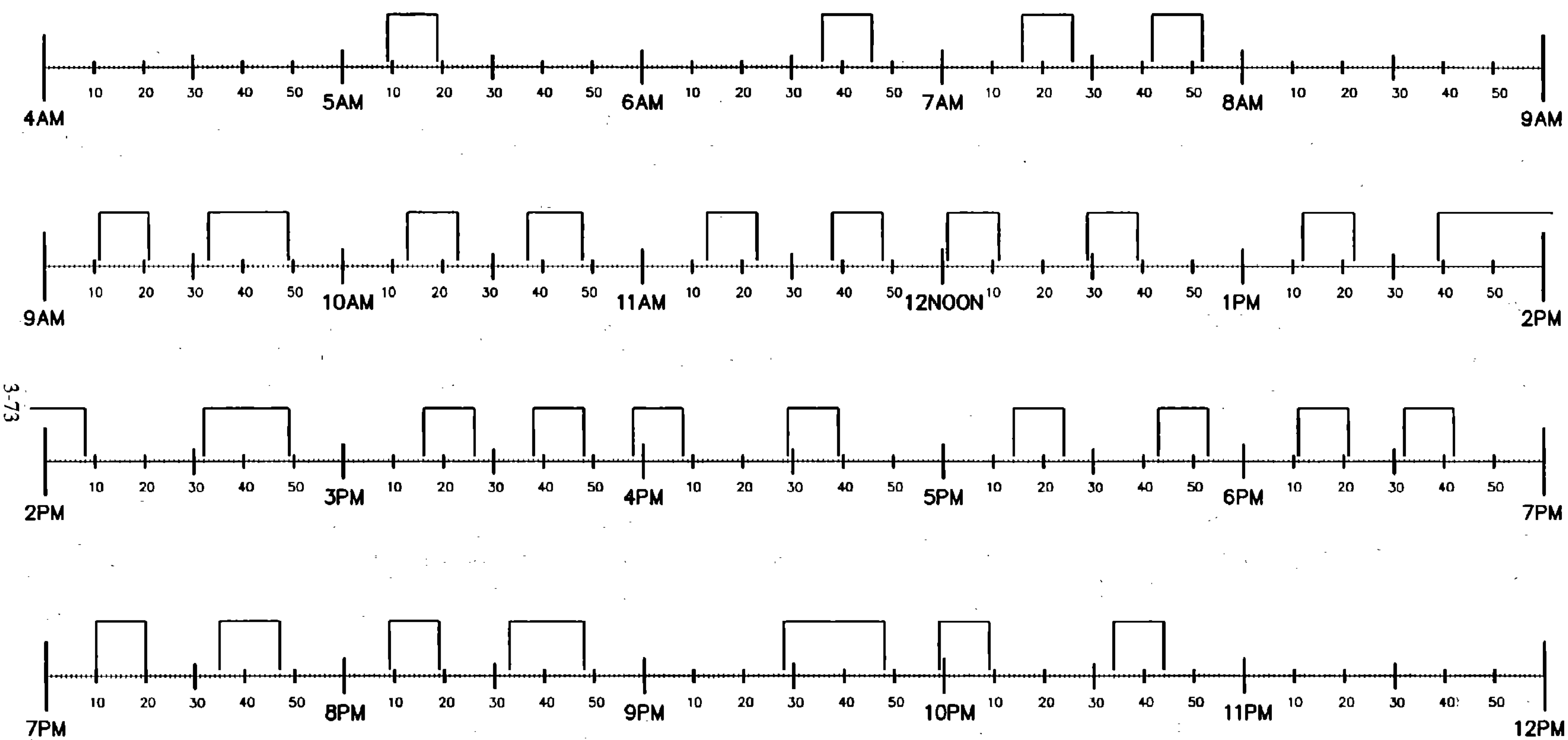
GROTON/THAMES RIVER MOVEABLE BRIDGE [M.P. 124.1]
1993 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

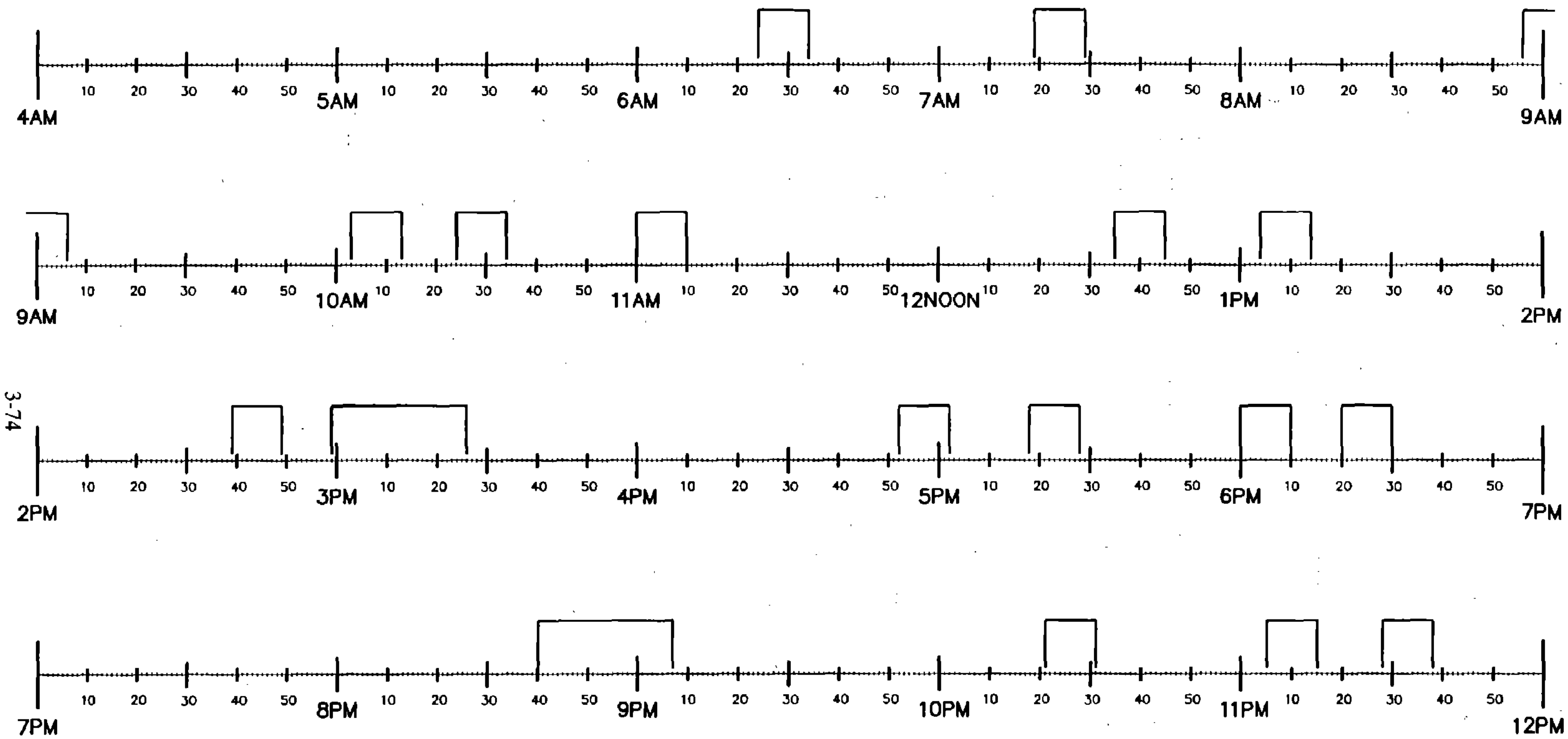
GROTON/THAMES RIVER MOVEABLE BRIDGE [M.P. 124.1]
2010 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

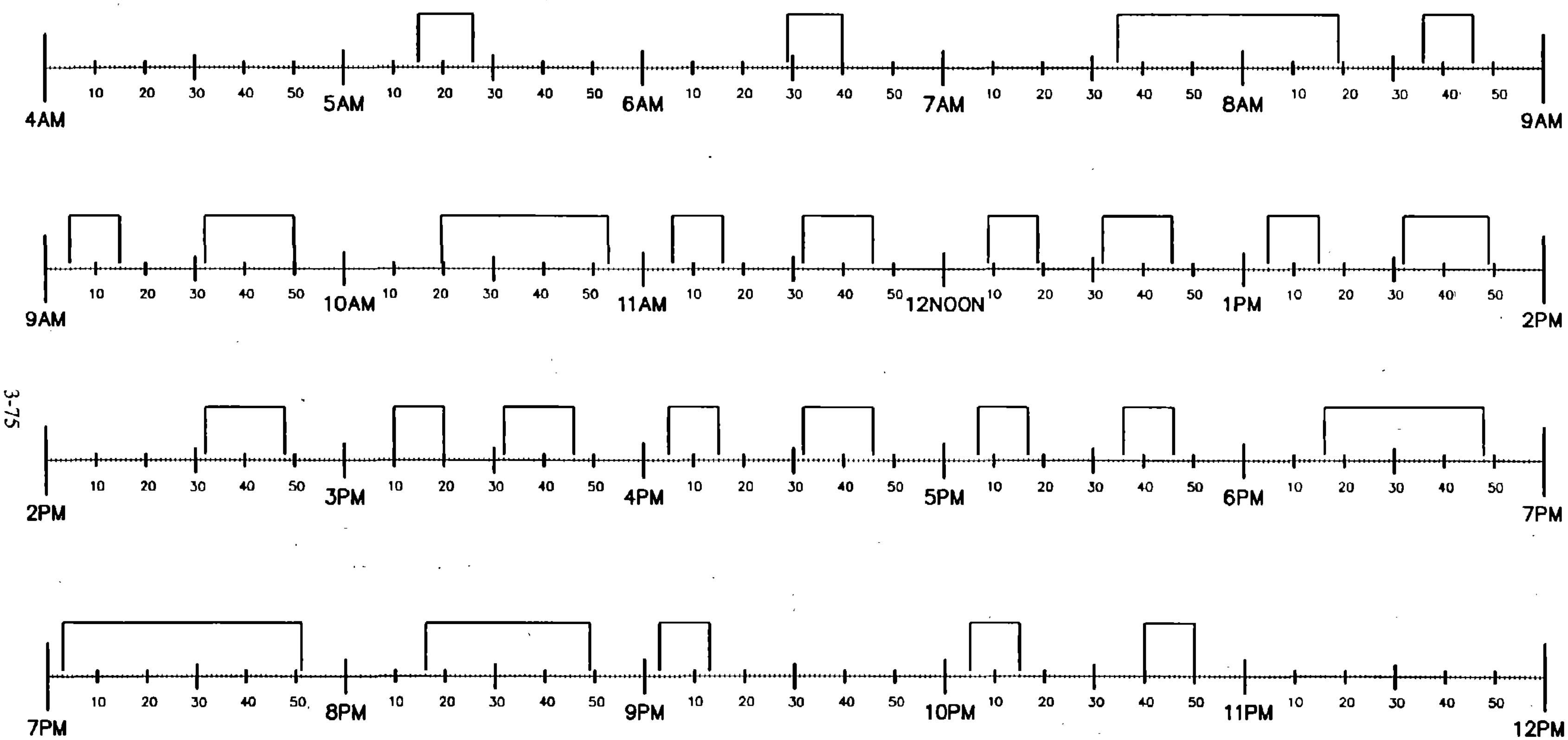
GROTON/THAMES RIVER MOVEABLE BRIDGE [M.P. 124.1]
2010 SATURDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

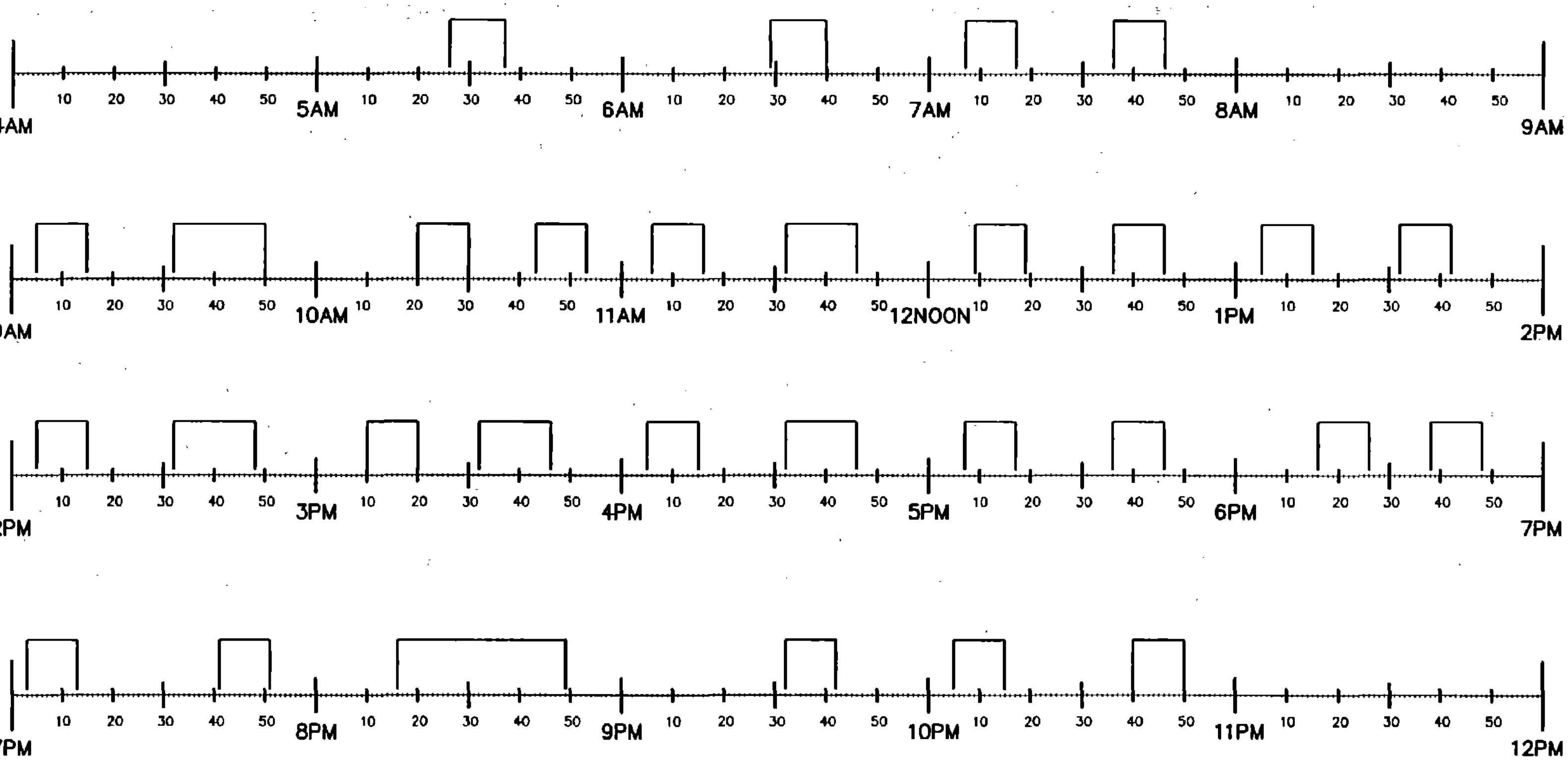
MYSTIC RIVER MOVEABLE BRIDGE [M.P. 132.2]
1993 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

MYSTIC RIVER MOVEABLE BRIDGE [M.P. 132.2]
2010 WEEKDAY OPERATING SCHEDULE



NOTE: MARKED TIME BLOCKS SHOW SHORELINE EAST (SE) OR FREIGHT (P&W) SERVICE COMBINED WITH AMTRAK SERVICE.

UNMARKED TIME BLOCKS ARE AMTRAK SERVICE ONLY.

MYSTIC RIVER MOVEABLE BRIDGE [M.P. 132.2]
2010 SATURDAY OPERATING SCHEDULE

Appendix 3C

TABLE 3C-1 Connecticut River Bridge [MP 106.7]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 1993

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
12:38a	4:59a	261'
5:09a	5:53a	44'
6:03a	7:49p	106'
7:59a	9:26p	87'
9:43a	10:13p	30'
10:23a	10:53p	30'
11:03a	11:31p	28'
11:41a	12:07p	26'
12:18p	1:36p	78'
1:46p	2:11p	25'
2:21p	2:50p	29'
3:00p	3:31p	31'
3:41p	4:22p	41'
4:32p	5:46p	74'
6:02p	6:32p	30'
6:42p	7:03p	21'
7:13p	8:26p	73'
8:36p	9:15p	39'
9:25p	9:50p	25'
10:00p	11:13p	73'
11:23p	12:28a	75'

TABLE 3C-2 Connecticut River Bridge [MP 106.7]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
4:35a	4:53a	18'
5:03a	5:42a	39'
5:52a	6:22a	30'
6:59a	7:12a	13'
7:42a	7:56a	14'
8:06a	8:17a	11'
8:42a	8:56a	14'
9:06a	9:21a	15'
9:38a	9:53a	15'
10:07a	10:24a	17'
10:34a	10:51a	17'
11:01a	11:12a	11'
12:02p	12:17p	15'
12:27p	12:52p	25'
1:05p	1:21p	16'
2:36p	2:52p	16'
3:02p	3:17p	15'
4:02p	4:17p	15'
4:27p	4:51p	24'
5:01p	5:17p	16'
5:41p	5:54p	13'
6:06p	6:19p	13'
6:29p	6:52p	23'
7:08p	7:23p	15'
8:02p	8:19p	17'
8;29p	8:51p	22'
9:01p	9:17p	16'
10:02p	10:21p	19'
10:31p	4:25a	354'

TABLE 3C-3 Connecticut River Bridge [MP 106.7]
Scheduled Train Crossings at Mid-Span (Windows)
Saturday Operations 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
4:35a	4:53a	18'
5:03a	5:42a	39'
5:52a	6:22a	30'
6:59a	7:12a	13'
7:22a	7:32a	10'
7:42a	7:56a	14'
8:06a	9:21a	75'
9:38a	9:53a	15'
10:07a	10:24a	17'
10:34a	11:12a	38'
12:02p	12:17p	15'
12:27p	12:55p	28'
1:05p	1:29p	24'
2:36p	2:52p	16'
3:02p	3:33p	31'
4:02p	4:17p	15'
4:27p	5:31p	64'
5:41p	5:54p	13'
6:06p	6:19p	13'
6:29p	6:52p	23'
7:08p	7:23p	15'
8:02p	8:19p	17'
8:29p	8:51p	22'
9:01p	9:17p	16'
9:27p	9:43p	16'
10:02p	10:21p	19'
10:31p	4:25a	354'
4:35p	4:53a	18'

TABLE 3C-4 Niantic River Bridge [MP 116.7]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 1993

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
12:29a	4:48a	259'
4:58a	6:03a	65'
6:13a	7:40a	87'
7:50a	9:17a	87'
9:27a	9:42a	15'
9:52a	10:06a	14'
10:16a	10:43a	27'
10:53a	11:22a	29'
11:32a	12:16p	44'
12:26p	1:28p	68'
1:38p	2:19p	41'
2:46p	2:58p	12'
3:08p	3:23p	15'
3:33p	4:31p	58'
3:41p	5:38p	57'
5:48p	6:00p	12'
6:10p	6:23p	13'
6:33p	7:12p	39'
7:22p	8:36p	64'
8:46p	9:05p	19'
9:15p	9:50p	35'
10:00p	10:44p	44'
10:54p	11:20p	26'
11:30p	11:49p	19'
11:59p	12:19a	20'

TABLE 3C-5 Niantic River Bridge [MP 116.7]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
4:29a	4:59a	30'
5:09a	5:50a	41'
6:00a	6:21a	21'
8:00a	8:22a	22'
8:36a	8:50a	14'
9:00a	9:22a	22'
9:37a	9:47a	10'
10:16a	10:30a	14'
10:55a	11:25a	30'
12:01p	12:22p	21'
12:32p	12:46p	14'
1:13p	1:23p	10'
1:36p	1:46p	10'
2:03p	2:25p	22'
2:35p	2:46p	11'
2:56p	3:22p	26'
3:59p	4:22p	23'
4:32p	4:46p	14'
4:56p	5:22p	26'
5:35p	5:51p	16'
6:35p	6:46p	11'
8:08p	8:26p	18'
8:55p	9:21p	26'
9:32p	9:48p	16'
10:04p	10:27p	23'
10:37p	4:19a	342'

TABLE 3C-6 Niantic River Bridge [MP 116.7]
Scheduled Train Crossings at Mid-Span (Windows)
Saturday Operations 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
4:29a	4:59a	30'
5:09a	5:50a	41'
6:00a	6:21a	21'
7:12a	7:26a	14'
7:36a	7:50a	14'
8:00a	9:22a	82'
9:37a	9:47a	10'
10:16a	10:30a	14'
10:40a	11:25a	45'
11:35a	11:46a	11'
12:01p	12:22p	21'
12:32p	1:03p	31'
1:13p	1:23p	10'
1:33p	1:46p	13'
2:03p	2:25p	22'
2:35p	2:46p	11'
2:56p	3:29p	33'
3:59p	4:22p	23'
4:32p	5:25p	53'
5:35p	5:51p	16'
6:35p	6:52p	17'
7:46p	7:58p	12'
8:08p	8:26p	18'
8:55p	9:22p	27'
9:32p	9:48p	16'
10:04p	10:27p	23'
10:37p	4:19a	342'

TABLE 3C-7 Shaw's Cove Bridge [MP 122.6]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 1993

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
12:21a	4:39a	258'
4:59a	6:08a	69'
6:18a	7:35a	77'
7:45a	9:11a	86'
9:21a	9:48a	27'
10:06a	10:36a	30'
10:46a	11:15a	29'
11:25a	12:23p	58'
12:33p	1:19p	46'
1:29p	2:24p	55'
2:34p	2:50p	16'
3:25p	4:37p	72'
4:47p	5:31p	44'
5:41p	6:05p	24'
6:28p	7:17p	49'
7:27p	8:42p	75'
9:06p	10:05p	59'
10:15p	10:50p	40'
11:00p	11:29p	27'

TABLE 3C-8 Shaw's Cover Bridge [MP 122.6]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
4:25a	5:02a	37'
5:12a	5:55a	43'
6:05a	6:15a	10'
6:25a	6:36a	11'
7:06a	7:23a	17'
7:57a	8:23a	34'
8:35a	8:47a	12'
8:57a	9:18a	21'
10:16a	10:33a	17'
10:53a	11:21a	28'
12:05p	12:25p	20'
12:35p	12:43p	13'
12:53p	1:09p	16'
2:02p	2:28p	26'
3:08p	3:24p	16'
4:01p	4:25p	24'
4:53p	5:21p	28'
5:35p	5:47p	12'
7:50p	8:01p	11'
8:11p	8:29p	18'
8:51p	9:17p	26'
10:11p	10:31p	20'
10:41p	4:15a	334'

TABLE 3C-9 Shaw's Cove Bridge [MP 122.6]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Saturday 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
4:25a	5:02a	37'
5:12a	5:55a	43'
6:05a	6:15a	10'
6:25a	6:36a	11'
7:06a	7:23a	17'
7:33a	7;47a	14'
7:57a	9:18a	81'
10:16a	10:33a	17'
10:43a	11:21a	38'
11:31a	11:43a	12'
12:05p	12:25p	20'
12:35p	1:09p	34'
1:29p	1:43p	14'
2:02p	2:28p	26'
3:08p	3:25p	17'
4:01p	4:25p	24'
4:35p	5:21p	46'
5:31p	5:47p	16'
6:55p	7:10p	15'
7:41p	8:01p	20'
8:11p	8:29p	18'
8:51p	9:25p	34'
10:11p	10:31p	20'
10:41p	4:15a	337'

TABLE 3C-10 Groton (Thames River) Bridge [MP 124.1]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 1993

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
12:15a	6:15a	360'
6:25a	7:27a	62'
7:37a	9:03a	86'
9:13a	9:39a	26'
10:05a	10:32a	27'
10:42a	11:06a	24'
11:16a	12:27p	71'
12:37p	1:11p	34'
1:21p	2:21p	60'
2:31p	3:08p	37'
3:18p	3:58p	40'
4:08p	4:44p	36'
4:54p	5:25p	31'
5:35p	6:10p	35'
6:21p	7:22p	61'
7:32p	8:48p	76'
8:58p	10:12p	74'
10:22p	10:57p	35'
1:07p	11:34p	27'
11:44p	12:05a	25'

TABLE 3C-11 Groton (Thames River) Bridge [MP 124.1]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
5:19a	6:36a	77'
6:46a	7:16a	30'
7:57a	8:16a	19'
8:53a	9:11a	18'
9:21a	9:33a	12'
9:55a	10:13a	18'
10:23a	10:37a	14'
10:48a	11:13a	25'
11:23a	11:37a	14'
11:48a	12:01p	13'
12:11p	12:29p	18'
12:48p	1:12p	24'
1:22p	1:33p	11'
2:08p	2:32p	24'
2:49p	3:16p	27'
3:48p	3:58p	10'
4:11p	4:29p	18'
4:48p	5:14p	26'
5:53p	6:11p	18'
6:21p	6:32p	11'
6:46p	7:09p	23'
7:20p	7:35p	15'
7:47p	8:09p	22'
8:19p	8:33p	14'
8:48p	9:10p	22'
9:48p	9:58p	11'
10:09p	10:34p	25'
10:44p	5:09a	385'

TABLE 3C-12 Groton (Thames River) Bridge [MP 124.1]
Scheduled Train Crossings at Mid-Span (Windows)
Saturday Operations 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
5:19a	6:36a	84'
6:46a	7:16a	30'
7:26a	7:42a	16'
7:52a	9:11a	79'
9:21a	9:33a	12'
9:49a	10:13a	24'
10:23a	10:37a	14'
10:47a	11:13a	26'
11:23a	11:38a	19'
11:48a	12:01p	13'
12:11p	12:29p	18'
12:39p	1:12p	33'
1:22p	1:39p	17'
2:08p	2:32p	24'
2:49p	3:16p	27'
3:26p	3:38p	12'
3:48p	3:58p	10'
4:08p	4:29p	21'
4:39p	5:14p	35'
5:24p	5:43p	19'
5:53p	6:11p	18'
6:21p	6:32p	11'
6:42p	7:10p	28'
7:20p	7:35p	15'
7:45p	8:09p	24'

Table 3C-12 Groton (Thames River) Bridge [MP 124.1] (continued)

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
8:19p	8:33p	14'
8:48p	9:28p	40'
9:48p	9:59p	11'
10:09p	10:34p	25'
10:44p	5:09a	385'

TABLE 3C-13 Mystic River Bridge [MP 132.2]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 1993

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
12:09a	6:24a	375'
6:34a	7:19a	45'
7:29a	8:56a	87'
9:06a	10:03a	57'
10:13a	10:24a	11'
10:34a	11:00a	26'
11:10a	12:35p	85'
12:45p	1:04p	19'
1:14p	2:39p	83'
2:49p	2:59p	10'
3:26p	4:52p	86'
5:02p	5:18p	16'
5:28p	6:00p	32'
6:10p	6:20p	10'
6:30p	8:40p	130'
8:50p	8:56p	6'
9:06p	10:21p	75'
10:31p	11:05p	34'
11:15p	11:28p	13'
11:38p	11:59p	21'
12:09p	6:24p	375'

TABLE 3C-14 Mystic River Bridge [MP 132.2]
Scheduled Train Crossings at Mid-Span (Windows)
Typical Weekday 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
5:26a	6:29a	63'
6:39a	7:07a	39'
7:17a	7:35a	18'
8:19a	8:36a	17'
8:46a	9:05a	19'
9:15a	9:32a	17'
9:50a	10:20a	30'
10:53a	11:06a	13'
11:16a	11:32a	16'
11:52a	12:09p	17'
12:19p	12:32p	13'
12:46p	1:05p	19'
1:15p	1:32p	17'
1:49p	2:05p	16'
2:15p	2:32p	17'
2:48p	3:10p	22'
3:20p	3:32p	12'
3:46p	4:05p	19'
4:15p	4:32p	17'
4:46p	5:07p	21'
5:17p	5:35p	18'
5:46p	6:16p	30'
6:48p	7:03p	15'
7:51p	8:16p	25'
8:49p	9:03p	14'
9:13p	9:32p	19'
9:45p	10:05p	20'
10:15p	10:40p	25'
10:50p	5:16a	386'

TABLE 3C-15 Mystic River Bridge [MP 132.2]
Scheduled Train Crossings at Mid-Span (Windows)
Saturday Operations 2010

BEGIN WINDOW	END WINDOW	TOTAL WINDOW IN MINUTES
5:26a	6:29a	63'
6:39a	7:07a	39'
7:17a	7:36a	19'
7:46a	9:05a	79'
9:15a	9:32a	17'
9:50a	10:20a	30'
10:30a	10:43a	13'
10:53a	11:06a	13'
11:16a	11:32a	16'
11:42a	12:09p	27'
12:19p	12:36p	17'
12:46p	1:05p	19'
1:15p	1:32p	17'
1:42p	2:05p	23'
2:15p	2:32p	17'
2:48p	3:10p	22'
3:20p	3:32p	12'
3:42p	4:05p	23'
4:15p	4:36p	21'
4:46p	5:07p	21'
5:17p	5:36p	19'
5:46p	6:16p	30'
6:26p	6:38p	12'
6:48p	7:03p	15'
7:13p	7:41p	28'
7:51p	8:16p	25'
8:49p	9:32p	43'
9:45p	10:05p	20'
10:15p	10:40p	25'
10:50p	5:16a	386'

CHAPTER 4
NOISE AND VIBRATION

This chapter constitutes the technical appendix for noise. It consists of seven major sections: a detailed report on the field of evaluation of the Rohr Turboliner (RTL) trainset in operation along Amtrak's Empire Corridor; analyses of various design modifications; a report on the field evaluation of the German InterCity Express (ICE) trainset; the detailed data and analyses on noise and vibration impacts compiled and completed for this FEIS/R; a discussion of noise and vibration mitigation measures; miscellaneous commentary on a number of noise issues raised by commenters on the DEIS/R; and a representative noise and vibration monitoring and test program.

4.1 RTL TRAINSET NOISE AND VIBRATION MEASUREMENTS

4.1.1 Introduction and Summary

This report summarizes the methods and results of train noise and vibration measurements carried out from March 30 to April 1, 1994, adjacent to Amtrak's Empire Corridor railroad line near Albany, NY. The objective of the measurements was to obtain wayside noise and ground-borne vibration data during operation of the RTL gas turbine-powered trainset in revenue service on the Empire Corridor. Noise and vibration emission levels obtained from these results are to be used to evaluate noise and vibration impacts along the NEC between New Haven, CT, and Boston, MA, using RTL trainsets as an alternative to electrification. These data are also compared with similar data available for the ICE and X2000 trainsets tested on the NEC in 1993, as well as for standard Amtrak trains hauled by F40PH diesel locomotives and AEM7 electric locomotives.

The RTL trainset measurements were carried out at four locations adjacent to the Empire Corridor, all in the Albany area. A listing of the measurements performed and a detailed description of each measurement site is provided in Table 4.1-1. As indicated, noise measurements were conducted at all four locations; vibration measurements were conducted at only two locations (Sites 2 and 4) at which trains were expected to be traveling at or close to maximum speed. Three of the measurement sites were located south of Rensselaer Station in Rensselaer, NY, and the fourth site north of Rensselaer Station in Colonie, NY. At the sites south of Albany there are two continuous welded rail (CWR) tracks composed of wood ties and ballast. At the site in Colonie there is a single track composed of CWR with wood ties and ballast.

4.1.1(a) Noise Measurements

The following summarizes the results of the noise measurements and their significance with respect to projected noise impact, based on an RTL no-build scenario for NECIP:

- It was found that the RTL power unit is about 2 to 4 dBA louder on average than the AEM7 locomotives in the speed range observed during these measurements, but about 3 to 5 dBA quieter than the diesel F40PH locomotive.

- Since the AEM7-hauled trains were found to be noisier than either the X2000 or ICE trainsets tested,[1] the results indicate that the RTL power unit generates the highest noise levels overall of the non-diesel locomotives considered for NECIP.

- At speeds greater than about 80 mph, however, the noise from the wheel/rail interaction dominates the overall noise level, and differences in locomotive noise are less pronounced among the different train technologies. Since the majority of the noise impact identified in the DEIS/R was along sections of the corridor where trains will be traveling at or close to maximum speed, the resulting differences in noise impact under the RTL alternative may not be significant.

- The noise measurements indicated that the RTL turbotrains were in compliance with the Federal Railroad Noise Emission Standard.

TABLE 4.1-1 Summary of Turbotrain Measurements

SITE	DATE	TIME PERIOD	NOISE				VIBRATION				
			Right Side		Left Side						
			50 ft.	100 ft.	50 ft.	100 ft.	25 ft.	50 ft.	75 ft.	100 ft.	150 ft.
1	3/30/94	06:00-06:30	✓								
		07:05-10:31			✓	✓					
2	3/30/94	19:42-20:15	✓	✓			✓	✓	✓	✓	✓
3	3/31/94	06:25-10:39	✓	✓							
4	3/31/94	17:20-18:40		✓	✓		✓	✓	✓	✓	✓
		19:21-19:55	✓	✓	✓		✓	✓	✓	✓	✓
	4/1/94	06:00-06:30	✓		✓	✓					
		07:09-10:23	✓		✓	✓	✓	✓	✓	✓	

Source: HMMH, Inc., 1994

In addition, the noise measurements showed that for train passbys where noise from both sides of the train was measured simultaneously at equal distances, noise levels on the right side of the RTL trainset are 2 to 3 dBA higher than those measured on the left side of the train, due to the location of the gas turbine engine intake on the power unit's right side. However, with identical power units on each end, it would be expected that the same maximum noise level measured on the *right* side of the *lead* power unit of an RTL train would occur on the *left* side of the *tail* power unit, given the symmetry of the trainset. This leads to the assumption that simultaneous measurements made on either side of the train would be likely to yield the same noise level, with the sources of the maximum level being the lead power unit on the right side and the tail power unit on the left side. In spite of this, the relatively few data points available showed that the engine intake noise of the lead power unit was found to be a few decibels higher than the equivalent engine intake noise of the tail power unit. This difference may be due to other factors such as different operating conditions of the two power units, exhaust noise, Doppler effect, etc.

Comparing the frequency content of the right side noise spectra with that of the left side further shows that this difference is primarily present in the upper frequencies from about 4 to 16 kilohertz (kHz). The difference becomes smaller as train speed increases, and wheel/rail noise rather than locomotive noise becomes the predominant noise source.

Frequency analysis also shows that the noise spectrum of the RTL is relatively flat and broadband across a wide frequency range, while the noise spectra of other non-diesel trains (AEM7, X2000, and ICE) show more distinctive peaks occurring in the 1.5 to 2 kHz range. The higher A-weighted noise level of the RTL as compared with the other equipment types appears to be caused by sound energy in the frequencies above 1,000 Hz. This is the frequency range over which the human ear is most sensitive.

4.1.1(b) Vibration Measurements

The ground-borne vibration measurements indicated that, at a given speed, root-mean-square (rms) velocity levels generated by the RTL trainset are about the same as those generated by the AEM7-pulled electric trains measured on the NEC. While slightly different behavior was observed with respect to attenuation of vibrations with distance, particularly at distances closer than about 50 feet, for critical distances of 50 to 200 feet the vibration levels from the two train types are virtually identical. From similar tests performed for the ICE and X2000 test trainsets,[2] both the AEM7 and RTL are about 3 dB higher than the ICE vibration levels and about 8 dB higher than the X2000 vibration levels.

Frequency analysis of selected events shows that most of the ground-borne vibration energy from the RTL train is concentrated in frequencies below 30 hertz (Hz), which is difficult to control and/or mitigate. While the overall levels may be about the same as those generated by the AEM7-powered trains, preliminary results show that the spectrum shapes are quite different. The AEM7 spectrum is centered around a peak at approximately 20 Hz, while the predominant RTL peak occurs at about 12 Hz. The ICE and X2000 spectra have been shown to be similar in shape to the AEM7, with lower overall levels. However, all but the RTL data were measured at a single NEC location in New Jersey; the difference in surrounding geology between the Albany area and the New Jersey site may be a significant factor affecting the vibration propagation characteristics.

4.1.2 Train Noise Measurements

4.1.2(a) Measurement Procedures and Equipment

Train noise measurements were carried out (1) for southbound turbotrains between the hours of 6:00 AM and 11:00 AM, and (2) for northbound turbotrains between the hours of 4:00 PM and 9:00 PM from March 30 through April 1, 1994. On the last day of testing, April 1, measurements were conducted only during the morning period of southbound trains. During these periods, a total of 17 passages of the RTL trainset and four passages of the older RTG-II trainset were measured.

The four noise measurement sites were selected to represent a range of train speeds, in order to provide an adequate range of data for calibrating the noise model so that noise levels from the RTL can be accurately projected along the NEC as a function of anticipated train speed. Other factors, such as differences in terrain, track condition, or wind can also affect noise measurements and may be attributable for variations or "scatter" in the data. The site locations and test performed at these sites are described below.

- Site 1 was located on the east (northbound) side of the corridor near MP 141 in Rensselaer, NY. Microphones were positioned at 50 feet and 100 feet from the centerline of Track 2 (southbound track). The separation distance between the two tracks is approximately 13.5 feet. Due to the surrounding terrain, the 100-foot microphone was positioned at a slightly higher elevation on an upwardly sloping grass-covered field. The track at this location is relatively straight and level, and the maximum allowable train speed is 60 mph in both directions.

- Site 2 was located on the northbound side of the track, just north of the Lincoln Avenue grade crossing northwest of Albany in Colonie, NY. The site was on a flat, grassy field off Petra Avenue which runs parallel to the track. Microphones were positioned at 50 feet and 100 feet from the centerline of the single track. The track is straight and level, with maximum allowable train speeds of 110 miles per hour (mph). Ground vibration measurements were also carried out at Site 2.

- Site 3 was located near MP 140 in Rensselaer, on the west (southbound) side of the corridor just south of the Teller Grade Crossing. The measurement site was on a level, flat clearing off a dirt road which runs parallel to the track for about 0.5 mile and continues through the industrial property on the west side of the tracks. Microphones were positioned at 50 feet and 100 feet from the centerline of Track 2 (southbound track). The track is straight and level, with maximum allowable train speeds of 80 mph in both directions.

- Site 4 was located near MP 136 in Rensselaer, along a narrow dirt road which runs perpendicular to the corridor surrounded by wetlands. The terrain has a slight downward slope on both sides of the corridor, with the tracks on a slight embankment. Microphones were positioned at 50 feet and 100 feet from the track centerline on the east side of the corridor, and one additional microphone was positioned at 50 feet from the track centerline on the west side of the corridor. Both AM and PM measurements were carried out at this site; as a result, the distances from track centerline were taken relative to Track 2 (southbound trains) during the AM measurement period, while they were taken relative to Track 1 (northbound trains) during the PM measurement period. The track is straight and level, with maximum allowable train speeds of 110 mph in both directions.

Train noise recordings were made using either a GenRad 0.5-inch electret microphone and preamplier, or a Brüel & Kjær (B&K) Type 2230 sound level meter, conforming to ANSI Standard S1.4 for precision (Type 1) sound level meters. The noise signals were recorded on a digital audio tape (DAT) using a SONY Model TCD-D10PRO recorder for subsequent laboratory analysis. For non-recorded noise data, a B&K Type 2225 handheld sound level meter (Type 2) was used to log maximum levels for each train event. Observed train consist information was noted on field data sheets and voice annotated on the data tapes. Additional information on daily trainset lineup and consists were obtained from the stationmaster at Rensselaer Station. Train speeds were obtained using a radar gun in the field.

Calibrations, traceable to the U.S. National Institute of Standards and Technology (NIST), were carried out before and after each set of measurements using an acoustical calibrator. A summary of the field instrumentation used for the noise measurements is provided in Table 4.1-2.

During all of the tests, noise measurements were made simultaneously for at least two positions. The distances used were 50 feet and 100 feet from the track centerline. At Site 4, an additional 50-foot measurement was also conducted on the opposite side of the track, with the goal of identifying differences in the noise emissions between the right and left sides of the RTL power car. The purpose of the 100-foot position was to obtain data for the RTL trainset at the standard measurement distance for evaluating compliance with the Federal Railroad Noise Emission Standards.

Analysis of the field data was carried out in a laboratory environment. Initially, the A-weighted maximum noise level (L_{Fmax}) and Sound Exposure Level (SEL) for each train event were obtained directly from the tape-recorded data using a B&K Type 2230 sound level meter. During this analysis, the "fast" response setting on the sound level meter was used as required to evaluate compliance with the Federal Railroad Noise Emission Standards. A Rion Model LR-04 graphic level recorder was also used to trace the continuous A-weighted sound level using a "slow" 1-second averaging time and the maximum level for each train event was recorded. The maximum noise level obtained using this slow averaging time (L_{Smax}) is more directly related to the SEL, and is appropriate for characterizing overall system noise exposure and modeling train noise mathematically.

TABLE 4.1-2 Field Instrumentation for Noise Measurements

MICROPHONE	PREAMPLIFIER	MICROPHONE POSITION						
		Site 1	Site 2	Site 3	Site 4[1]		Site 4[2]	
		Left Side	Right Side	Right Side	Right Side	Left Side	Right Side	Left Side
B&K 4129 S/N 1393201	B&K 2225 S/N 796692	50 ft.	50 ft.	50 ft.	50 ft.	--	50 ft.	--
B&K 4155 S/N 1683358	B&K 2230 S/N 1082194	100 ft.	100 ft.	100 ft.	--	50 ft.	--	--
GR 1962-9610 S/N 15735	GR 1560-P42 S/N 3841	--	--	--	50 ft.	--	--	100 ft.
GR 1962-9160 S/N 11646	GR 1560-P42 S/N 4349	--	--	--	--	--	--	50 ft.

Tape Recorder: SONY TCD-D10 PRO, S/N 15207
Calibrators: GR 1987, S/N 0894 (GR mic)
GR 1987, S/N 1096287007 (B&K mic)

[1] March 31, 1994 measurement period
[2] April 1, 1994 measurement period

Source: HMMH, Inc., 1994

Frequency analysis was carried out for selected events, using a Tektronix Model 2630 dual-channel FFT spectrum analyzer to obtain one-third octave band spectra averaged over intervals of maximum event noise levels. First, the noise signals were fed into the narrowband analyzer, and post-processing software was used to combine the narrowband results into one-third octave noise spectra.

4.1.2(b) Measurement Results and Evaluation

The results of the wayside noise measurements are listed in Appendix 4A, and are summarized graphically in Figure 4.1-1. This figure shows A-weighted noise level versus train speed, normalized to a 50-foot receiver position, in terms of the maximum level (L_{Fmax}) and SEL. The distance normalization was based on an average attenuation rate of 6 decibels (dB) per doubling of distance for L_{Fmax} and 3 dB per doubling of distance for SEL. The fairly wide scatter exhibited in these data can be attributed partially to the site-specific nature of wayside noise, based on differences in ground effect, shielding and track condition, and also to the different train consists and equipment conditions encountered during the testing period.

Data from Figure 4.1-1 were used to develop a "speed coefficient" describing the relationship between noise level and speed, which was used as a parameter in the development of a train noise model for the RTL turbotrain. This coefficient was calculated using a least mean squares regression method. The following speed adjustment to L_{Fmax} at a given speed V (in mph) was found to best fit the data:

$$\Delta L_{Fmax} = 25 \times \log\left(\frac{V}{V_{ref}}\right)$$

where V_{ref} = some reference train speed, in miles per hour. Since the overall maximum level is likely to be caused by the locomotive (i.e., RTL power unit), this speed dependency applies only to locomotive noise. The noise level from rail cars is generally assumed to have a single speed relationship irrespective of train technology; that is,

$$\Delta L_{Fmax} = 30 \times \log\left(\frac{V}{V_{ref}}\right)$$

This is primarily because the wheel/rail contact, which is the source of noise, exhibits similar behavior regardless of whether the power mechanism is gas turbine, diesel, electric, etc.

Since the mathematical model for train noise uses the maximum noise level (L_{Smax}) as the basis for calculating sound exposure in terms of SEL and L_{dn}, the two relationships given above are sufficient in defining the speed parameters for a given trainset. An analysis of the actual measured speed dependency of the SEL is less meaningful because it is also a function of train length. A detailed description of the model and the specific parameters used for the NECIP, previously reported in the DEIS/R,[3] are provided in Appendix 4B. The model is based on standard approaches found in the literature[4,5] and are based on available measurement data.

Figures 4.1-2 and 4.1-3 give a comparative overview of the different train noise emission levels modeled for the NECIP, with the L_{Fmax} (a) and SEL (b) plotted against speed for all of the train types considered. The curves represent a comparison of equivalent train consists of *one* locomotive and *eight* passenger cars, with the exception of the ICE, X2000 and RTL trainsets, which were modeled assuming a consist of *two* locomotives or power units and *seven* passenger cars. The standard consist for each of these train types contains two power units, one on either end, and were measured in the field as such. Thus, in order to maintain real world conditions in the prediction model while providing an equivalent basis on which to compare the noise levels, the standard number of locomotives for each train type was preserved for each of the technologies.

The measurement data obtained from each of the systems in Figures 4.1-2 and 4.1-3 were used to calibrate and develop generalized curves describing the relationship between noise level and speed, using the mathematical model described in the DEIS/R.[6] It can be seen that the RTL turbotrain falls somewhere between the F40 and AEM7 locomotive-hauled trains in terms of projected noise level, at speeds below 70 to 80 mph. In this speed regime, locomotive-generated noise such as diesel exhaust and turbo-engine intake are likely to be the predominant sources. However, with increasing speeds these sources become less of a factor as the wheel/rail noise component dominates. Since wheel/rail noise is only a function of the wheel and track condition, there is little difference in noise level between the various technologies in this higher speed regime.

Figures 4.1-4 through 4.1-7 show the results of the frequency analyses performed for the noise data, in the form of one-third octave band spectra of the sound pressure level. The overall A-weighted sound level corresponding to each spectrum is also given. Figures 4.1-4 and 4.1-5 give comparisons of noise spectra measured simultaneously on the right and left sides of the RTL turbotrain at the 50-foot position, for two passbys at different speeds. The figures show that the noise spectrum measured on the right side of the train, where the engine intake is located, and show more energy in the higher frequencies above about 3,000 Hz. This difference is greater for the 38-mph train than for the 52-mph train, since at higher speeds the wheel/rail noise component begins to dominate the overall noise and engine noise has less of an effect.

Figure 4.1-6 shows the RTL noise spectrum over a range of speeds, measured at 100 feet at each of four locations. In general, the increase in speed corresponds to a sound pressure level increase in the 1,000 to 5,000 Hz range. Finally, Figure 4.1-7 provides a comparison of the average noise spectra of the different systems considered for NECIP: RTL, AEM7, X2000, and ICE. The spectra shown are at the 100-foot measurement position normalized to 90 mph. While the figure may imply that the RTL is noisier than any of the other trains at high speed (contrary to what was shown in Figures 4.1-2 and 4.1-3), the spectrum was obtained by sampling the signal over the *maximum* level achieved in the corresponding time history. Thus, the RTL spectrum shown in Figure 4.1-7 represents only the power unit noise normalized from some measured speed (less than 90 mph) to 90 mph. It does not include the wheel/rail noise component, which at high speed is a significant source of noise and, as Figures 4.1-2 and 4.1-3 show, is essentially equal in magnitude for all of the train technologies considered in this study.

One can also see from Figure 4.1-7 that the sound spectra for the three electric locomotives have very similar shapes, with the only significant differences between them being the respective magnitudes of emitted sound energy. The RTL spectrum, however, shows a broadband quality that is consistently higher in level than the other three electric alternatives. The difference in the higher frequencies (> 1,000 Hz) is most significant, since the human ear is most sensitive at these frequencies.

4.1.2(c) Compliance with Federal Railroad Noise Emission Standards

Pursuant to the Noise Control Act, the U.S. Environmental Protection Agency (EPA) has issued noise emission standards for specific types of railroad equipment (40 CFR Part 201). FRA has adopted these regulations for the purpose of enforcement in the FRA Railroad Noise Emission Compliance Regulations (49 CFR Part 210). The standards provide specific noise limits for stationary and moving locomotives, moving railroad cards, active retarders, car coupling, and locomotive load cell test stands in terms of the A-weighted sound level at a specified measurement location. Table 4.1-3 summarizes the standards for locomotives and rail cars that are relevant to the measurements of train passby noise summarized in this report. The results obtained from these measurements were compared with the standards and allowable tolerances to determine compliance with the Federal regulations.

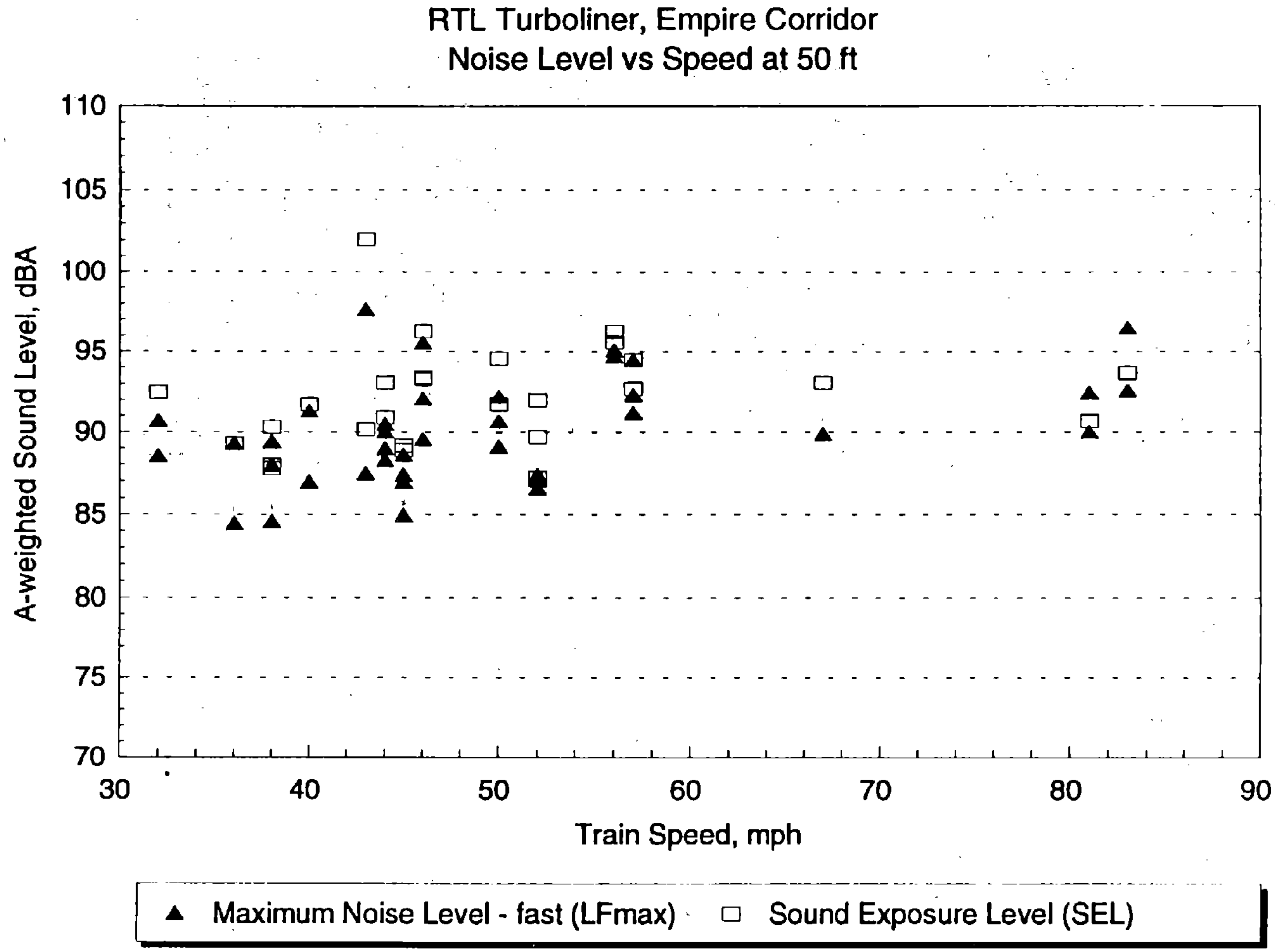
The EPA standards specify different limits for moving locomotives and railroad cars, presumably aimed at evaluating noise from diesel-hauled freight trains, which can be several hundred cars long. Amtrak passenger trains usually consist of 10 cars or less, and as a result the maximum noise levels generated by the locomotive and rail cars are generally indistinguishable from each other. For this reason, only the EPA standard for railroad cars is applied to this measurement program. Thus, the applicable standards are (1) an L_{Fmax} of 88 dBA for train speeds of less than or equal to 45 mph, and (2) 93 dBA for trains faster than 45 mph, plus the allowable measurement tolerance. This tolerance is defined in 49 CFR §210.25 as 2 dBA, and is intended to account for rounding errors, instrument tolerances, topographical variations, atmospheric conditions and reflected sound effects. In other words, moving trains would be considered not in compliance with the Federal noise regulation whenever the measured L_{Fmax} at a perpendicular distance of 100 feet from the track centerline exceeds 90 DBA for speeds $\leq$45 mph and 95 dBA for speeds > 45 mph.

The noise measurements of RTL trainset passbys were conducted using a 100-foot microphone position in compliance with the measurement procedure described in 40 CFR Part 201. Of the 17 RTL train passbys recorded at this distance in the field, all resulted in maximum noise levels below the criteria described above. In all cases, the measured L_{Fmax} was well below the applicable Federal standard.

4.1.3 Ground-Borne Vibration Measurements

4.1.3(a) Measurement Procedures and Equipment

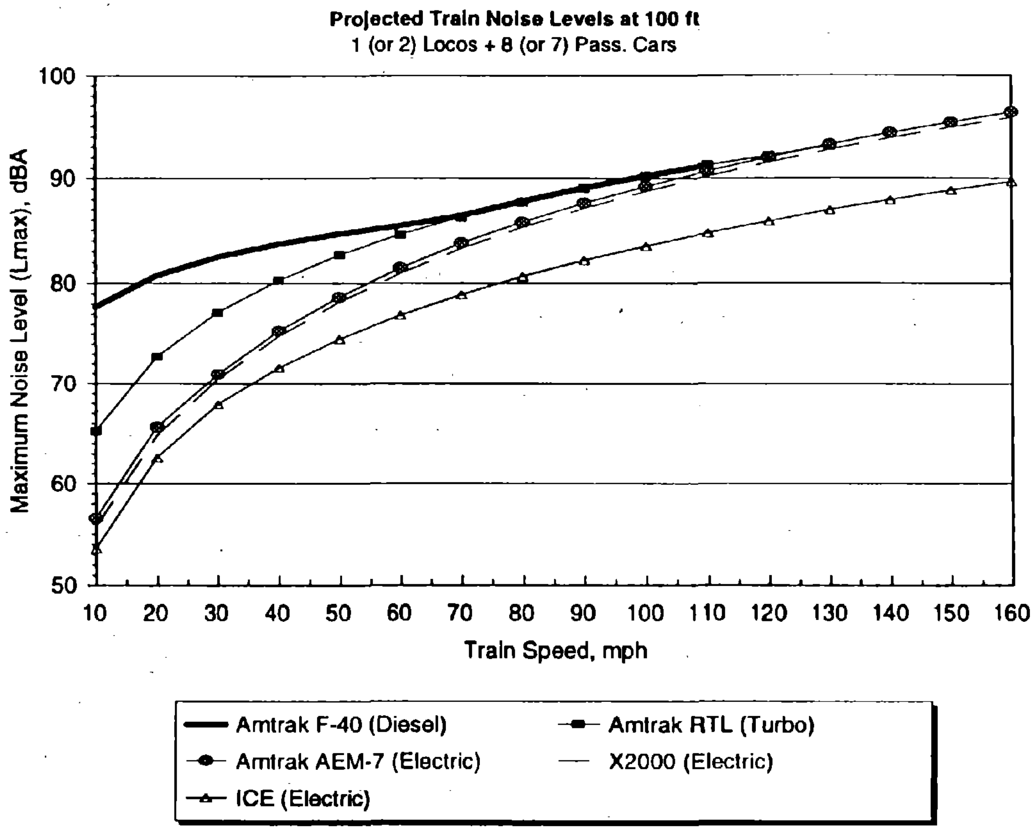
Ground vibration measurements were carried out at Sites 2 and 4 only. At Site 2, two northbound turbotrain passages were measured between the hours of 7:00 PM and 9:00 PM on March 30, 1994. At Site 4, four northbound turbotrains were measured between 5:00 PM and 8:00 PM on March 31, 1994, and five southbound on turbotrains were measured between 6:00 AM and 10:00 AM on April 31, 1994. The measurements were performed using accelerometers as the vibration transducers, and the acceleration signals



MEASURED RTL NOISE LEVELS

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

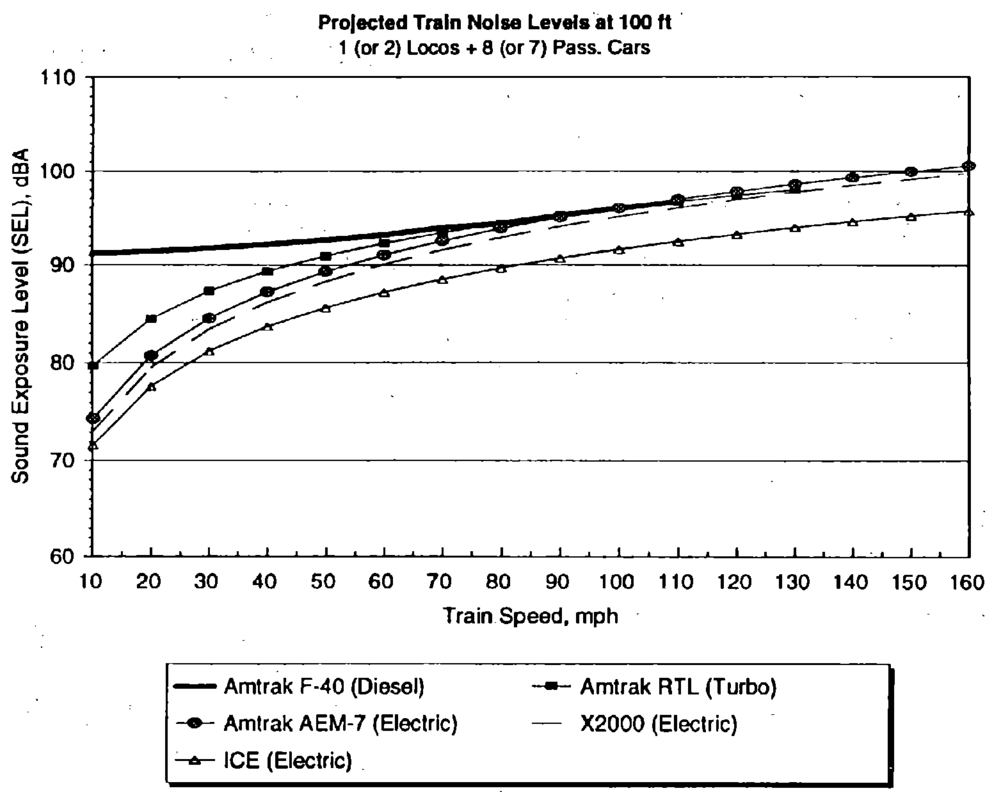
Figure 4.1-1



PROJECTED L_{Fmax} VS TRAIN SPEED

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

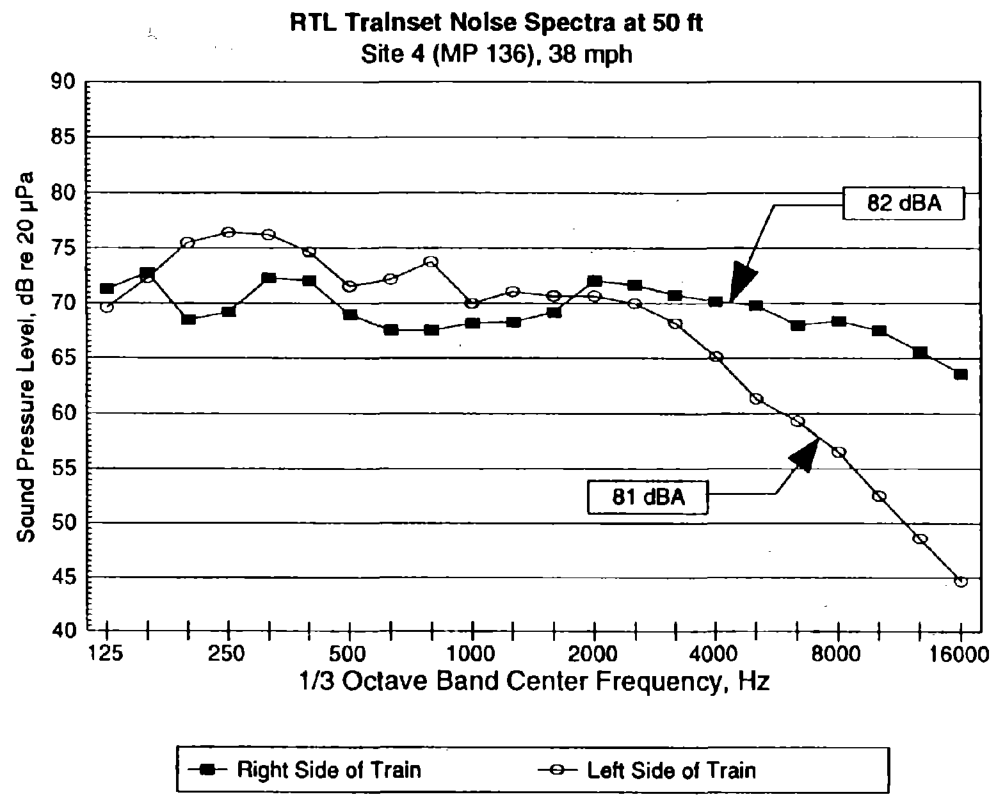
Figure 4.1-2



PROJECTED SEL VS TRAIN SPEED

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

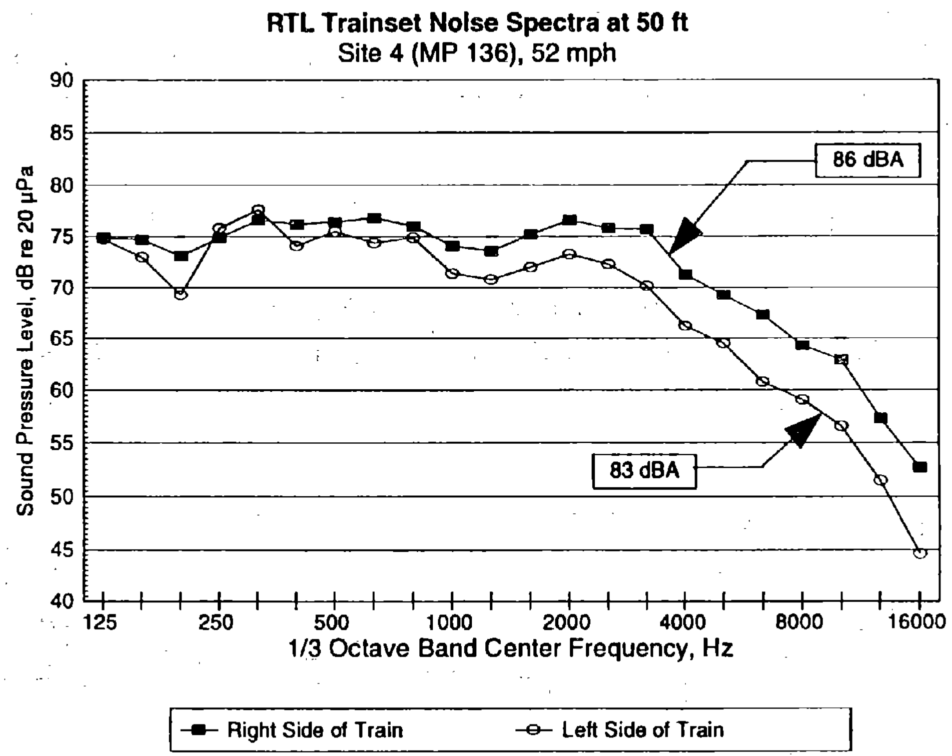
Figure
4.1-3



RTL NOISE SPECTRA AT 38 MPH

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

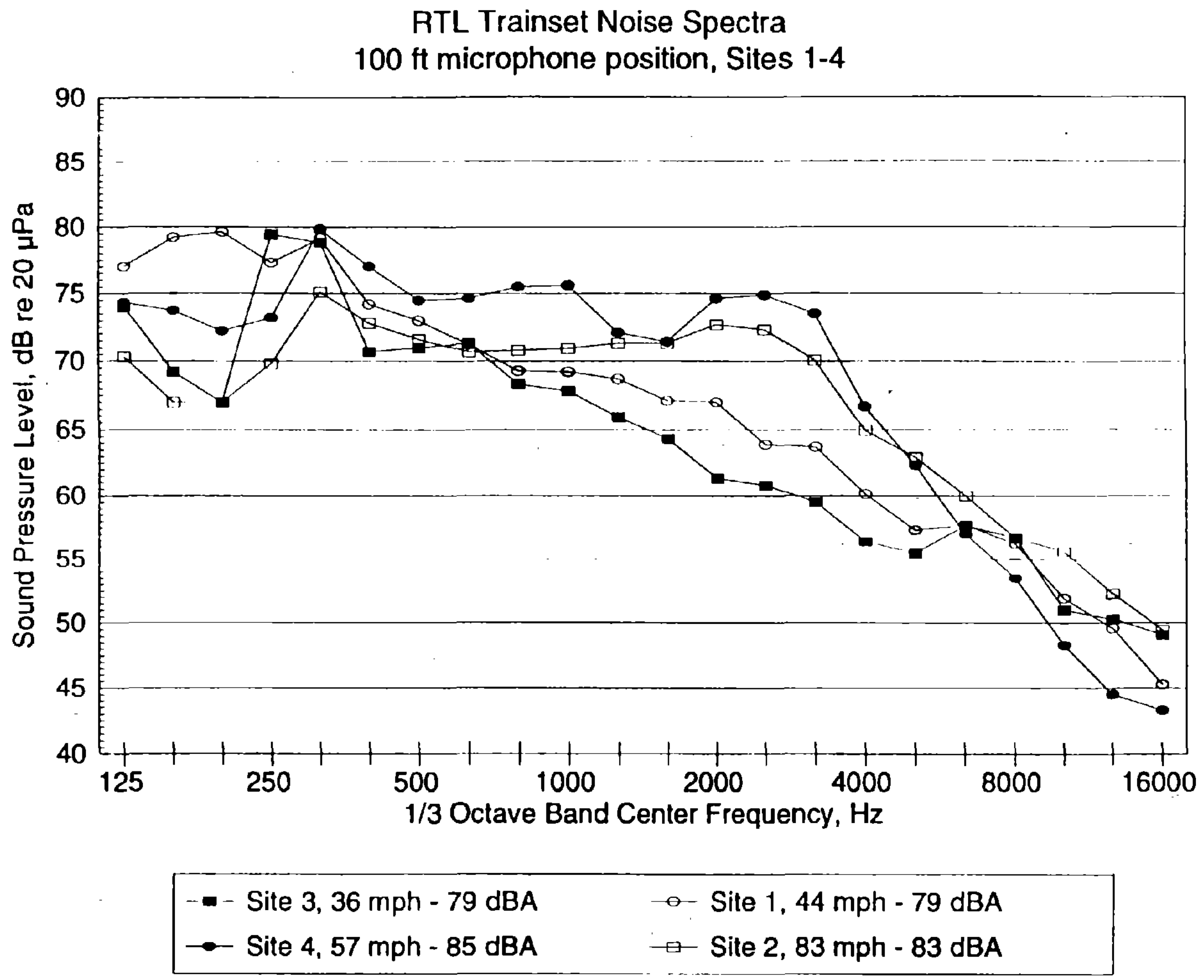
Figure 4.1-4



RTL NOISE SPECTRA AT 52 MPH

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

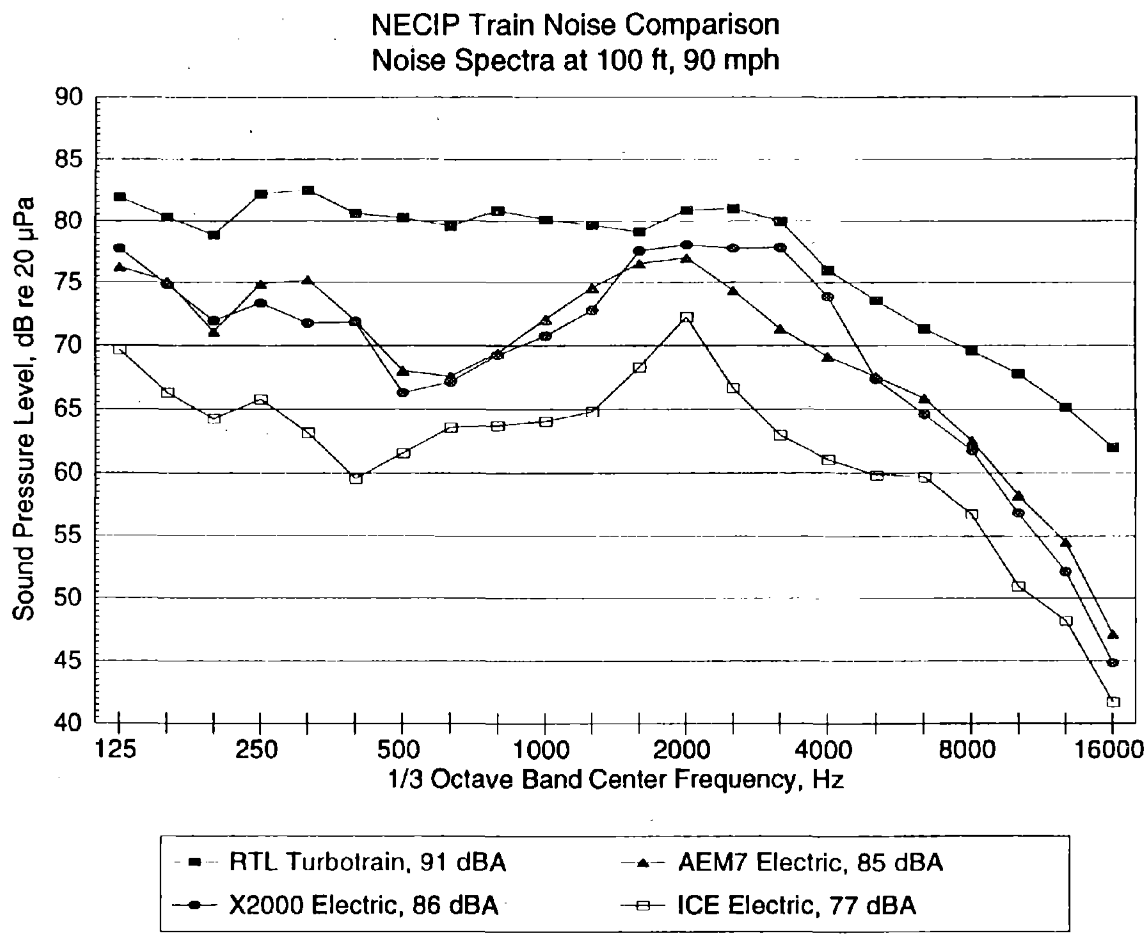
Figure 4.1-5



RTL NOISE SPECTRA AT 100 FT

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure
4.1-6



NECIP TRAIN NOISE SPECTRA AT 100 FT

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.1-7

were recorded on a DAT recorder for subsequent analysis in the HMMH laboratory. Observed train consist information was noted on field data sheets and voice annotated on the data tapes. Train speeds were obtained using a radar gun.

TABLE 4.1-3 Summary of Applicable EPA Railroad Noise Standards

NOISE SOURCE	OPERATING CONDITION	NOISE METRIC	MEASUREMENT DISTANCE	STANDARD
Non-Switcher Locomotives built after 12/31/79	Moving	L_{max} (Fast)	100 ft.	90 dBA
Railroad Cars	Speed ≤ 45 mph	L_{max} (Fast)	100 ft.	88 dBA
	Speed > 45 mph	L_{max} (Fast)	100 ft.	93 dBA

Source: HMMH, Inc., 1994

During all of the tests, vibration measurements were made simultaneously at five positions along the ground at distances of 25, 50, 75, 100, and 150 feet from the applicable track centerline. These positions are consistent with those used for previous train vibration tests performed for the NEC. All measurements were performed using high-sensitivity accelerometers as the vibration transducers. All accelerometers were oriented to measure vibration in the vertical direction, and were mounted on top of ground-driven steel stakes using putty to secure them to the top plates of the stakes.

The signals from the accelerometers were amplified using low-noise amplifiers, and recorded on an eight-channel instrumentation tape recorder for subsequent laboratory analysis. The amplifiers were set for optimum signal-to-noise ratio, and the amplifier and tape recorder gains were recorded on field data sheets and voice annotated on the data tapes. A 1-volt peak test signal, a built-in feature of the tape recorder, was recorded on each tape for calibration of the system, based on the individual sensitivities of the accelerometers. A summary of the field instrumentation used for the vibration measurements is provided in Table 4.1-4.

Analysis of the field data was carried out in the HMMH laboratory. For all analysis, the recorded acceleration signals were integrated to obtain vibration velocity, using a Brüel & Kjær (B&K) Model 2635 amplifier and signal conditioner. The resulting signals were fed into a Rion Model LR-04 graphic level recorder to obtain strip charts of root-mean-square vibration velocity as a function of time. The rms time constant on the level recorder was set for 1 second, which is equivalent to the "slow" response setting on a standard sound level meter, and the maximum vibration level for each train event was obtained from the strip charts.

Frequency analysis was carried out for selected events, using a Tektronix Model 2630 dual-channel FFT spectrum analyzer to obtain one-third octave band spectra averaged over intervals of maximum event vibration levels. The acceleration signals were fed into the narrowband analyzer, and post-processing software was used to integrate the narrowband data and combine the narrowband results into one-third octave vibration velocity spectra.

4.1.3(b) Measurement Results and Evaluation

Detailed results of the ground-borne train vibration measurements are included in Appendix 4C, and are shown graphically in Figure 4.1-8. This figure presents the results of the vibration measurements in the form of maximum rms vibration velocity level (re: 1 μinch/sec) from each train event as a function of distance from the track centerline, normalized to a train speed of 90 mph.

TABLE 4.1-4 Field Instrumentation for Vibration Measurements

<table>
<tr><th rowspan="2">EQUIPMENT</th><th colspan="5">EQUIPMENT MODEL, SERIAL NUMBER AND SENSITIVITY (volts/g)</th></tr>
<tr><th>25-ft Position</th><th>50-ft Position</th><th>75-ft Position</th><th>100-ft Position</th><th>150-ft Position</th></tr>
<tr><td>Accelerometer</td><td>PCB 393B
S/N 162
(1.09 V/g)</td><td>PCB 393C
S/N 2480
(1.10 V/g)</td><td>PCB 393C
S/N 2481
(1.11 V/g)</td><td>PCB 393C
S/N 2482
(1.10 V/g)</td><td>Wilcoxon 731
S/N 143
(10 V/g)</td></tr>
<tr><td>Power Unit</td><td rowspan="2">PCB 480C06
S/N 1550</td><td>PCB 480C02
S/N 2366</td><td>PCB 480C02
S/N 2367</td><td>PCB 480C02
S/N 2368</td><td rowspan="2">Wilcoxon P31
S/N 180</td></tr>
<tr><td>Amplifier</td><td>EPAC 60/10 LN
S/N 68</td><td>EPAC 60/10 LN
S/N 69</td><td>EPAC 60/10 LN
S/N.0A</td></tr>
<tr><td>Tape Recorder</td><td colspan="5">TEAC RD-130TE (8-Ch. DAT Recorder) S/N 512546</td></tr>
</table>

Source: HMMH, Inc., 1994

The following adjustment was made in normalizing the data to account for speed variations:

$$\Delta L_v = 20 \times \log\left(\frac{V}{90}\right)$$

where V = train speed in miles per hour.

Also shown in Figure 4.1-8 is a curve representing the vibration projection model used in the DEIS/R to predict maximum existing and future vibration levels from Amtrak trains along the NEC, also at 90 mph. This curve was developed as a result of a comprehensive measurement program, which included both diesel and electric-powered trains measured at several locations distributed along the corridor. It was found in the DEIS/R study that both diesel and electric-locomotive trains generate about the same level of vibration at similar speeds, and as a result the same vibration projection curve was used to characterize both equipment types. Superimposed on the RTL vibration data in Figure 4.1-8, by inspection the curve passes through the middle of the data measured on the Empire Corridor, and exhibits a similar attenuation rate with distance. In fact, the curve represents a close approximation of the curve that would be obtained by curve-fitting the points in a regression analysis. Given this observation, it is safe to say that the RTL turbotrain would generate about the same level of vibration as the AEM7 and F40PH-hauled trains, and that the projection model used in the DEIS/R for these trains is also valid for the RTL applied to the NEC.

A least-mean squares curve fit was performed on the data to obtain the regression curve for the RTL trainset shown in Figure 4.1-7. This regression curve provides a clear representation of the "average" levels generated by the turboliner and the rate at which these levels propagate with distance, for purposes of comparison. The figure also has superimposed on it similar curves for the AEM7,[7] ICE, and X2000 trainsets, all measured at a site along the NEC in Plainsboro, New Jersey. As concluded from inspection of Figure 4.1-8, Figure 4.1-9 shows that the maximum rms vibration levels generated by the AEM7 and RTL trainsets are nearly the same, with slight differences in rate of decay at distances closer than 50 feet and farther than 200 feet. These are likely to be due more to the residual effects of the curve-fitting and/or differences in the data sample size, rather than any real differences in soil or propagation characteristics. As previously reported, the ICE vibration levels are about 3 dB lower than the AEM7 and RTL, and the X2000 vibration levels are about 8 dB lower than the AEM7/RTL and 5 dB lower than the ICE.[8]

To provide a better understanding of the nature of ground-borne vibration, the vibration velocity spectra of two RTL train passbys measured at Sites 2 and 4 are shown in Figures 4.1-10 and 4.1-11, respectively. For each passby, the 1/3 octave band spectra obtained simultaneously at three accelerometer positions along the ground at increasing distances from the track are given to illustrate the frequency-dependent attenuation of vibration energy as it travels away from the track. The figures show a pronounced difference between the distribution of vibration energy over the peak frequencies between the 50-foot spectra, but overall similarities in the peak frequency values and shapes. The differences may be due to train speed, although speed correction is not normally considered frequency-dependent for ground vibration, or to site-specific factors such as soil properties and track condition. At the 100-foot and 150-foot positions, however, the peaks appear to have decayed to a degree where the differences are less pronounced and the spectrum shapes are generally the same.

Finally, Figure 4.1-12 provides a comparison summary of the vibration spectra of four Amtrak train types evaluated for the NECIP: RTL, AEM7, ICE, and X2000. The spectra shown are normalized to a single distance (100 feet) from the track centerline. Overall velocity levels are also plotted for the four equipment types. AEM7 vibration data from several train passbys and RTL data from Site 2 were normalized to a train speed of 90 mph and energy-averaged to obtain the spectra shown. The ICE spectrum consists of an energy-average of two speed-normalized passbys, while the X2000 spectrum represents only a single data sample normalized to 90 mph.

Figure 4.1-12 shows that there is a significant difference in the shape of the RTL spectrum as compared with that of the AEM7, ICE, and X2000 trainsets. Most of the vibration energy from the RTL is centered around a peak frequency of about 12 Hz, with a smaller peak at 25 Hz. For the AEM7, most of the energy centers around 20 Hz with a narrower peak at 40 Hz. The ICE and X2000 spectra are basically similar in shape to the AEM7. However, the ICE spectrum peak appears to be spread out over a slightly wider bandwidth from about 16 Hz up to 50 Hz. While the overall level of the X2000 is lower than any of the other trainsets, low-frequency energy remains in tact, since the effect of the X2000's lower unsprung weight appears to be primarily in the 30 Hz and above range.

Differences such as those observed in Figure 4.1-12 may be attributable to factors other than the source of vibration (i.e., the force transmitted by the train's unsprung weight through its rolling stock). For example, location-specific geologic conditions have been found to affect both the magnitude and frequency content of ground-borne vibration, as do other factors such as condition of the running surface of the rails. These may also help explain the discrepancy in vibration spectrum shape observed between the RTL trainset, measured along the Empire Corridor in New York State, and the other three trainsets which were measured along the NEC in New Jersey.

In any case, standard track support vibration mitigation treatments, such as ballast mats, are most effective in the 30 Hz and above frequency range. The frequency characteristics of the measured ground-borne train vibration shown in Figure 4.1-12 indicate that such treatment may not be very effective for any of the Amtrak trains tested, since most of the energy transmitted to the ground is concentrated below 30 Hz. However, there are variations among the data that indicate which equipment may be more or less difficult to mitigate for ground vibration. While the overall levels of the RTL and AEM7 are about the same, the RTL spectrum contains low-frequency vibration below 20 Hz that is quite difficult to mitigate with standard vibration control treatments. The vibration spectra from the ICE trainset indicate that, while overall levels may be higher than those measured for the X2000, a ballast mat may be more effective in reducing the vibration due to a wider distribution of energy that contains higher frequencies which are less difficult to control.

4.2 NOISE IMPACT FROM AMTRAK DESIGN MODIFICATIONS

4.2.1 Summary

We have evaluated the potential noise and vibration impact of the design modifications at nine electrification facilities proposed for the NECIP electrification. The evaluation includes projection of noise from normal facility operations, as well as noise and vibration from construction of such facilities. The criteria and methodology used are consistent with those developed for the DEIS/R Technical Study, and are summarized in this section.

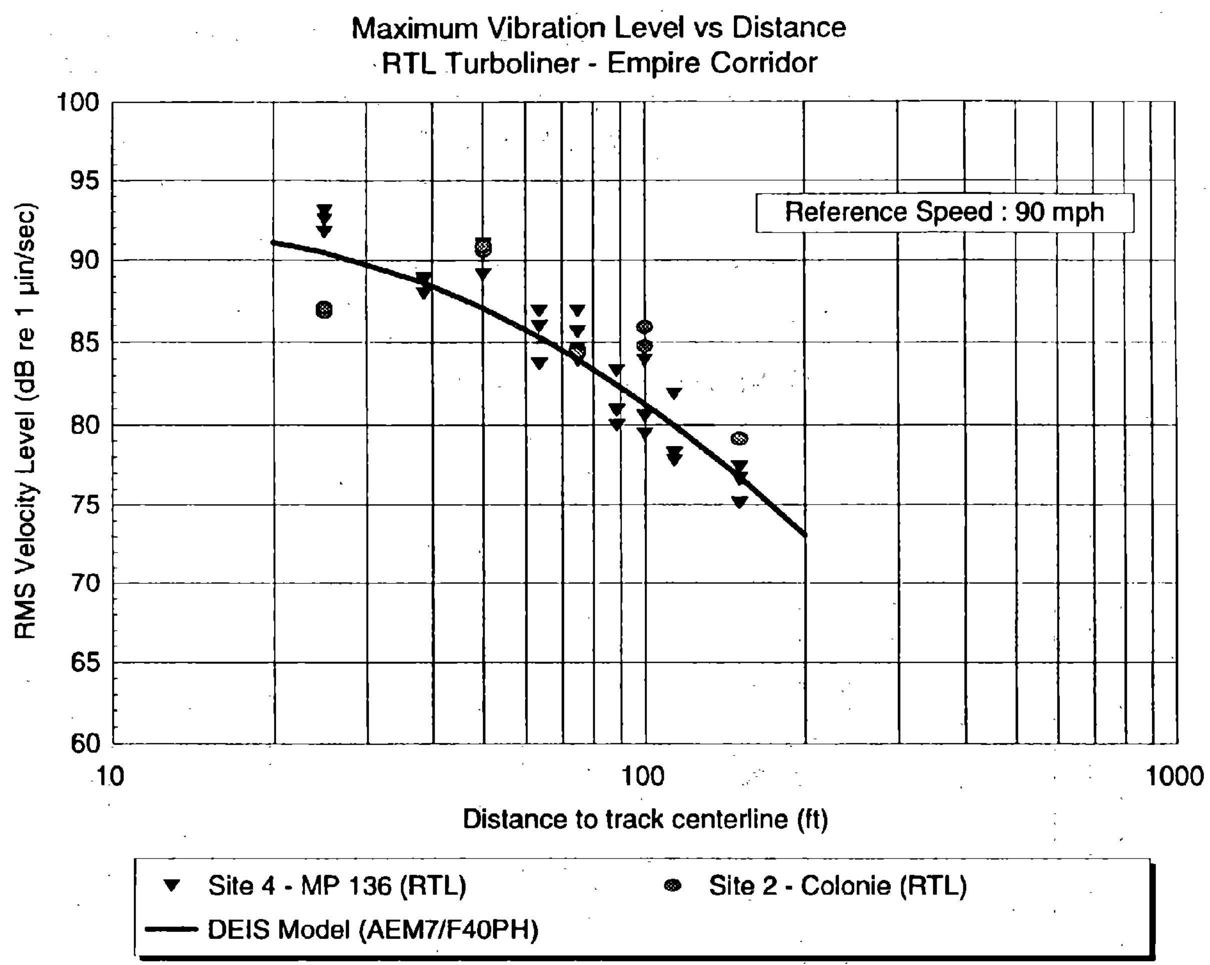
In general, the facility relocations reflect only small modifications in the overall impact inventory of the DEIS/R, with the only modifications in noise impacts from facility operation at the Westbrook Switching Station, the Noank Paralleling Station, and the Canton Paralleling Station. Since none of the nine proposed refinements applies to facilities previously identified as causing potential construction noise and vibration impact, there is no change in the impact inventory from fixed facility construction.

4.2.2 Background

The fixed facilities affected include one traction power substation, two switching stations, and six paralleling stations. Such facilities contain noise-generating electrical and mechanical equipment that may affect nearby noise-sensitive land use during normal operation. The major sources of noise at these facilities are expected to include transformers and HVAC units. Because these sources contain discrete acoustic "tones" which are considered more annoying than broadband noise, there is a 5 decibel penalty imposed in assessing their noise impact.

In addition, because the criteria are based on the background noise level of the land use during the hours when it is normally occupied, and since human sensitivity to noise depends on the time of day and type of land use, the noise impact thresholds defined for daytime occupancy (e.g., schools and places of worship) and nighttime occupancy (e.g., residences, hospitals, and hotels) differ by 5 decibels. The noise impact criteria, as described in the DEIS/R, are summarized in Table 4.2-1.

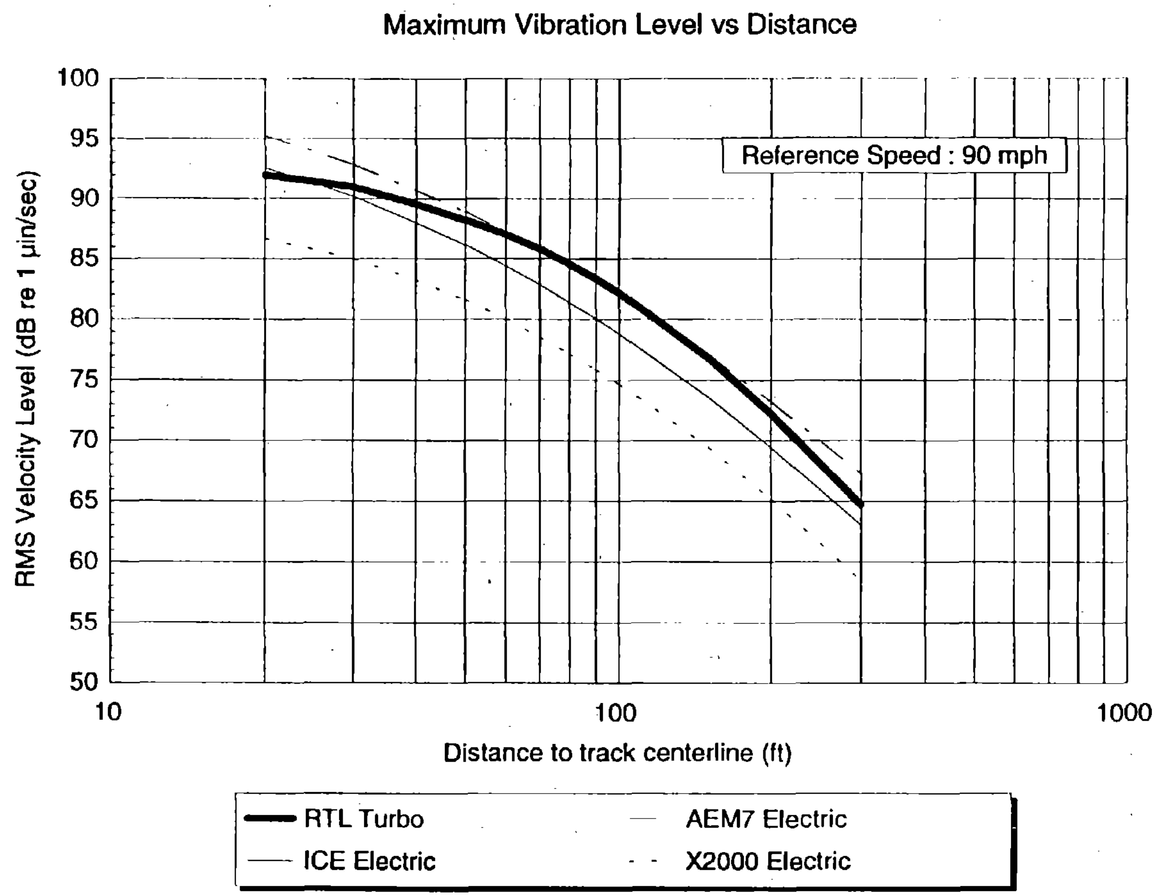
Noise projections from facility operation are calculated using baseline noise levels at some reference distance, anticipated operating characteristics, and standard sound propagation prediction methods. Baseline noise levels as a function of the operating parameters are generally taken as empirical relationships found in the literature. These projections are then evaluated according to the criteria given in Table 4.2-1 to obtain screening distances for noise impact. A summary of the resulting noise projections and impact distances, as detailed in the DEIS/R, is shown in Table 4.2-2.



MEASURED MAXIMUM RMS TRAIN VIBRATION

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

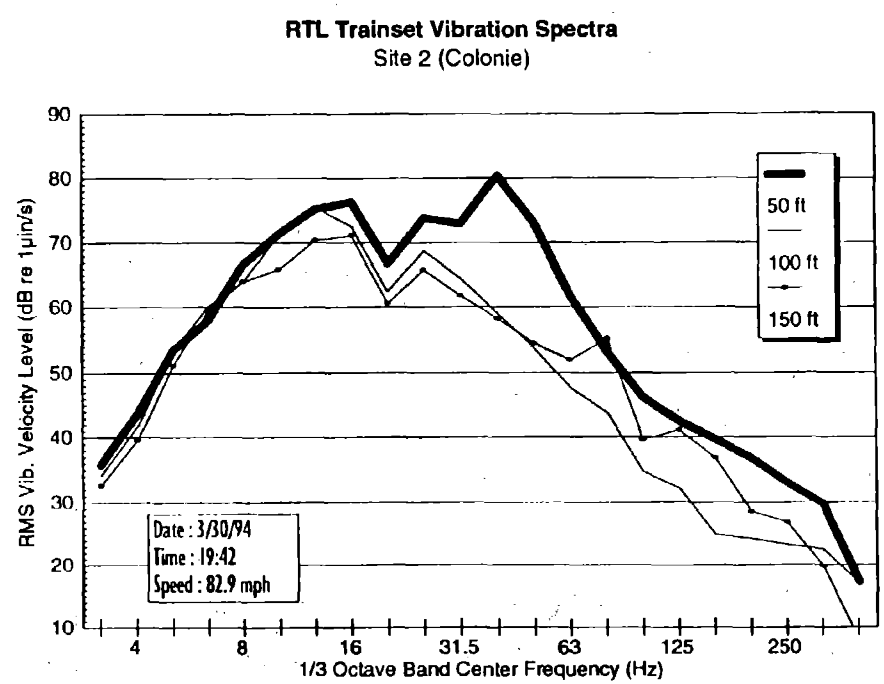
Figure 4.1-8



REGRESSION CURVES OF TRAIN VIBRATION

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

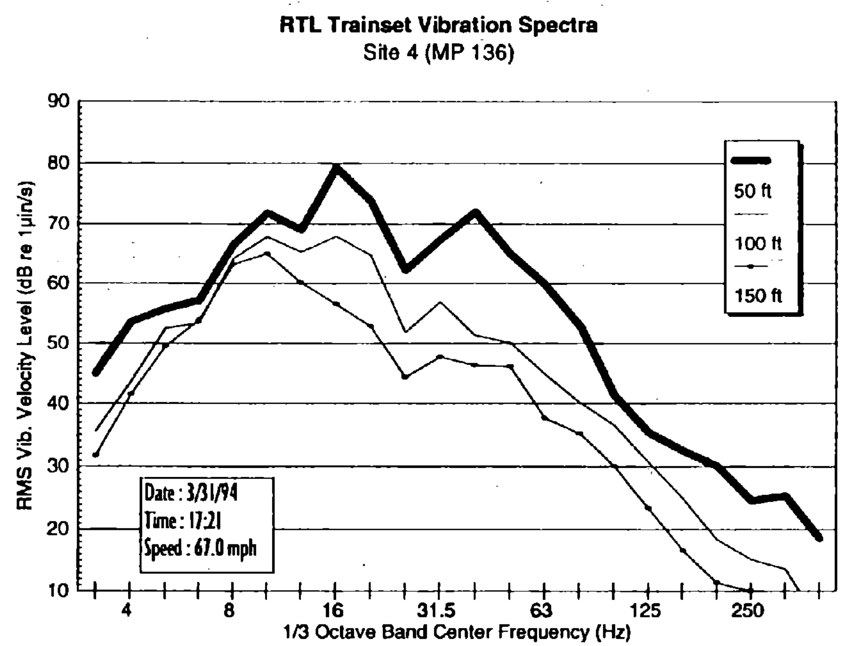
Figure 4.1-9



1/3 OCTAVE BAND VIBRATION SPECTRA OF RTL AT SITE 2

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

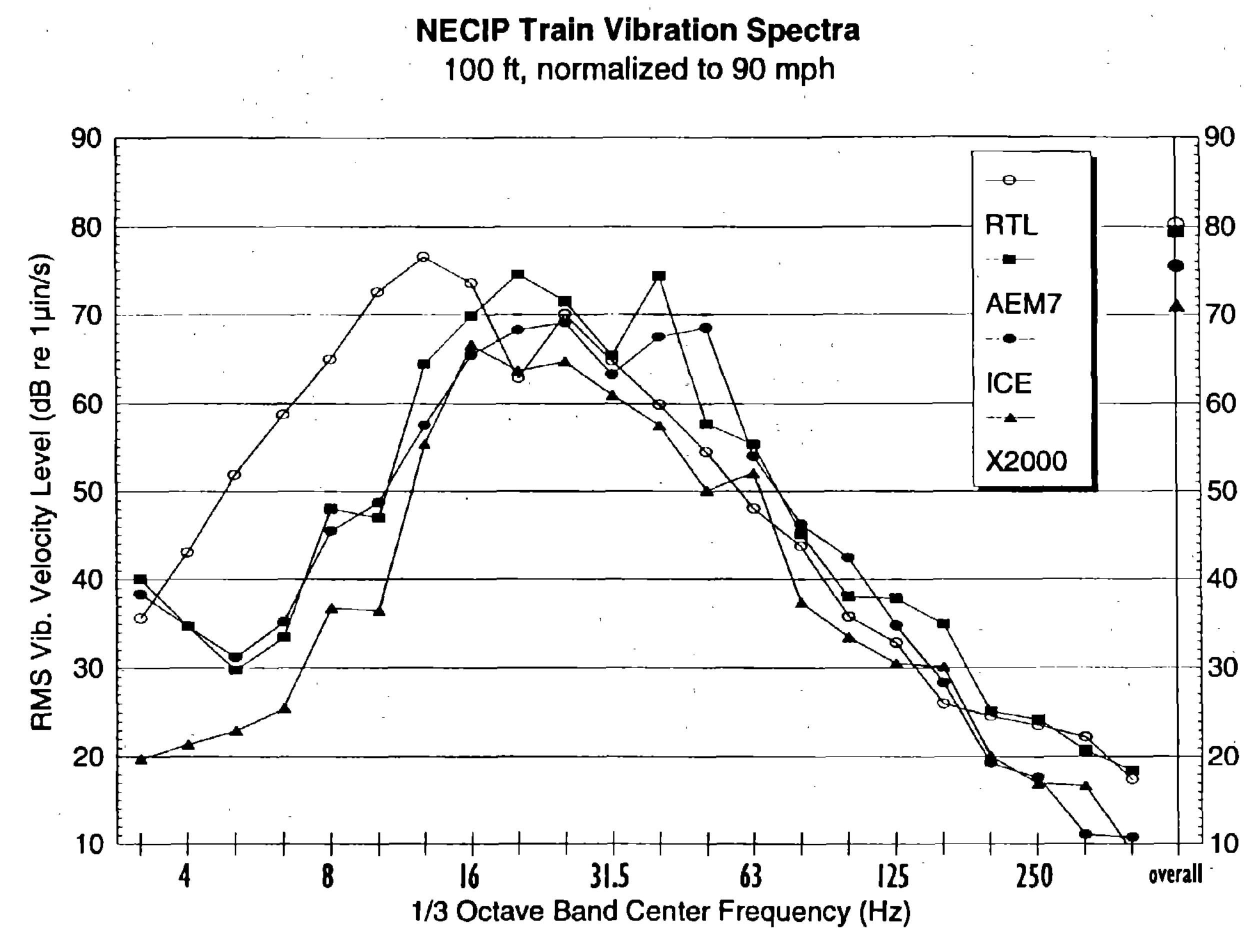
Figure 4.1-10



1/3 OCTAVE BAND VIBRATION SPECTRA OF RTL AT SITE 4

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.1-11



1/3 OCTAVE BAND VIBRATION SPECTRA OF NECIP AMTRAK TRAINS

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.1-12

TABLE 4.2-1 Noise Impact Criteria for Fixed Facility Operations

LAND USE	BACKGROUND NOISE LEVEL (dBA)	PROJECT NOISE IMPACT THRESHOLD (dBA)
Daytime (schools, churches, etc.)	≤50	50
Nighttime (residences, hospitals, etc.)	≤45	45
Daytime (schools, churches, etc.)	>50	Same as Background Level
Nighttime (residences, hospitals, etc.)	>45	Same as Background Level

Source: HMMH, Inc., 1993

4.2.3 Revised Impact Inventory

A revised noise impact assessment was carried out for the facility modifications, based on the distances in Table 4.2-2 and with the aid of aerial photographs. The results, along with revisions to the DEIS/R inventory, are provided in Table 4.2-3. The total inventory now indicates potential noise impact at a total of 75 residences corridorwide, with 37 located near substation sites, two located near switching station sites, and 36 located near paralleling station sites. In terms of modification to the DEIS/R, the greatest difference occurs at the Canton Paralleling Station, for which six residences on Trayer Road identified in the DEIS/R are no longer within the impact distance. At the revised Westbrook switching station site, only one of three residences on Gilbert Road identified in the DEIS/R is within the impact screening distance. At the new Noank paralleling site, five residences at the end of Seneca Drive are identified within the noise impact zone, compared with four identified in the DEIS/R.

TABLE 4.2-2 Noise Projection and Impact Distance Summary

FACILITY	OPERATING ASSUMPTIONS		PROJECTED TOTAL NOISE LEVEL at 500 ft (dBA)	DISTANCE to NOISE IMPACT	
	TRANSFORMER RATING (MVA)	HVAC COOLING CAPACITY (Tons)		DAYTIME LAND USE (ft)	NIGHTTIME LAND USE (ft)
Traction power substation	2 @ 50	10	45	280	500
Switching station	3 @ 5	10	42	200	350
Paralleling station	3 @ 5	10	42	200	350

Source: HMMH, Inc., 1993

TABLE 4.2-3 Noise Impact Summary for Facility Modifications

FACILITY	MILEPOST (new)	NUMBER OF NOISE IMPACTED RESIDENCES		DESCRIPTION
		DEIS/R	REVISED	
Branford Substation	79.04	1	1	SF off Hosley Ave, 300 ft from center of substation site
Westbrook Switching Station	103.51	3	1	SF off Gilbert Rd, 180 ft from center of site
Millstone Paralleling Station	117.54	0	0	
New London Utility Corridor	N/A	NA	NA	No operational activity will occur along utility corridor
Noank Paralleling Station	129.52	4	5	SF at end of cul-de-sac (Seneca Drive)
Richmond Switching Station	150.15	0	0	
Elmwood Paralleling Station	181.50	0	0	
Providence Paralleling Station	187.60	0	0	
Canton Paralleling Station	212.37	6	0	
Readville Paralleling Station	219.07	6	6	SF on Prescott St

Source: HMMH, Inc., 1993, 1994

4.3 ICE TRAINSET NOISE AND VIBRATION

4.3.1 Introduction and Summary

This report summarizes the methods and results of train noise and vibration measurements carried out on November 10 and 11, 1993, adjacent to Amtrak's NEC railroad tracks in Plainsboro, New Jersey. The objective of the measurements was to obtain wayside noise and ground-borne vibration data during operation of the ICE trainset in revenue service on the Northeast Corridor, and to compare the results with similar data available for the X2000 trainset and for standard Amtrak trains hauled by AEM7 electric locomotives. These data are relevant to the ongoing environmental impact study for the planned electrification of the NEC between New Haven, CT, and Boston, MA.

The ICE trainset measurements November 10 and 11, 1993, were carried out in an open area next to the NEC, at about MP 45.45 in Plainsboro, New Jersey. There are four continuous welded rail tracks at this location, with the two inner (high-speed) tracks composed of concrete ties and ballast and the two outer (local) tracks composed of wood ties and ballast. As shown on the photograph in Figure 4.3-1, this location was on the westbound side of the tracks, just south of the Plainsboro Road overhead bridge. This is the same site where HMMH performed noise and vibration measurements for the X2000 trainset on March 5, 1993. During both measurement surveys, noise and vibration data were also obtained during passages of standard Amtrak trains hauled by AEM7 electric locomotives.

The noise measurements indicated that the ICE trainset was about 5 to 10 dBA quieter on average than the Amtrak trains with AEM7 locomotives, and about 3 to 5 dBA quieter than the X2000 train tested in March 1993. Despite the large amount of scatter in measured noise levels of the AEM7-hauled trains, the data showed good agreement with tests performed in 1976, just before the AEM7 was brought into revenue service on the NEC. Furthermore, the measurements indicated that trains were essentially in compliance with the Federal Railroad Noise Emission Standard, although two trains with AEM7 locomotives were only marginally so.

Comparing the frequency characteristics of the broadband noise spectra show that the overall spectrum shapes of the three train types are similar, with peaks occurring in the 1 to 2 kHz range. However, a consistent difference in levels below 2 kHz was observed between trains traveling on the two high-speed inner tracks, indicating a possible difference in rail condition (e.g., roughness).

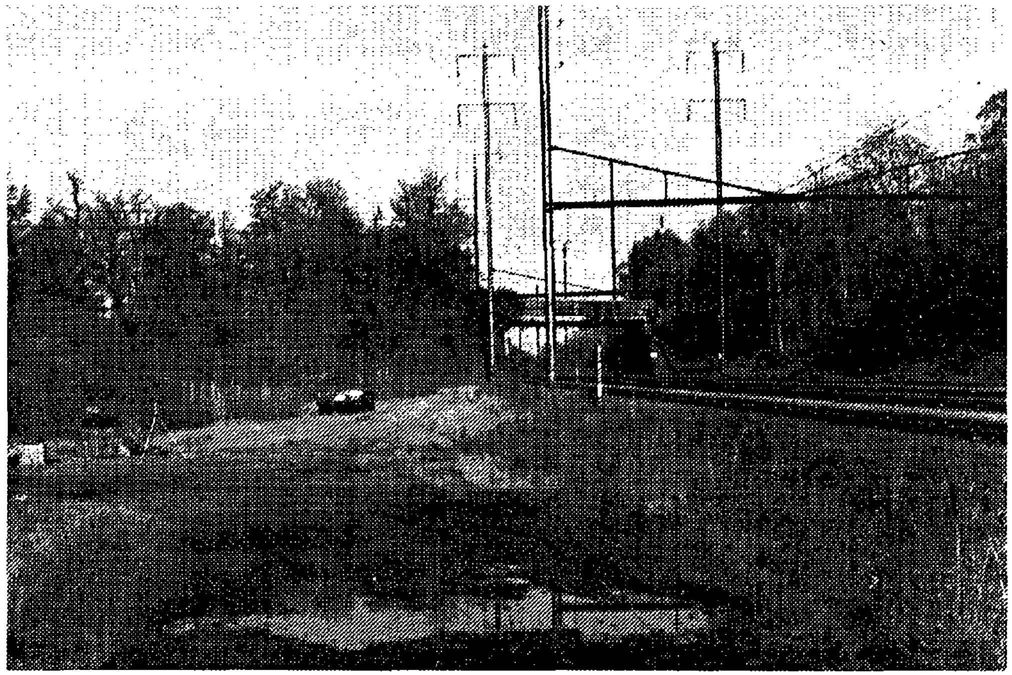
The ground-borne vibration measurements indicated that, at a given speed, rms velocity levels generated by the ICE trainset are about 3 dB lower than those generated by the AEM7 locomotive-powered trains, but are about 5 dB higher than the X2000 vibration levels measured in March 1993. However, frequency analysis shows that the X2000 vibration velocity spectrum contains most of its energy at low frequencies, while the AEM7 and ICE spectra exhibit energy spread out over a slightly wider frequency range. This may indicate that mitigation, such as ballast mat treatment, would not be as effective in reducing ground vibration generated by the X2000, and that *with* mitigation the ICE and X2000 vibration levels may be about the same.

4.3.2 Train Noise Measurements

4.3.2(a) Measurement Procedures and Equipment

Train noise measurements were carried out between the hours of 1:00 PM and 6:00 PM on both November 10 and 11, 1993. During these periods, four passages of the ICE trainset and 35 passages of Amtrak trains with AEM7 locomotives were measured. The measurements were performed using 0.5 inch electret microphones, and the noise signals were recorded on a DAT recorder for subsequent analysis in the HMMH laboratory. Observed train consist information was noted on field data sheets and voice annotated on the data tapes. Train speeds were clocked using a stopwatch in the field and/or in the laboratory based on video tapes recorded during the train passages.

During all of the tests, noise measurements were made simultaneously at two positions. The first position was at 50 feet from the near track (Track 4) centerline, identical to the measurement position used during the tests on 5 March 1993. The second position was at 100 feet from the centerline of Track 2 during about half of the tests, and at 100 feet from the centerline of Track 3 during the remainder of the tests. The purpose of the second position was to obtain data for the ICE trainset, and for other trains on the high-speed tracks, at the standard measurement distance for evaluating compliance with the Federal Railroad Noise Emission Standards. As shown in the photograph in Figure 4.3-2, the microphones were supported on tripods at a height of 4.5 feet at both positions, and were protected by windscreens.



NORTHEAST CORRIDOR MEASUREMENT SITE IN PLAINSBORO, NJ

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure
4.3-1

The field instrumentation included two microphones, two preamplifiers and one two-channel DAT recorder. Calibrations, traceable to the U.S. National Institute of Standards and Technology, were carried out before and after each set of measurements using an acoustical calibrator. A summary of the field instrumentation used for the noise measurements is provided in Table 4.3-1.

TABLE 4.3-1 Field Instrumentation for Noise Measurements

EQUIPMENT	MODEL AND SERIAL NUMBER	
	Position 1	Position 2
Microphone	GR 1962-9610 S/N 15735	GR 1962-9610 S/N 11646
Preamplifier	GR 1560-P42 S/N 3841	GR 1560-P42 S/N 4349
Tape recorder	SONY TCD-D10 PRO S/N 15207	
Calibrator	GR 1987 S/N 0894	

Source: HMMH, Inc., 1994

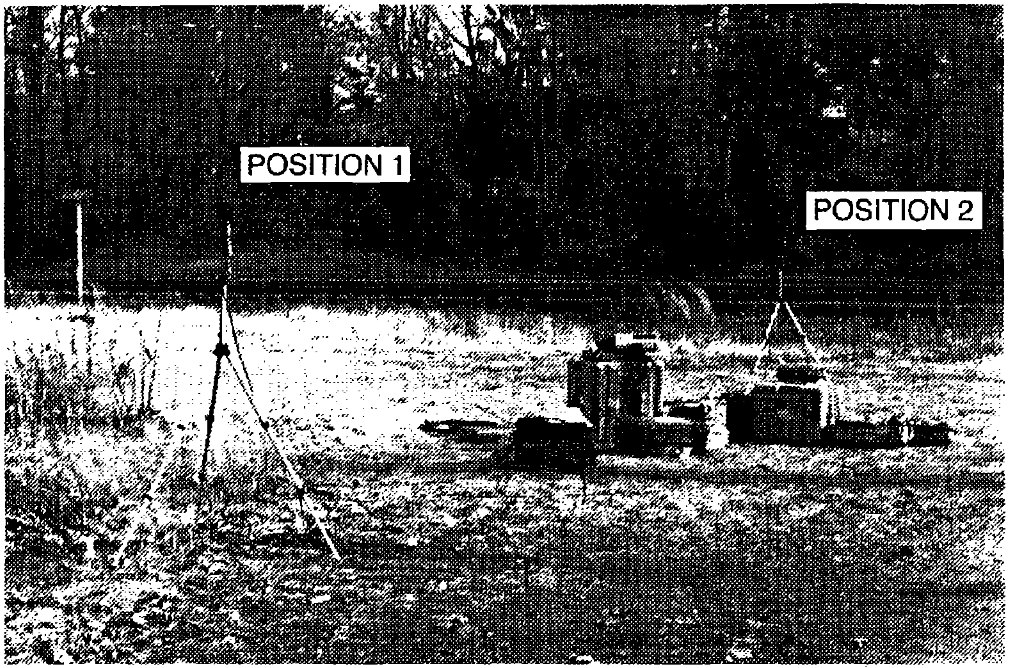
Analysis of the field data was carried out in the HMMH laboratory. Initially, the A-weighted maximum noise level (L_{max}) and SEL for each train event were obtained directly from the tape-recorded data using a Bruel & Kjaer (B&K) Type 2230 sound level meter. During this analysis, the "fast" setting on the sound level meter was used as required to evaluate compliance with the Federal Railroad Noise Emission Standards.

Frequency analysis was carried out for selected events, using a Tektronix Model 2630 dual-channel FFT spectrum analyzer to obtain one-third octave band spectra averaged over intervals of maximum event noise levels. The noise signals were fed into the narrowband analyzer, and post-processing software was used to combine the narrowband results into one-third octave noise spectra.

4.3.2(b) Measurement Results and Evaluation

The results of the wayside noise measurements are listed in Appendix 4D, and are shown graphically in Figure 4.3-3. This figure shows L_{max} versus train speed, normalized to a 100-foot receiver position. Figure 4.3-3 also includes data from the March 1993 measurements, previously reported in the DEIS/R for the NECIP electrification.[9] The November data were normalized to 100 feet based on a specific attenuation rate with distance for each event, obtained from the measured sound attenuation between the two microphone positions. For the March data, the normalization was based on an average attenuation rate of 7 dB per doubling of distance from the November data. Figure 4.3-3 also shows the L_{max} versus speed relationship obtained empirically in 1976 from noise measurements of a test train with the Swedish-built ASEA RC4 locomotive, precursor to the U.S.-built AEM7 locomotive.[10] It can be seen that this line bisects the 1993 AEM7 data and can be viewed as an "average" best-fit representation of the noise levels. The wide scatter exhibited in these data can be attributed to the many different train consists and equipment conditions encountered during the testing period.

Figures 4.3-4 and 4.3-5 show the results of the frequency analyses of the wayside noise recordings, in the form of one-third octave band spectra of the sound pressure level, in decibels relative to 20 μPascals. Figure 4.3-4 presents the 100-foot position noise spectra of the four individual ICE passbys measured on November



VIEW OF TRAIN NOISE MEASUREMENT POSITIONS

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure
4.3-2

10 and 11, 1993, normalized to a train speed of 125 mph. The speed normalization relation was taken from the 1976 study, which reported an empirical relationship of sound level and speed as:

$$\Delta L = 34.5 \times \log \left[\frac{V}{125} \right]$$

where V = train speed in miles per hour.

It can be seen from Figure 4.3-4 that there is an apparent difference in the sound spectra between the two high-speed tracks, Tracks 2 and 3. Since the operating equipment was identical for each of the four runs (i.e., a single ICE train consist was used), the higher levels of sound energy below 2 kHz shown in the Track 3 spectra would seem to indicate a difference between the running surface of the rails of the two tracks. Rail roughness and corrugations can cause higher dynamic forces at the wheel/rail interface, causing greater vibration of the two components and thus more radiated noise at particular frequencies. In terms of overall A-weighted sound level, this difference translates to about 3 dBA higher noise levels for the ICE train operating on Track 3 (westbound direction) than on Track 2 (eastbound direction), at a given train speed and receiver distance.

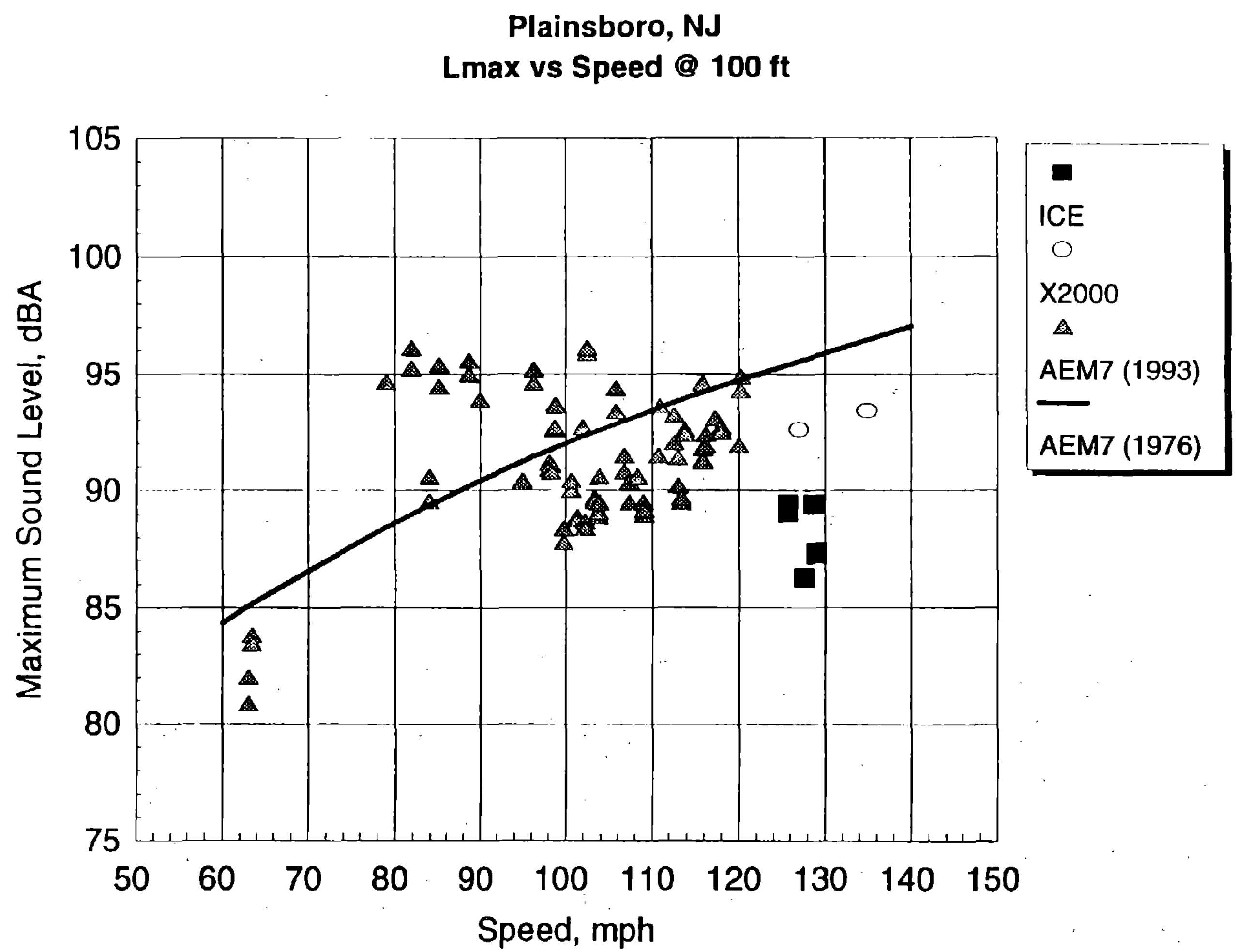
The individual spectra for all train events were averaged at each separate measurement position and track location for the purpose of comparing the frequency characteristics of wayside noise generated by the three Amtrak train types measured at this location: AEM7, ICE, and X2000. The data were also normalized to a single train speed. The results for a representative measurement distance, 76 feet, are shown in Figure 4.3-5. All of the samples at this distance were obtained from trains operating on Track 2.

One can see from Figure 4.3-5 that the sound spectra for the three train types have very similar shapes, with the only significant differences between them being the respective magnitudes of emitted sound energy. A slight distinction can be made between the AEM7 and X2000 spectra, in that there seems to be some higher-frequency sound energy in the 2.5 to 3 kHz range of the X2000 spectrum that does not appear in the AEM7. The ICE appears to generate lower noise levels across the entire frequency range of interest, but with in a sharper peak in the 2 kHz band.

4.3.2(c) Compliance with Federal Railroad Noise Emission Standards

Pursuant to the Noise Control Act, EPA has issued noise emission standards for specific types of railroad equipment (40 CFR Part 201). FRA has adopted these regulations for the purpose of enforcement in the FRA Railroad Noise Emission Compliance Regulations (49 CFR Part 210). The standards provide specific noise limits for stationary and moving locomotives, moving railroad cards, active retarders, car coupling and locomotive load cell test stands in terms of the A-weighted sound level at a specified measurement location. Table 4.3-2 summarizes the standards for locomotives and rail cars that are relevant to the measurements of train passby noise summarized in this report. The results obtained from these measurements were compared with the standards and allowable tolerances to determine compliance with the Federal regulations.

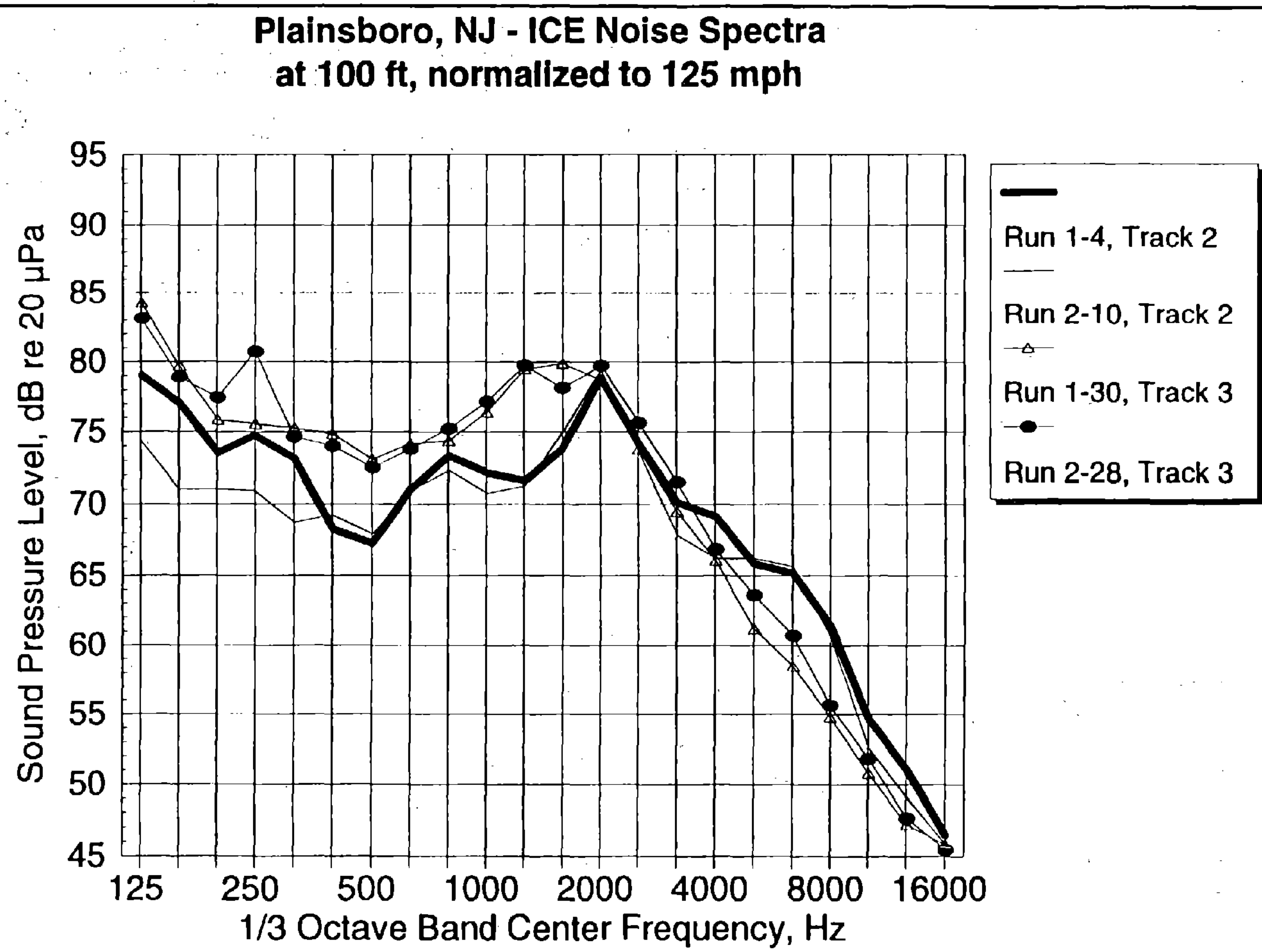
The EPA standards specify different limits for moving locomotives and railroad cars, presumably aimed at evaluating noise from diesel-hauled freight trains, which can be several hundred cars long. The Amtrak passenger trains operating on the NEC usually consist of 10 cars or less, and as a result the maximum noise levels generated by the locomotive and rail cars are generally indistinguishable from each other. This distinction is even smaller in the case of electric locomotive-hauled passenger trains. For this reason, only the EPA standard for railroad cars is applied to this measurement program. Since all trains sampled were traveling faster than 45 mph, the applicable standard is an L_{max} of 93 dBA, plus the allowable measurement tolerance. This tolerance is defined in 49 CFR §210.25 as 2 dBA, and is intended to account for rounding errors, instrument tolerances, topographical variations, atmospheric conditions, and reflected sound effects.



MEASURED L_{MAX} AT 100 FT AS A FUNCTION OF SPEED

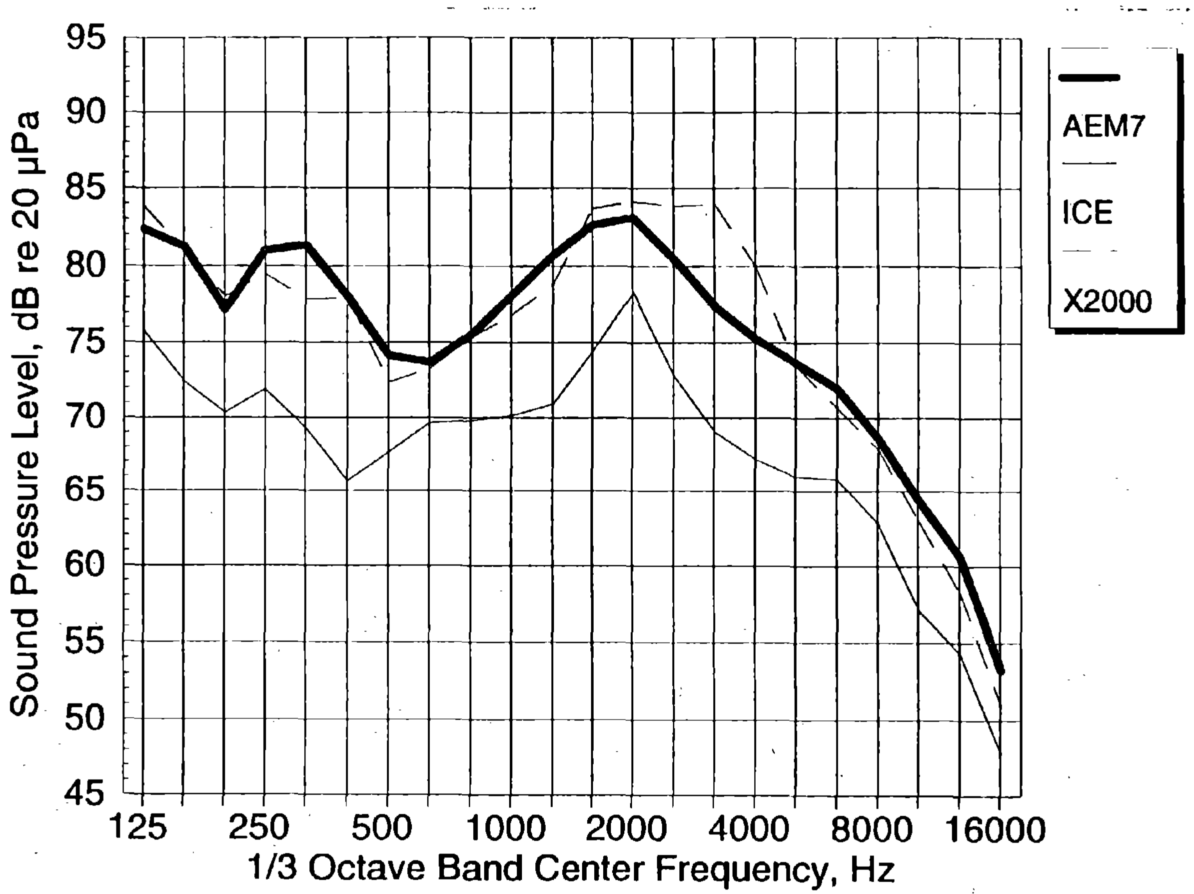
Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure
4.3-3



1/3 OCTAVE BAND NOISE SPECTRA FOR ICE TRAIN PASS-BYS	Figure 4.3-4
Northeast Corridor Improvement Project Electrification - New Haven CT to Boston MA	

Plainsboro, NJ - Train Noise Spectra
at 76 ft, normalized to 125 mph



1/3 OCTAVE BAND NOISE SPECTRA FOR AEM7, ICE AND X2000

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.3-5

TABLE 4.3-2 Summary of Applicable EPA Railroad Noise Standards

NOISE SOURCE	OPERATING CONDITION	NOISE METRIC	MEASUREMENT DISTANCE	STANDARD
Non-switcher locomotives built after 12/31/79	Moving	L_{max} (Fast)	100 ft.	90 dBA
Railroad cars	Speed ≤ 45 mph	L_{max} (Fast)	100 ft	88 dBA
	Speed > 45 mph	L_{max} (Fast)	100 ft.	93 dBA

Source: U.S. EPA

In other words, moving Amtrak trains on the Northeast Corridor would be considered not in compliance with the Federal noise regulation whenever the measured L_{max} at a perpendicular distance of 100 feet from the track centerline exceeds 95 dBA.

The November 1993 noise measurements at this location in Plainsboro, NJ, were conducted using a 100-foot microphone position in compliance with the measurement procedure described in 40 CFR Part 201. Of 21 Amtrak train passbys recorded at this distance in the field, all but two resulted in maximum noise levels below 95 dBA at 100 feet. These two trains were of the AEM7 locomotive-hauled type, with train speeds of 89 mph and 98 mph, respectively. These trains are just marginally in compliance with the Federal Railroad Noise Emission Standard. The measured L_{max} at 100 feet for the four ICE passbys recorded at speeds of 126 to 129 mph ranged from 86 to 90 dBA, well below the Federal standard.

4.3.3 Ground-Borne Vibration Measurements

4.3.3(a) Measurement Procedures and Equipment

Ground-borne vibration measurements were carried out between the hours of 1:00 PM and 6:00 PM on both November 10 and 11, 1993. During these periods, four passages of the ICE trainset and 35 passages of Amtrak trains with AEM7 locomotives were measured. The measurements were performed using accelerometers as the vibration transducers, and the acceleration signals were recorded on a DAT recorder for subsequent analysis in the HMMH laboratory. Observed train consist information was noted on field data sheets and voice annotated on the data tapes. Train speeds were clocked using a stopwatch in the field and/or in the laboratory based on video tapes recorded during the train passages.

During all of the tests, vibration measurements were made simultaneously at five positions along the ground at distances of 25, 50, 75, 100, and 150 feet from the near track (Track 4) centerline. These positions were identical to those used for the tests on March 5, 1993. All measurements were performed using high-sensitivity accelerometers as the vibration transducers. All accelerometers were oriented to measure vibration in the vertical direction, and were mounted on top of ground-driven steel stakes using putty to secure them to the top plates of the stakes. The photograph in Figure 4.3-6 shows the accelerometer mounted at the 50-foot position, adjacent to the microphone tripod used for the noise measurements at Position 1.

The signals from the accelerometers were amplified using low-noise amplifiers, and recorded on an eight-channel instrumentation tape recorder for subsequent laboratory analysis. The amplifiers were set for optimum signal-to-noise ratio, and the amplifier and tape recorder gains were recorded on field data sheets and voice annotated on the data tapes. A 1-volt peak test signal of the tape recorder was recorded on each tape for calibration of the system, based on the individual sensitivities of the accelerometers. A summary of the field instrumentation used for the vibration measurements is provided in Table 4.3-3.

TABLE 4.3-3 Field Instrumentation for Vibration Measurements

EQUIPMENT	EQUIPMENT MODEL, SERIAL NUMBER AND SENSITIVITY (Volts/g)				
	25-ft Position	50-ft Position	75-ft Position	100-ft Position	150-ft Position
Accelerometer	PCB 393B S/N 162 (1.09 V/g)	PCB 393C S/N 2480 (1.10 V/g)	PCB 393C S/N 2481 (1.11 V/g)	PCB 393C S/N 2482 (1.10 V/g)	Wilcoxon 731 S/N 143 (10 V/g)
Power unit	PCB 480C06	PCB 480C02 S/N 2366	PCB 480C02 S/N 2367	PCB 480C02 S/N 2368	Wilcoxon P31
Amplifier	S/N 1550	EPAC 60/10 LN S/N 68	EPAC 60/10 LN S/N 69	EPAC 60/10 LN S/N 0A	S/N 180
Tape recorder	TEAC RD-130TE (8-Ch. DAT Recorder) S/N 512546				

Source: HMMH, Inc., 1993

Analysis of the field data was carried out in the HMMH laboratory. For all analysis, the recorded acceleration signals were integrated to obtain vibration velocity, using a B&K Model 2635 amplifier and signal conditioner. The resulting signals were fed into a Rion Model LR-04 graphic level recorder to obtain strip charts of rms vibration velocity as a function of time. The rms time constant on the level recorder was set for 1 second, which is equivalent to the "slow" setting on a standard sound level meter, and the maximum vibration level for each train event was obtained from the strip charts.

Frequency analysis was carried out for selected events, using a Tektronix Model 2630 dual-channel FFT spectrum analyzer to obtain one-third octave band spectra averaged over intervals of maximum event vibration levels. The acceleration signals were fed into the narrowband analyzer, and post-processing software was used to integrate the narrowband data and combine the narrowband results into one-third octave vibration velocity spectra.

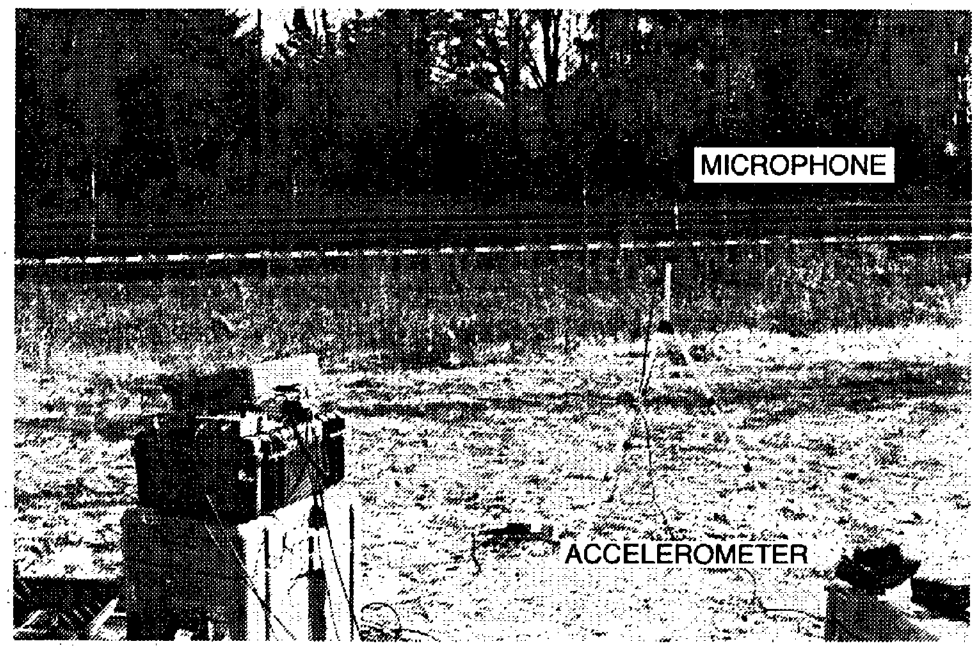
4.3.3(b) Measurement Results and Evaluation

The results of the ground-borne train vibration measurements are included in Appendix 4E, and are shown graphically in Figure 4.3-7. This figure presents the results of the vibration measurements in the form of maximum rms vibration velocity level (re: 1 μin./sec) for each train event as a function of distance from the track centerline, normalized to a train speed of 125 mph. The following adjustment was made in normalizing the data to account for speed variations:

$$\Delta L = 20 \times \log \left[\frac{V}{125} \right]$$

where V = train speed in miles per hour.

The data are sorted by the three Amtrak train types measured at this location, including data from the March 1993 measurements that were previously reported in the DEIS for the Northeast Corridor Improvement Project Electrification.[11] While the number of data points for the AEM7-type train is significantly greater than for the ICE or X2000, Figure 4.3-7 suggests that both the ICE and X2000 trains generate lower overall



VIEW OF 50 FT VIBRATION AND NOISE MEASUREMENT POSITION

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.3-6

vibration levels than the AEM7. A least-mean squares curve fit was performed on the data to obtain the regression curves shown in Figure 4.3-8 to provide a clear representation of the "average" levels generated by each train type and the rate at which these levels attenuate with distance.

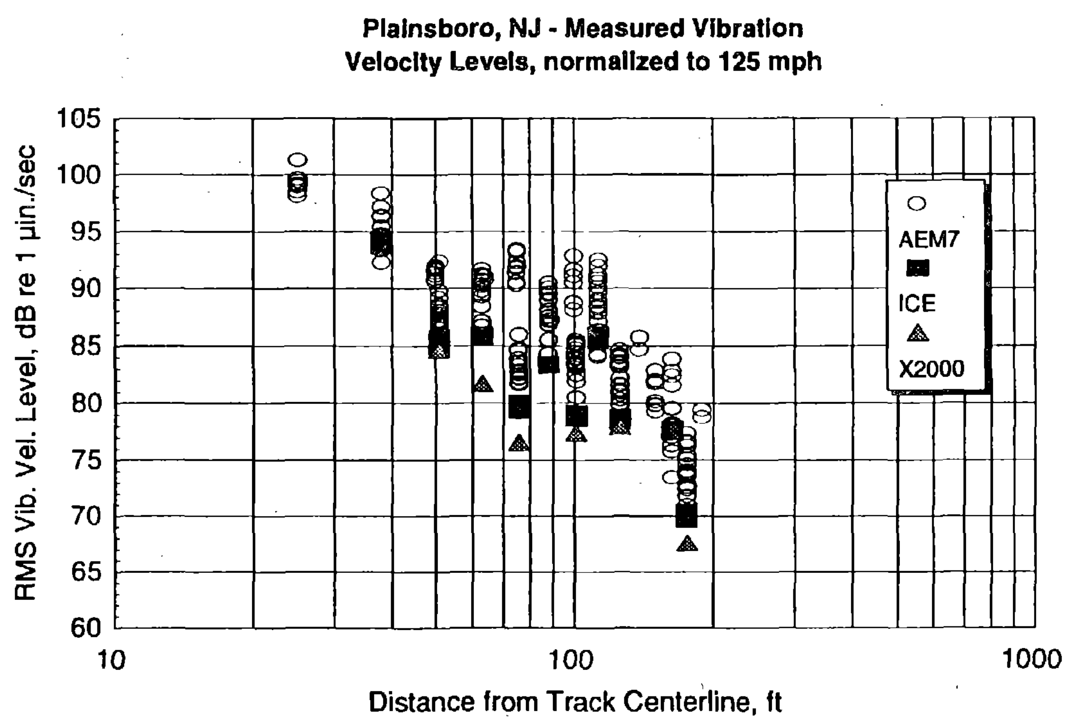
The curves show that the ICE vibration levels are about 3 dB lower than the AEM7, and that the X2000 vibration levels are about 8 dB lower than the AEM7 and 5 dB lower than the ICE. The fact that the AEM7 levels are higher is not surprising, given that both the ICE and X2000 rolling stock were relatively new, compared to the fleet of standard revenue service Amtrak trains. This factor may account for the small difference found between the AEM7 and the ICE curves in Figure 4.3-8 (3 to 4 dB). However, specific differences in equipment design between the three train types may account for larger variations in vibration levels. For example, the X2000 is known to have as a truck feature a low unsprung weight per axle, which can result in lower dynamic loads and thus generate lower vibration.

To provide a better understanding of the nature of ground-borne vibration, the one-third octave band vibration velocity spectra of two ICE train passbys are shown in Figures 4.3-9 and 4.3-10. For each passby, the spectra obtained simultaneously at three accelerometer positions along the ground at increasing distances from the track are given to illustrate the frequency-dependent attenuation of vibration energy as it travels away from the track. As with the frequency analysis for noise, the vibration spectra in Figures 4.3-9 and 4.3-10 were compared to determine differences between the vibration generated by the same train on the two high-speed tracks (Tracks 2 and 3). Because all data were not available at the same measurement distance, comparison is more difficult. The results suggest similar vibration spectra, with generally higher vibration levels for operations on Track 3.

Finally, Figure 4.3-11 provides a comparison of the vibration spectra of the three Amtrak train types recorded at this measurement site. The spectra shown are for a single accelerometer position, located 101 feet from the centerline of Track 2. AEM7 vibration data from several train passbys were energy-averaged and normalized to a train speed of 125 mph to obtain the spectrum shown. The ICE spectrum consists of an energy-average of two speed-normalized passbys, while the X2000 spectrum represents only a single data sample normalized to 125 mph.

It can be seen from Figure 4.3-11 that the ICE vibration spectrum shows a slight shift upward in its dominant frequency bands, while maintaining a more or less similar shape as the AEM7 spectrum. The X2000 spectrum shows most of the energy concentrated in the one-third octave bands below 31.5 Hz, with consistently lower levels than the AEM7 across the frequency range. The effect of the low unsprung weight appears to be most pronounced in the 30 to 60 Hz range.

Standard track support vibration mitigation treatments, such as ballast mats, are similarly most effective in the 30 to 100 Hz range. The frequency characteristics of the measured ground-borne train vibration indicate that such treatment is not likely to be very effective for the three types of Amtrak trains tested, since most of the energy is concentrated below 30 Hz. However, the results of the ICE trainset data indicate that, while overall levels may be higher than those measured for the X2000, a ballast mat would be more effective in reducing the vibration. In other words, environmental impacts from ICE train vibration may be easier to mitigate using standard vibration control treatments.

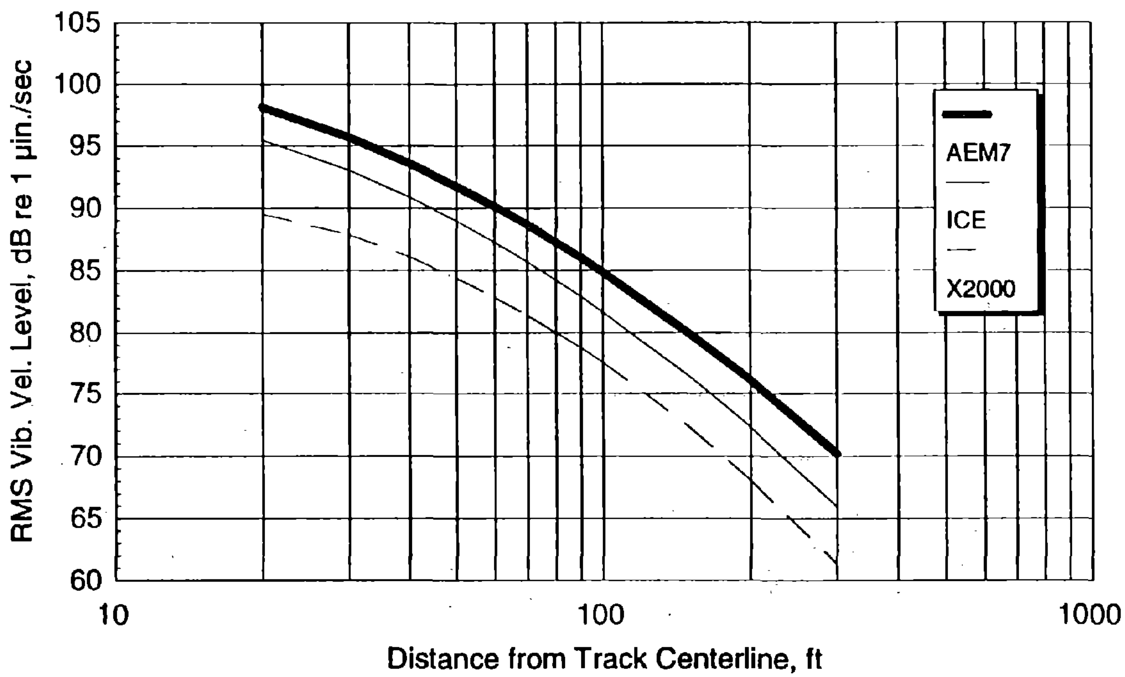


MEASURED MAXIMUM RMS TRAIN VIBRATION AT 125 MPH

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.3-7

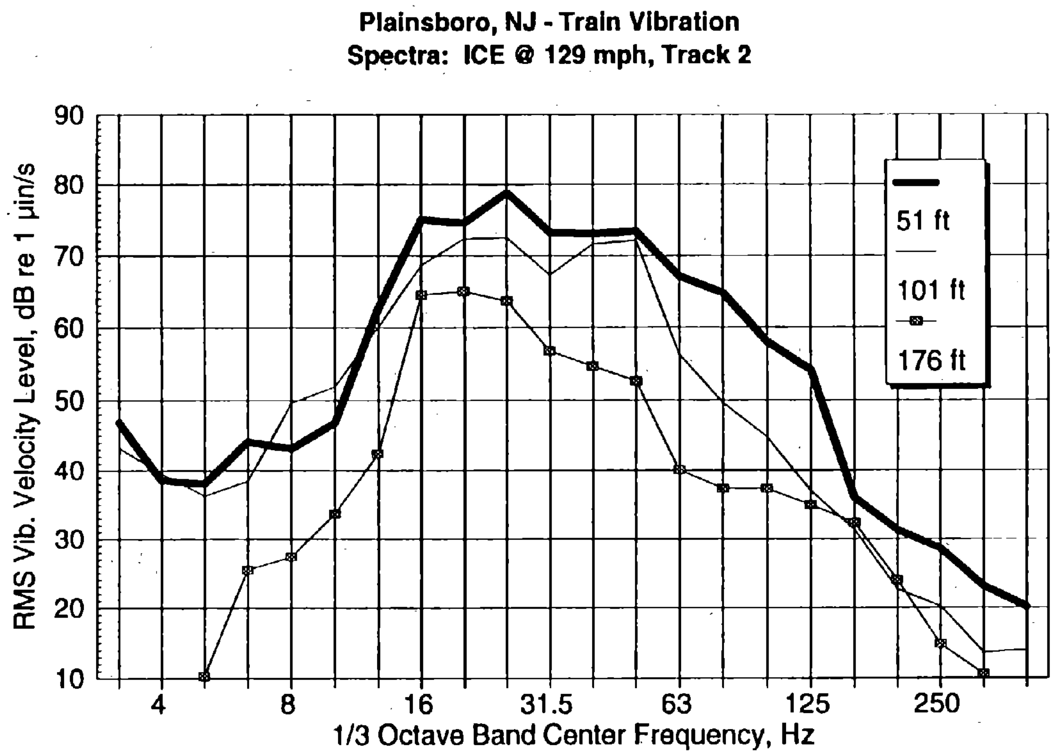
Plainsboro, NJ - Train Vibration
Velocity Levels, normalized to 125 mph



REGRESSION CURVES OF TRAIN VIBRATION AT 125 MPH

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

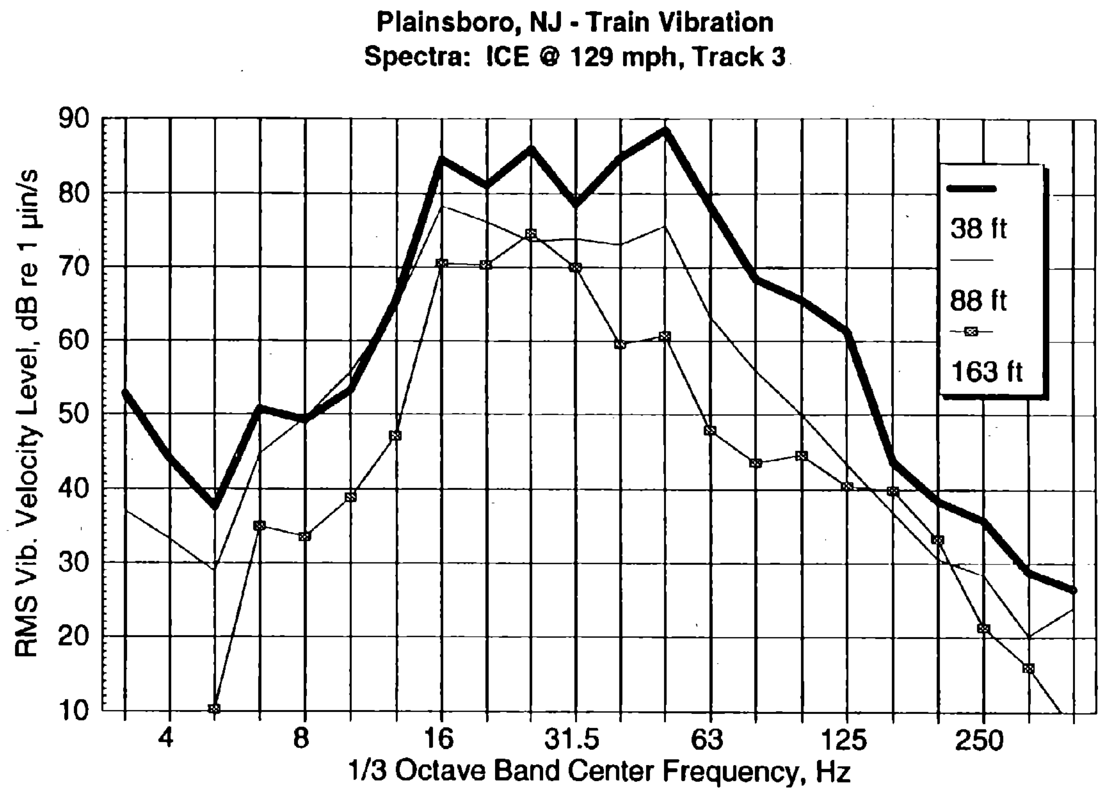
Figure 4.3-8



1/3 OCTAVE BAND VIBRATION SPECTRA OF ICE PASS-BY ON TRACK 2

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

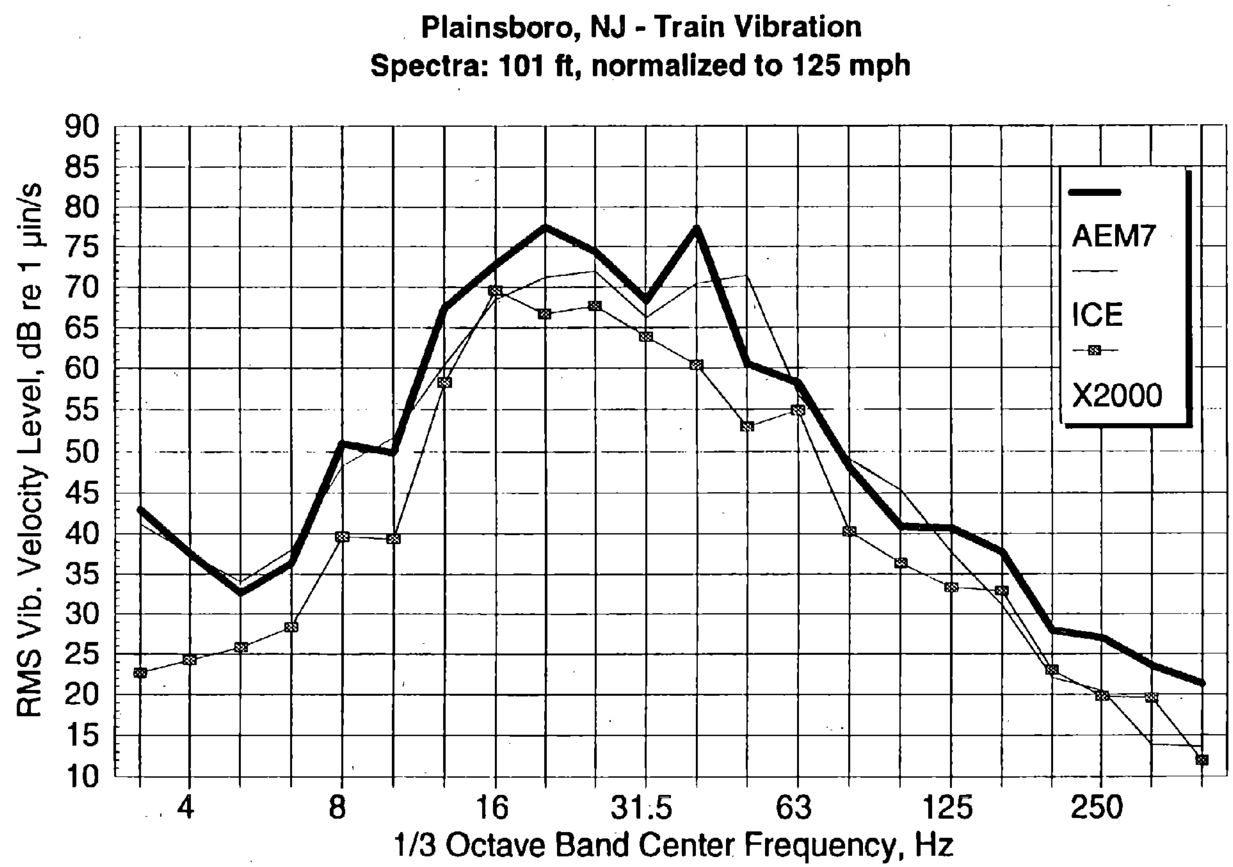
Figure 4.3-9



1/3 OCTAVE BAND VIBRATION SPECTRA OF ICE PASS-BY ON TRACK 3

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.3-10



1/3 OCTAVE BAND VIBRATION SPECTRA OF AEM7, ICE AND X2000

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.3-11

4.4 TRAIN NOISE AND VIBRATION IMPACTS

4.4.1 Introduction

This section presents an assessment of the potential long-term train noise and vibration impacts from a range of alternatives for the NECIP electrification, based on methods developed for the DEIS/R. The approximate extent and locations of noise and vibration impact are evaluated for three project "Build" cases and the No-Build Alternatives - AMD-103 and FF-125 scenarios. These cases are as follows:

- ***#1-Maximum impact for NECIP.*** This case assumes electrification with increased train speeds and maximum projected train lengths and frequencies, along with maximum train noise and vibration emission levels based on data for existing Amtrak electric equipment. This case is referred to throughout this chapter as the Worst-Case Build scenario.

- ***#2-Minimum impact for NECIP.*** This case assumes electrification with increased train speeds and maximum projected train lengths and frequencies, but with minimum train noise and vibration emission levels based on data for the Swedish X2000 and Germany's ICE trainsets tested in revenue service on the NEC. This is referred to as the Best-Case Build scenario.

- ***#3-Minimum impact for initial electrification.*** This case assumes electrification with increased train speeds, but with no increase in train service and with the minimum train noise and vibration emission levels based on X2000 and ICE trainset data. This is referred to as the Initial Build scenario.

- ***#4-No-Build base case.*** This alternative assumes no electrification and the continued use of the present AMD-103 diesel-electric locomotives. This alternative is referred to as the No-Build Alternative - AMD-103 Scenario.

- ***#5-No electrification, Gas Turbine Alternative.*** This No-Build Alternative assumes no electrification but maximum projected train frequencies and a gas turbine (or other fossil fuel) locomotive capable of increased train speeds up to 125 mph. The noise and vibration emission levels are based on data for the existing RTL gas turbine locomotive in service on Amtrak's Empire Corridor. This case is referred to as the No-Build Alternative - FF-125 Scenario.

The results of Build cases 1 and 2 are intended to provide the projected range of impact for the project, while those of Build case 3 are intended to represent the minimum initial impact of the project, on "Day One" of electrification. The No-Build Alternative - FF-125 Scenario is intended to address the potential impact of fossil fuel technologies as a feasible high-speed alternative to electrification.

Noise and vibration impacts for each of the above cases are described in detail in Sections 4.4.2 and 4.4.3, respectively. The evaluation criteria, projection methods, and impact assessment for each type of impact are also contained in these sections. A summary of the potential noise and vibration impacts is provided in Section 4.4.4.

4.4.2 Noise Impact from Train Operations

Although the NEC has been actively carrying intercity rail traffic for many years, the proposed changes in train operations may affect the noise environment along the corridor. These changes relate primarily to increased train schedules, consists, and speeds. Noise impact criteria, projections, and assessment for the proposed changes in train operations are consistent with those used in the DEIS/R and are described below.

4.4.2(a) Train Noise Impact Criteria

The significance of noise impacts from train operations on the NEC for the Build and No-Build alternatives is assessed based on the projected noise increase relative to existing conditions at noise-sensitive locations. Depending on land use, this increase is measured in terms of either the 24-hour equivalent sound level, $L_{eq}(24)$, or the day-night sound level, L_{dn}. These descriptors correlate well with the effects of noise on people and are the environmental noise measures recommended by the U.S. Environmental Protection Agency.[12] Both of these measures represent the total dose of noise energy at a given outdoor location over a 24-hour period in terms of the A-weighted sound level (dBA). Definitions and applications of these measures are as follows:

- $L_{eq}(24)$ is a single value of sound level which includes all of the time-varying sound energy received over a 24-hour period. This descriptor is applied for institutional land use, or noise-sensitive land use where the sensitivity does not depend on the time of occurrence (e.g., at schools, places of worship, recreational areas).

- L_{dn} is the A-weighted equivalent sound level for a 24-hour period, with an added 10-decibel weighting imposed on the equivalent sound levels occurring during the nighttime hours (10 PM to 7 AM). This descriptor is applied for residences and other buildings where people normally sleep.

Significance criteria for train noise impact are based on those currently being proposed for adoption by the U.S. Federal Transit Administration.[13] These criteria, presented in Table 4.4-1, are based on the increase in cumulative noise due to a project. They have been developed based on Federal noise standards, and on well-documented criteria and research into human response to community noise.

As indicated in Table 4.4-1, the proposed criteria allow less of a noise increase in already noisy areas than in areas where the existing noise levels are lower. For example, at residential locations where the existing L_{dn} is 50 dBA, the proposed criteria would allow a noise increase of up to 10 dBA before significant noise impact would occur. However, the allowable increase would be reduced to 5 dBA at residences where the existing L_{dn} is 60 dBA, and to 3 dBA where the existing L_{dn} is 70 dBA. At extremely noisy residential locations where the existing L_{dn} is 80 dBA, the noise increase would be limited to 1 dBA to avoid significant impact.

As is also indicated in Table 4.4-1, the allowable increases in $L_{eq}(24)$ are greater than the allowable increases in L_{dn}. This is to account for the lower noise sensitivity at sites with daytime use only, where $L_{eq}(24)$ would be applied as a measure of noise impact.

The justification for the proposed criteria is that people already exposed to high levels of noise will notice and be annoyed by even a small increase in the cumulative noise in their community. In contrast, if the existing noise levels are quite low, a greater change in the community noise will be required for the equivalent degree of annoyance. Finally, because the project involves potential changes in train noise rather than the introduction of a new noise source in the communities along the corridor, it is appropriate to base the significance criteria for train noise impact on the noise increase relative to existing conditions.

4.4.2(b) Train Noise Projection Model

This section summarizes the theoretical model used to develop a general model of wayside train noise that is based on available measurement data. The same basic model can be used for all types of trains including the diesel-hauled Amtrak, commuter, and freight trains, as well as the electric- and gas-turbine powered

Amtrak trains. Given the maximum noise level (L_{max}) of a train passby under a specific set of reference conditions, the model allows one to estimate L_{max}, SEL,[14] and other noise metrics for varying distances from the track, train speeds, train consists, and schedules. The standard approach is to model rail cars as moving incoherent dipole line sources,[15] while locomotives are modeled as moving monopole line sources.[16] The corresponding equations which describe the noise metrics as functions of various physical parameters are given in Appendix 4B.

TABLE 4.4-1 Noise Impact Criteria for Fixed Facility Operations

EXISTING NOISE LEVEL, L_{dn} or $L_{eq}(24)$ (dBA)	LIMIT FOR NOISE LEVEL INCREASE (dBA)	
	L_{dn}	$L_{eq}(24)$
<45	15	20
45	14	19
46	13	18
47-48	12	17
49	11	16
50	10	15
51	10	14
52	9	14
53-54	8	13
55	7	12
56	7	11
57-58	6	11
59	6	10
60-61	5	10
62	5	9
63	4	9
64-66	4	8
67-69	3	7
70-73	3	6
74-77	2	5
78-79	2	4
>79	1	3

Source: FTA, 1990

Standard reference noise source emission levels for existing diesel equipment on the NEC between New Haven and Boston (Amtrak, commuter, and freight) and electric AEM-7 locomotive Amtrak trains on the southern end of the NEC were developed for locomotives and rail cars based on the source noise measurements documented in the DEIS/R. Reference source levels for the RTL and ICE trainsets are based on subsequent measurements performed for the project which are summarized in Sections 4.1 and 4.3, respectively. The theoretical model is first used to predict the L_{max} and SEL for the observed trains, using available reference level data from the literature.[17] These reference levels are then adjusted to minimize the discrepancies between energy-average predicted and measured noise levels. The results of this procedure yield the source reference levels given in Appendix 4F.

To provide an understanding of the train noise model, Figures 4.4-1 and 4.4-2 indicate projected train noise levels at a distance of 100 feet for representative train consists operating within their appropriate speed limits. At this distance, excess sound attenuation from ground effects, atmospheric absorption and shielding can be ignored.

Figure 4.4-1 shows a graph of L_{max} versus train speed for typical express-service Amtrak passenger train consists. A typical passenger train is defined as consisting of one locomotive and eight cars, except for the RTL consist which is defined as two locomotive and seven cars. The reason for this difference is that the RTL trainsets observed on the Empire Corridor operate with exclusively two-locomotive consists, both of which have some passenger capacity.

The curves in Figure 4.4-1 show that at lower speeds, diesel locomotive noise is dominant and electric- and gas turbine-powered trains are significantly quieter than diesel trains. The RTL locomotive, however, is louder in this speed range than the electric, due primarily to the fact that gas turbine engines operate at a high rotational rate irrespective of speed. At high speeds, where wheel/rail noise becomes dominant, the AEM7 electric train is projected to be as noisy as the diesel and gas turbine trains. The ICE electric train, however, is projected to be approximately 5 to 7 dB quieter even in this higher speed regime, attributable to such factors as differences in wheel conditions and aerodynamic design.

Although L_{max} is useful for comparing the overall noise of train equipment and is easy to understand, the SEL is more relevant to the assessment of noise impact since the impact criteria are based on total sound energy exposure. Thus it is instructive to examine Figure 4.4-2, which displays a graph of projected SEL as a function of speed.

The curves projected in Figure 4.4-2 show that the ICE electric trains are expected to generate less sound energy over the anticipated speed range than any of the other diesel, gas turbine or electric trains. The RTL gas turbine-powered locomotive is projected to generate more sound energy than either the AEM7 or ICE electric trains, but only up to speeds of about 60 mph. The diesel locomotive produces the highest level of sound exposure of all train types. At speeds greater than about 80 mph, however, all of the train SELs excluding that of the ICE locomotive converge to approximately the same level.

The above discussion has concentrated on wayside noise levels for single train passages. However, to project the overall daily noise exposure upon which the impact criteria are based, the noise from all train operations that occur over a 24-hour period must be combined. The SEL, which is a measure of the total sound energy received from a single event such as a train passage, is used as the basis for computing the L_{dn} and $L_{eq}(24)$. The equations for computing these metrics are given in Appendix 4B.

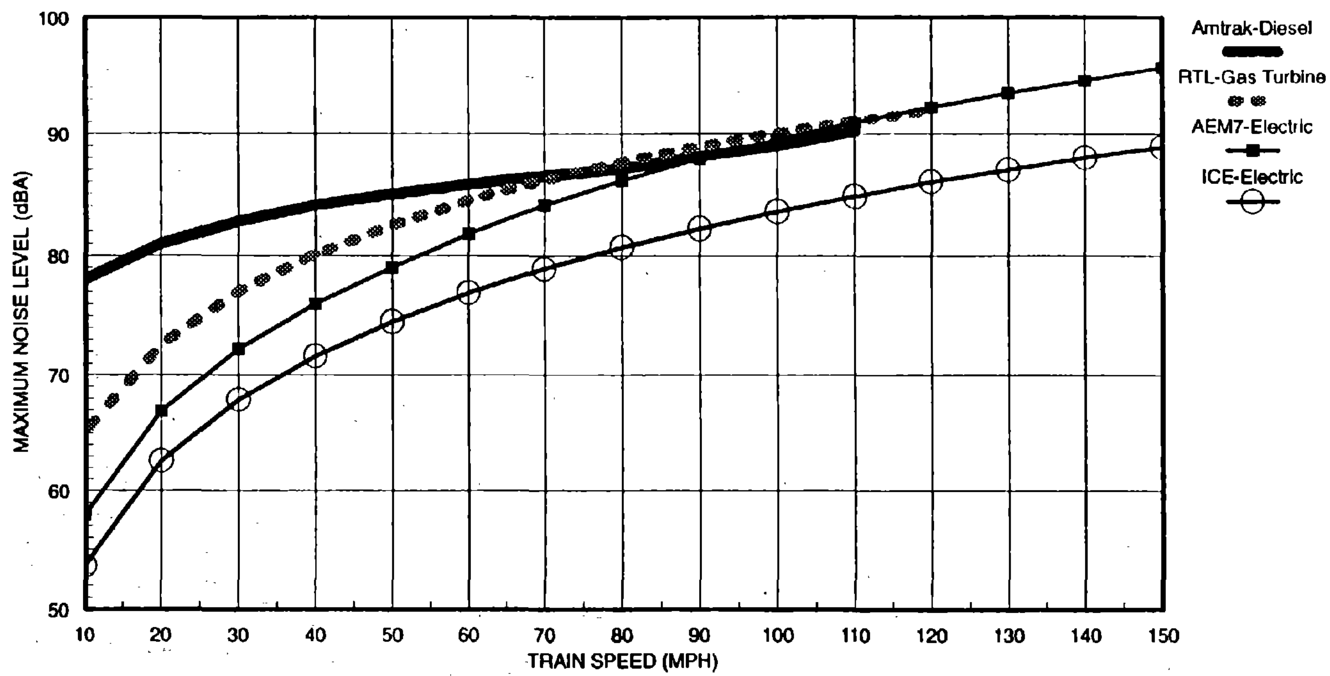
The basic train noise model does not take into account the excess sound attenuation at greater distances due to ground effects, atmospheric absorption, or shielding. Furthermore, it does not account for the additional noise generated by trains in the vicinity of grade crossings or special trackwork (i.e., switches and crossovers). The extent to which these effects have been added to the train noise model in the assessment of impacts is described in Appendix 4G.

4.4.2(c) Train Nose Projections

Projections of train noise, in terms of L_{max}, and $L_{eq}(24)$, were carried out for the three future build and No-Build Alternative - FF-125 Scenario defined in Section 4.4.1. Data for the No-Build Alternative

Projected Train Noise Levels at 100 ft

(1 Loc. + 8 Pass. Cars or 30 Frt. Cars)*



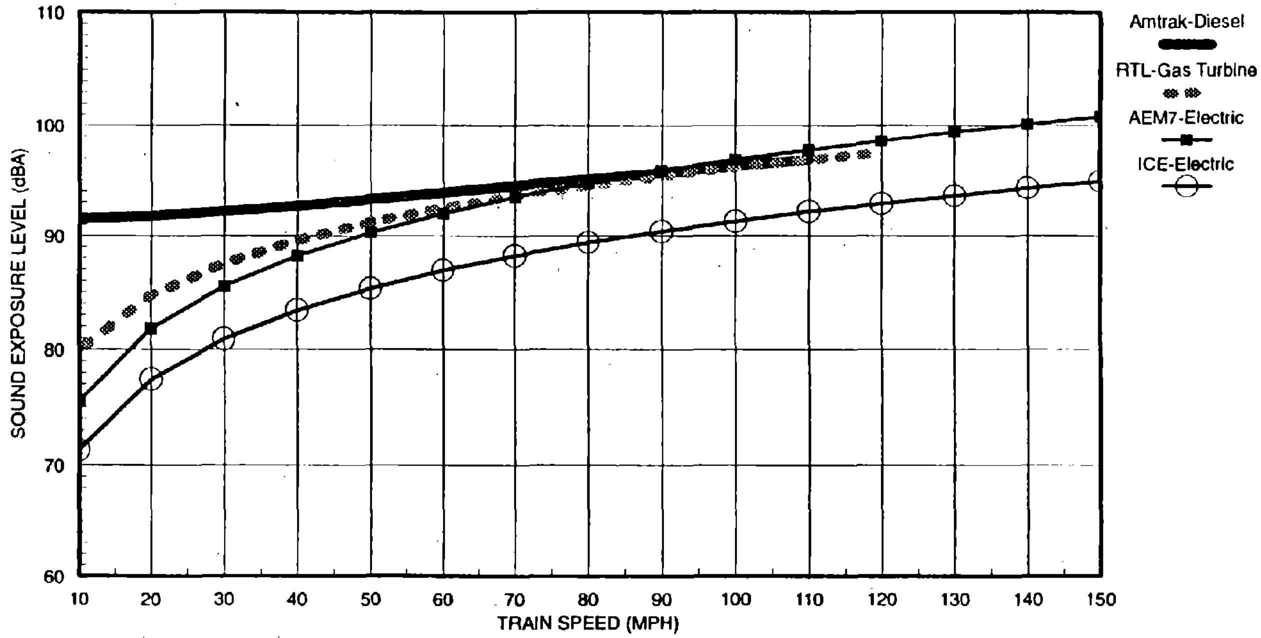
*Except for RTL consist = 2 Loc. + 7 Pass. Cars

Source: HMMH

	PROJECTED L_{max} FOR TRAINS AT 100 FT	Figure 4.4-1
	Northeast Corridor Improvement Project Electrification - New Haven CT to Boston MA	

Projected Train Noise Levels at 100 ft

(1 Loc. + 8 Pass. Cars or 30 Frt. Cars)*



*Except for RTL consist = 2 Loc. + 7 Pass. Cars

Source: HMMH

PROJECTED SEL FOR TRAINS AT 100 FT

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-2

AMD-103 Scenario were initially developed for the DEIS/R and remain current. The projections were based on projected train schedules, consists, and speeds along the project corridor, using the above prediction model and source reference levels for each equipment type. Existing noise levels are based on projections carried out in the DEIS/R noise study, and are used for implementing the noise impact criteria presented in 4.4.2(a).

A summary of the projected Amtrak schedules and train consists is provided for the five future alternatives in Table 4.4-2. Included are the number of daily train operations during the daytime (7 AM to 10 PM) and nighttime (10 PM to 7 AM), as well as the average number of locomotives and cars assumed in each case. The future No-Build Alternative - FF-125 Scenario, Best-Case Build, and Worst-Case Build schedules are based on the Amtrak Power Systems Specifications and train graph (Amtrak, 1991), consistent with the Future Build schedule used in the DEIS/R. These data indicate an approximate doubling in the number of daily trains and their consists relative to existing conditions. The existing Amtrak schedule used at the time of the DEIS/R study (Winter 1992/93) is used to project operations for the No-Build Alternative - AMD-103 Scenario and Initial Build scenarios. For the AMD-103 alternative four additional express trains are projected for the design year. For the Initial Build case, only train speeds will be increased with no increase in service.

Future build train speeds were taken from Amtrak train performance calculations[18] used in the DEIS/R study. Express train speeds for the three build scenarios were simulated based on a consist of two X2000 power units and five cars with a maximum speed of 150 mph. Express train speeds for the No-Build Alternative - FF-125 Scenario, as well as speeds for conventional trains for all cases, were based on a consist of one AEM7 locomotive and eight cars, with a maximum speed of 120 mph.

Future projected commuter rail service and freight operations were also included in the train noise projections, with the same schedules, equipment, speed profiles, train consists as those used in the DEIS/R (see Section 4.4.1.4, Volume III of the DEIS/R). These future non-Amtrak operations are assumed unchanged between the five future Amtrak alternatives, and hence do not affect the overall differences in total train noise between the alternatives.

Projections of total noise along the project corridor for the future build and no-build alternatives were made by combining the modeled train noise from all future sources, and the "background" noise. As used here, background noise refers to the L_{dn} or $L_{eq}(24)$ that would exist without all trains. The background levels along the corridor were established in the DEIS/R and were estimated by generalizing the results at the existing noise measurement sites (see Section 4.3.2 of the DEIS/R Technical Appendix). Based on the range of levels indicated by the measurements, the background L_{dn} were estimated to be either 55 dBA, 60 dBA, or 65 dBA, depending on location and proximity to other noise sources. As suggested by the measurement data, the background $L_{eq}(24)$ were estimated to be 5 dBA less than the corresponding background L_{dn}.

4.4.2(d) Train Noise Impact Assessment

Tables 4.4-3 through 4.4-5 present an overview of train noise impact along the project corridor, based on the results at the representative measurement sites originally presented in the DEIS/R. Table 4.4-3 compares the maximum train noise levels projected for the following six cases: Existing, No-Build Alternative - AMD-103 Scenario, No-Build Alternative - FF-125 Scenario, Initial Build, Best-Case Build, and Worst-Case Build. These results are useful in indicating the differences in the noisiest trains among the different alternatives, but they do not account for the train schedules, consists, and train frequencies, and thus provide only one component of overall noise impact.

Tables 4.4-4 and 4.4-5 together provide a better overall assessment of noise impact, by indicating the projected L_{dn} at each measurement site and the predicted noise increase compared with existing conditions, respectively. Table 4.4-5 also lists the site-specific impact criteria in terms of the increase in total L_{dn} and

TABLE 4.4-2 Projected Amtrak Train Schedules and Consists

CORRIDOR TRACK SEGMENT	TYPE OF TRAIN SERVICE	NO-BUILD: AMD-103				NO-BUILD: FF-125				BUILD: Initial				BUILD: Best Case / Worst Case			
		# Trains		Consist		# Trains		Consist		# Trains		Consist		# Trains		Consist	
		Day	Night	#loco	#cars	Day	Night	#loco	#cars	Day	Night	#loco	#cars	Day	Night	#loco	#cars
New Haven - New London	Express	6	2	1	6	30	2	2	7	4	0	1	6	30	2	1	8
	Conven.	15	3	1	6	16	4	2	17	15	3	1	6	16	4	2	18
New London - Back Bay	Express	6	2	1	6	29	3	2	7	3	1	1	6	29	3	1	8
	Conven.	14	2	1	6	14	4	2	17	14	2	1	6	14	4	2	18
Back Bay - South Sta.	Express	6	2	1	6	27	5	2	7	3	1	1	6	27	5	1	8
	Conven.	18	5	1	6	17	7	2	17	18	5	1	6	17	7	2	18

Source: Amtrak

TABLE 4.4-3 Maximum Projected Train Noise Levels at Measurement Sites

SITE NO.	SITE LOCATION	DIST. TO CORRIDOR C.L. (ft)	MAXIMUM NOISE LEVEL (dBA)					
			EXISTING and NO-BUILD AMD-103		NO-BUILD FF-125	BUILD Initial	BUILD Best Case	BUILD Worst Case
			Meas.	Proj.				
A-1	New Haven, CT (MP 76.1)	94	79-103	87	88	86 (c)	86 (c)	88
A-2	Westbrook, CT (MP 101.5)	111	75-94	86	89	83	83	90
A-3	Waterford, CT (MP 117.7)	86	79-97	87	90	83	83	90
A-3a	W. Mystic, CT (MP 131.3)	42	90-114	109 (h)	109 (h)	109 (h)	109 (h)	109 (h)
A-4	Stonington, CT (MP 140.5)	79	83-112	103 (h)	103 (h)	103 (h)	103 (h)	103 (h)
A-5	Charlestown, RI (MP 152.2)	59	78-103	91	94	89	89	95
A-6	Warwick, RI (MP 172.6)	69	76-107	91	94	92	92	96
A-7	Central Falls, RI (MP 190.3)	32	81-100	96	94	94 (c)	94 (c)	94 (c)
A-8	W Mansfield, MA (MP 201.4)	50	72-100	94	98	95	95	102
A-9	Canton, MA (MP 213.2)	68	78-99	90	94	90	90	97
A-10	Hyde Park, MA (MP 221.2)	78	74-98	90	94	90	90	96

(c) indicates source of L_{max} is diesel commuter train
(h) indicates source of L_{max} is grade crossing horn

Source: HMMH, Inc., 1994

the corresponding assessment result. The increase for each case is reported in decibels rounded to the nearest whole number, while noise impact itself is assessed according to whether the increase exceeds the criterion by any amount. For example, an increase of 3.2 dB would result in significant impact relative to a criterion of 3 dB while a 2.8 dB increase would not. In both cases the increase would be listed in Table 4.4-5 as 3 dB.

Furthermore, Figures 4.4-3 through 4.4-13 provide graphical representations of the predicted L_{dn} as a function of distance from the mainline for the different alternatives, in the vicinity of each measurement site. It should be noted that these graphs assume no shielding from terrain features or buildings along the corridor, and only account for operational parameters of the different train services.

TABLE 4.4-4 Day-Night Equivalent Sound Level (L_{dn}) at Measurement Sites

SITE NO.	SITE LOCATION	DIST. TO CORRIDOR C.L. (ft)	DAY-NIGHT EQUIVALENT SOUND LEVEL (dBA)						
			EXISTING		NO-BUILD AMD-103	NO-BUILD FF-125	BUILD Initial	BUILD Best Case	BUILD Worst Case
			Meas.	Proj.					
A-1	New Haven, CT (MP 76.1)	94	69	67	69	70	67	68	70
A-2	Westbrook, CT (MP 101.5)	111	68	67	68	70	66	68	71
A-3	Waterford, CT (MP 117.7)	86	68	65	67	69	64	66	70
A-3a	W. Mystic, CT (MP 131.3)	42	--	75	76	80	77	79	79
A-4	Stonington, CT (MP 140.5)	79	77	72	74	77	74	77	77
A-5	Charlestown, RI (MP 152.2)	59	68	64	66	71	62	68	72
A-6	Warwick, RI (MP 172.6)	69	72	65	68	72	67	70	73
A-7	Central Falls, RI (MP 190.3)	32	74	70	72	73	69	71	74
A-8	W Mansfield, MA (MP 201.4)	50	72	72	73	76	73	75	77
A-9	Canton, MA (MP 213.2)	68	73	69	69	73	68	72	74
A-10	Hyde Park, MA (MP 221.2)	78	74	72	72	75	72	73	76

Source: HMMH, Inc., 1994

A corridorwide inventory of train noise impact is provided in Table 4.4-6. This table indicates the estimated number of residences located within the noise impact zone for both the No-Build Alternatives - AMD-103 and FF-125 scenarios, in addition to the range of build alternatives from Initial to Worst-Case. The noise impact zone was determined by comparing the noise projections with the project criteria along individual segments of the corridor, and by estimating the distances within which impact would occur. These train noise impact distances are given by corridor milepost segment in Appendix 4H. The numbers of noise-sensitive sites located within the impact zone were then counted with the aid of land use maps and aerial photographs of the project corridor.

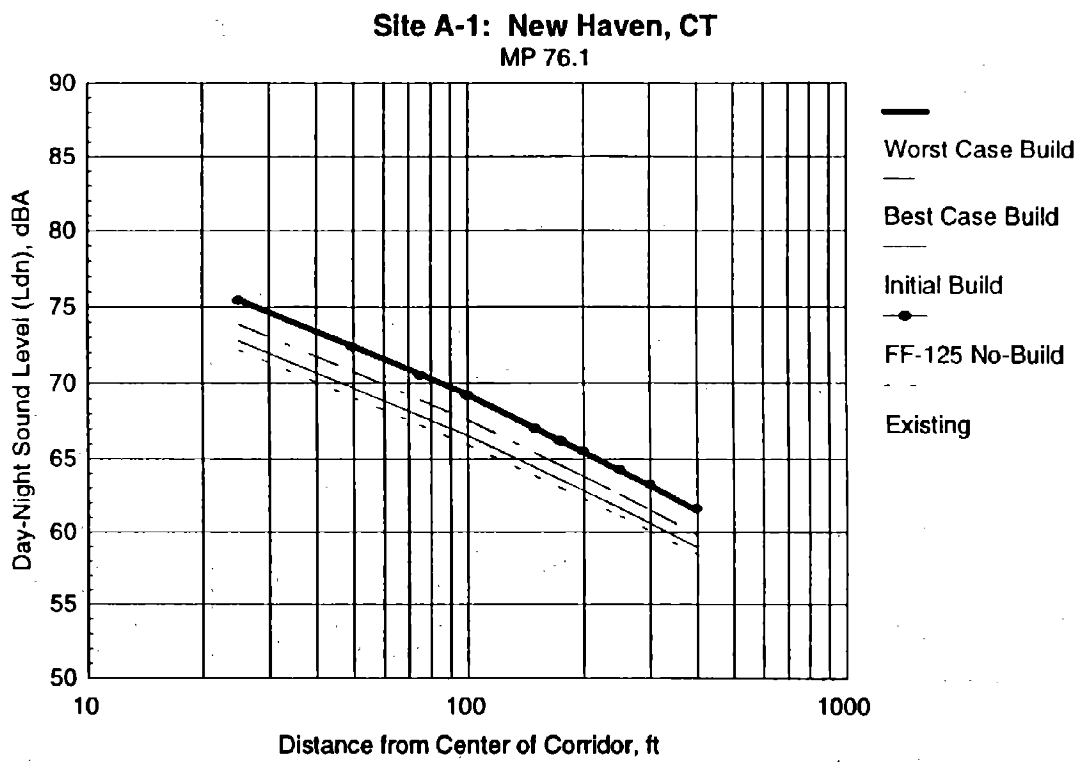
TABLE 4.4-5 Train Noise Impact Assessment at Measurement Sites

SITE NO.	SITE LOCATION	TOTAL NOISE INCREASE (dB)						SIGNIFICANT NOISE IMPACT				
		Crit.	NO-BUILD		BUILD			NO-BUILD		BUILD		
			AMD-103	FF-125	Init.	Best	Worst	AMD-103	FF-125	Init.	Best	Worst
A-1	New Haven, CT (MP 76.1)	3	2	3	0	1	3	No	No	No	No	No
A-2	Westbrook, CT (MP 101.5)	3	1	3	-1	1	4	No	Yes	No	No	Yes
A-3	Waterford, CT (MP 117.7)	4	2	4	-1	1	5	No	Yes	No	No	Yes
A-3a	W. Mystic, CT (MP 131.3)	2	1	5	2	4	4	No	Yes	No	Yes	Yes
A-4	Stonington, CT (MP 140.5)	3	2	5	2	5	5	No	Yes	No	Yes	Yes
A-5	Charlestown, RI (MP 152.2)	4	2	6	-2	4	8	No	Yes	No	Yes	Yes
A-6	Warwick, RI (MP 172.6)	4	3	7	2	5	8	No	Yes	No	Yes	Yes
A-7	Central Falls, RI (MP 190.3)	3	2	3	-1	1	4	No	Yes	No	No	Yes
A-8	W Mansfield, MA (MP 201.4)	3	1	4	1	3	5	No	Yes	No	Yes	Yes
A-9	Canton, MA (MP 213.2)	3	0	4	-1	3	5	No	Yes	No	Yes	Yes
A-10	Hyde Park, MA (MP 221.2)	3	0	3	0	1	4	No	No	No	No	Yes

Source: HMMH, Inc., 1994

The results indicate minimal noise impact for the Initial Build alternative, with only 14 residences located within the zone of significant impact. For the other build scenarios, noise impacts are projected at a minimum of 826 residences for the Best-Case Build alternative and at a maximum 2,243 residences for the Worst-Case Build alternative. Noise impacts for the No-Build Alternative - AMD-103 Scenario are expected to occur at 67 residences. Impacts for the No-Build Alternative - FF-125 Scenario are expected to occur at 1,486 residences, in the middle of the range of the three build alternatives.

Tables 4.4-7 through 4.4-10 summarize the case-specific impact inventories for the No-Build Alternative - FF-125 Scenario and for all of the future build alternatives, providing an indication of potential impact areas by milepost in each municipality affected. Each table also lists the corresponding impact distances for each affected area.

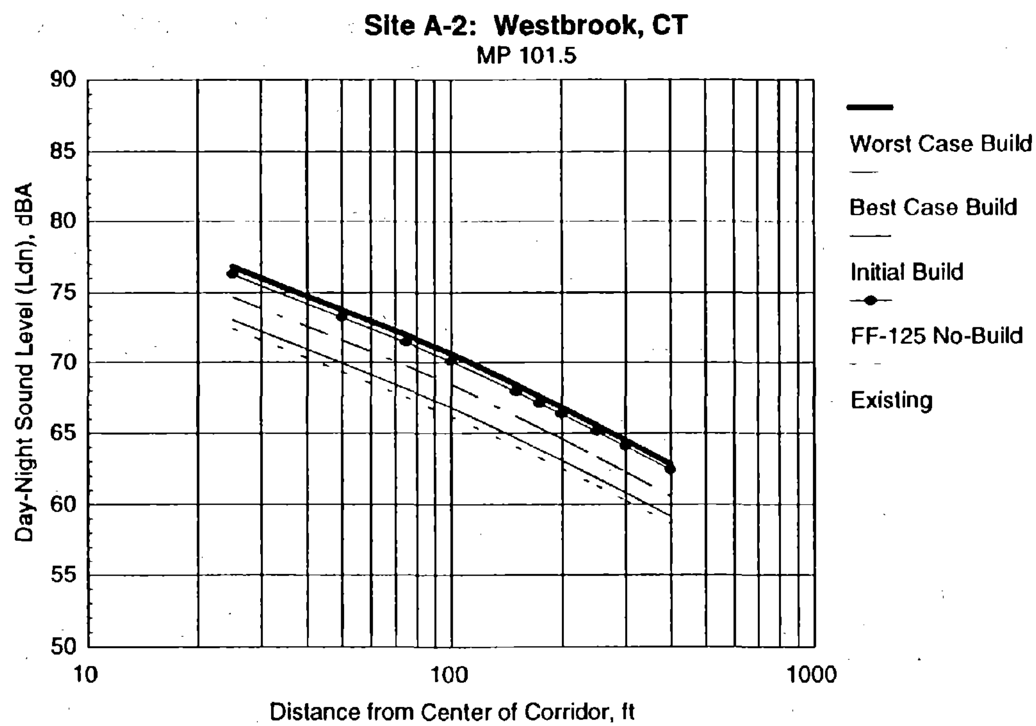


Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-1

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure
4.4-3

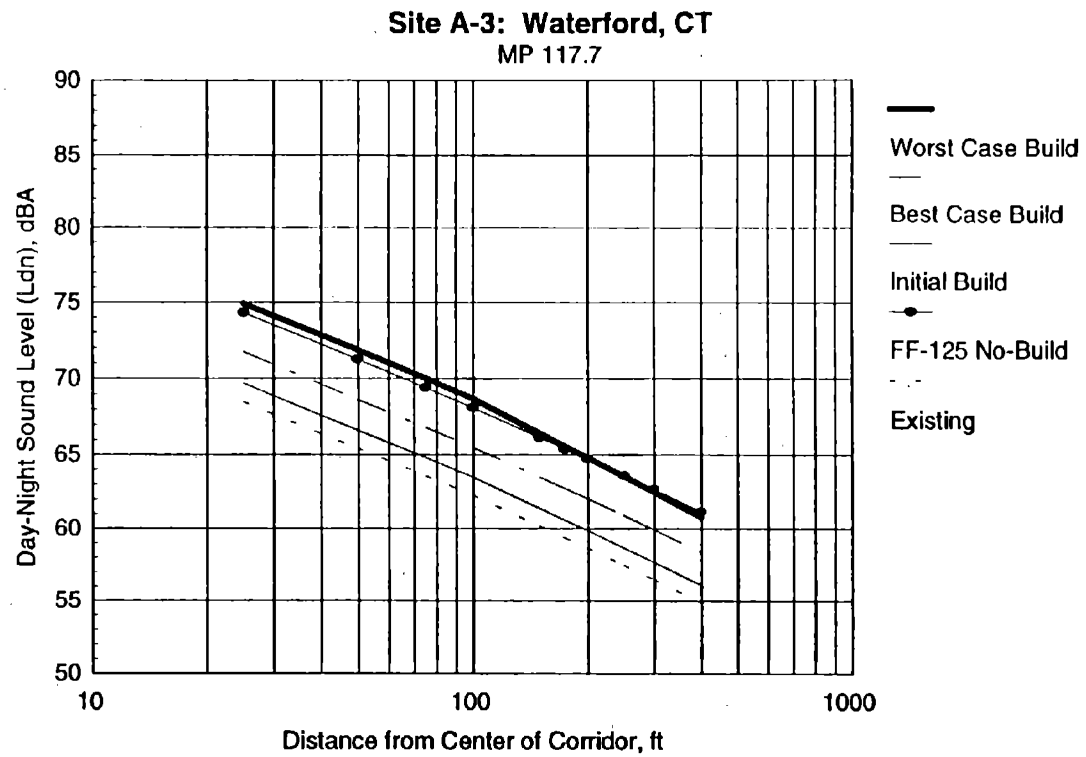


Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-2

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-4



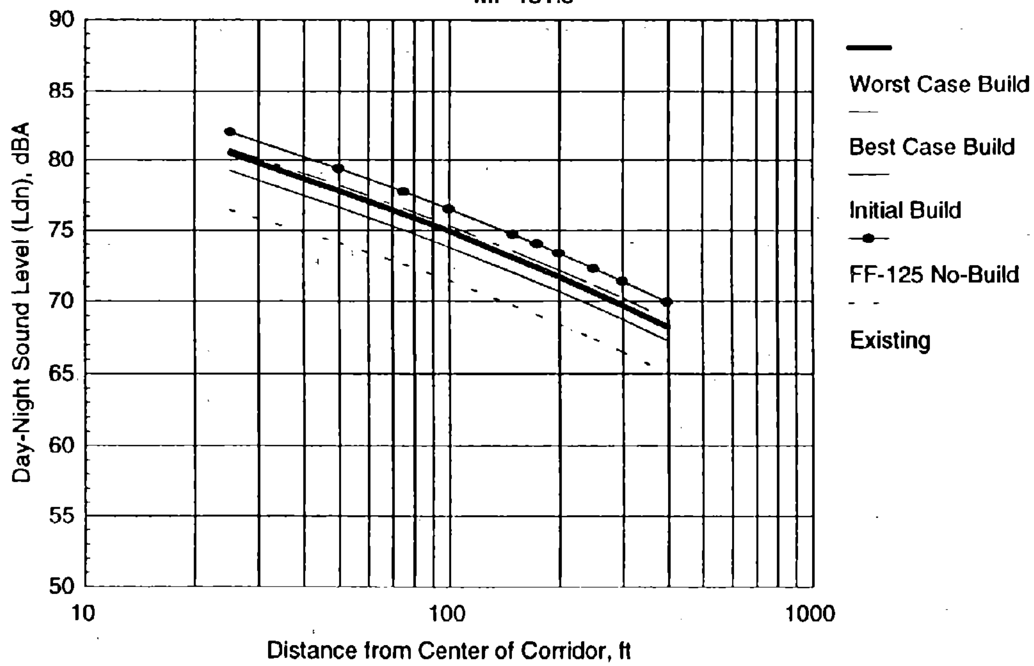
Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-3

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-5

Site A-3a: West Mystic, CT
MP 131.3

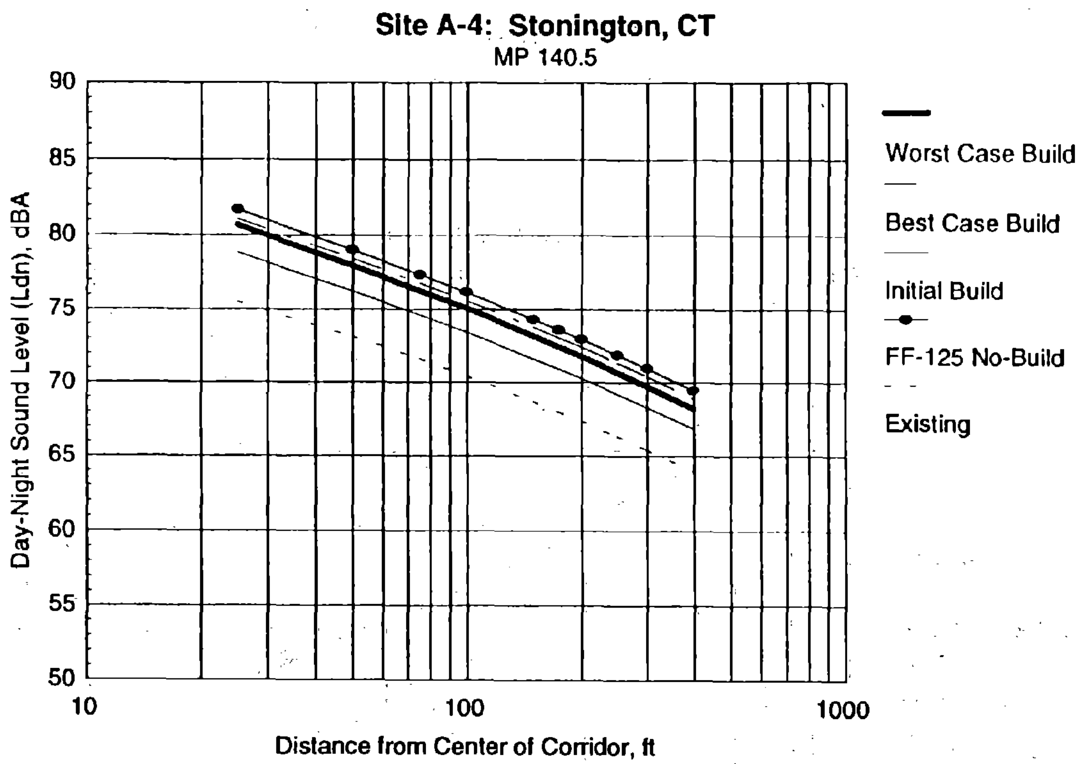


Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-3A

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-6

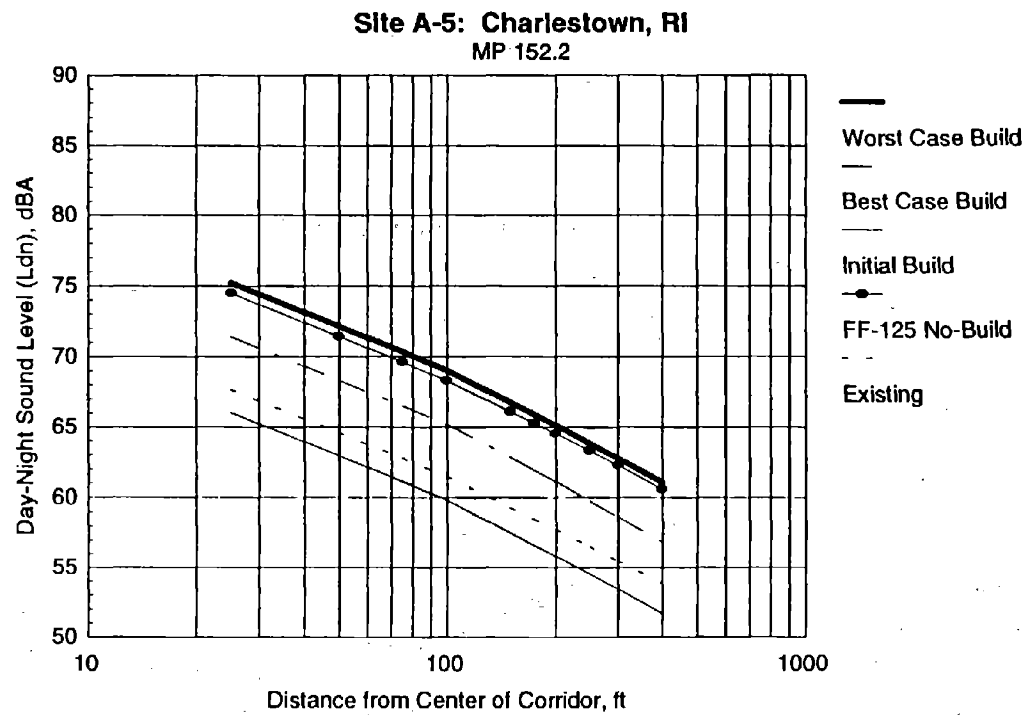


Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-4

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-7

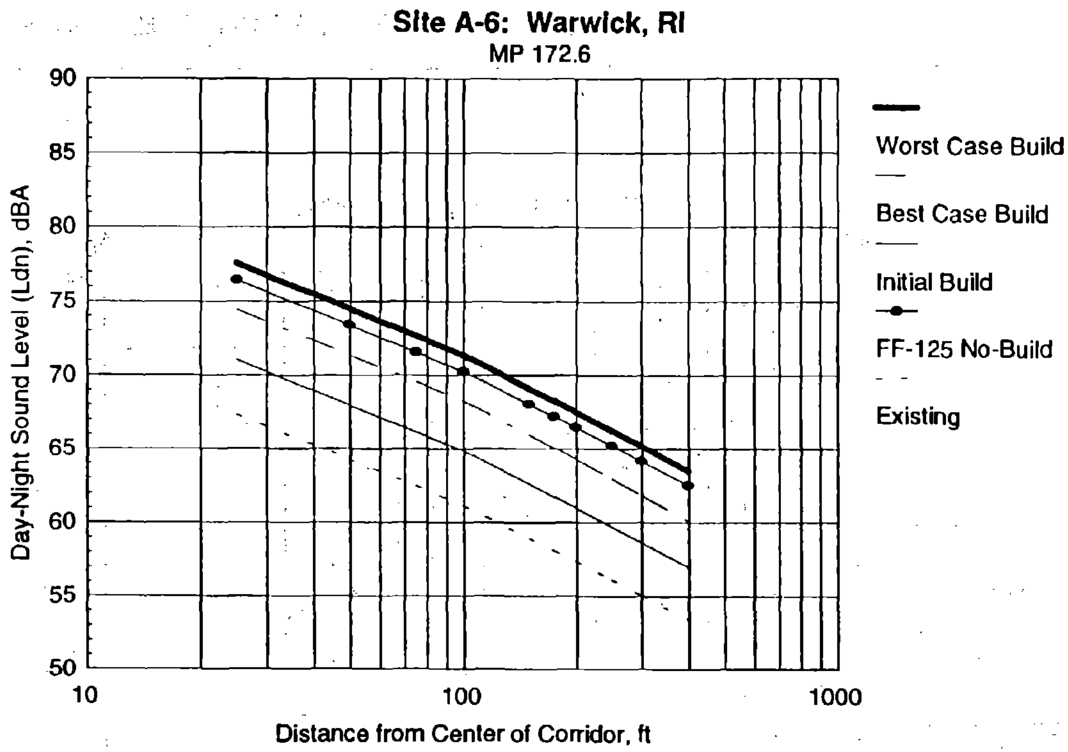


Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-5

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-8

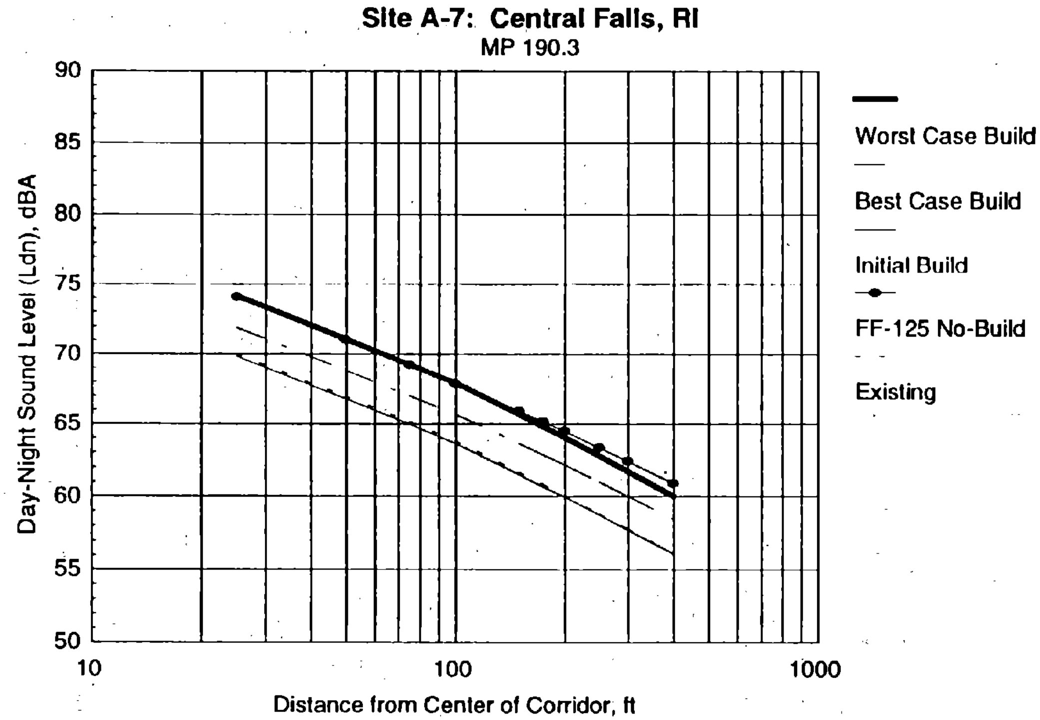


Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-6

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-9

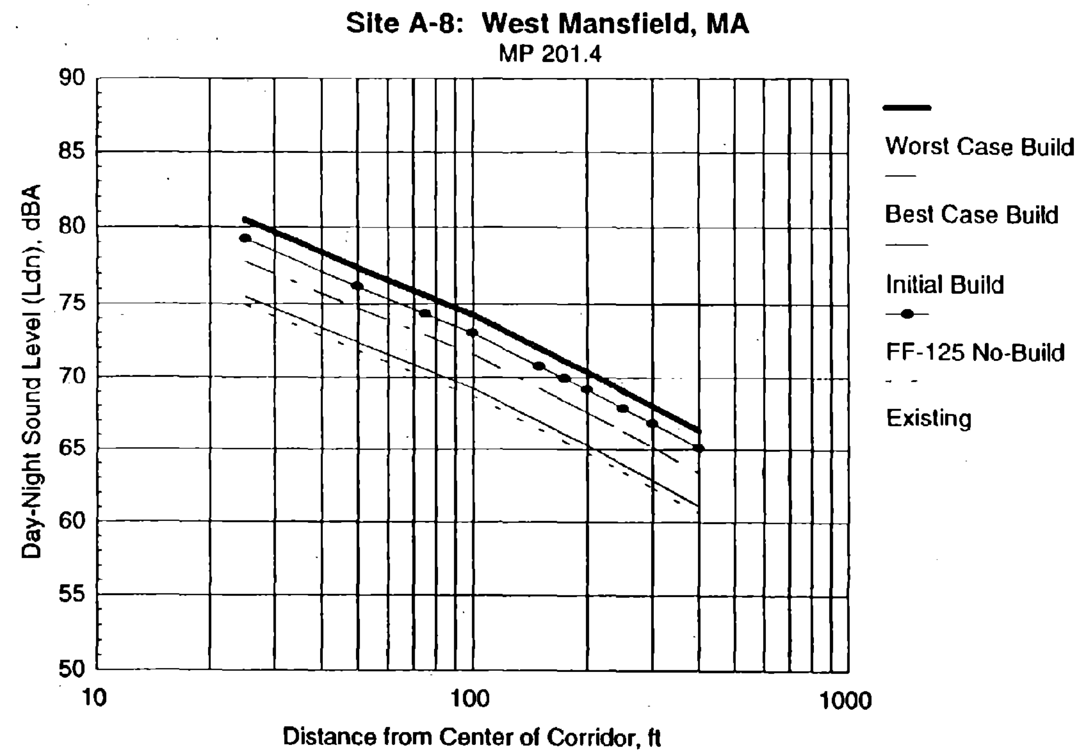


Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-7

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-10

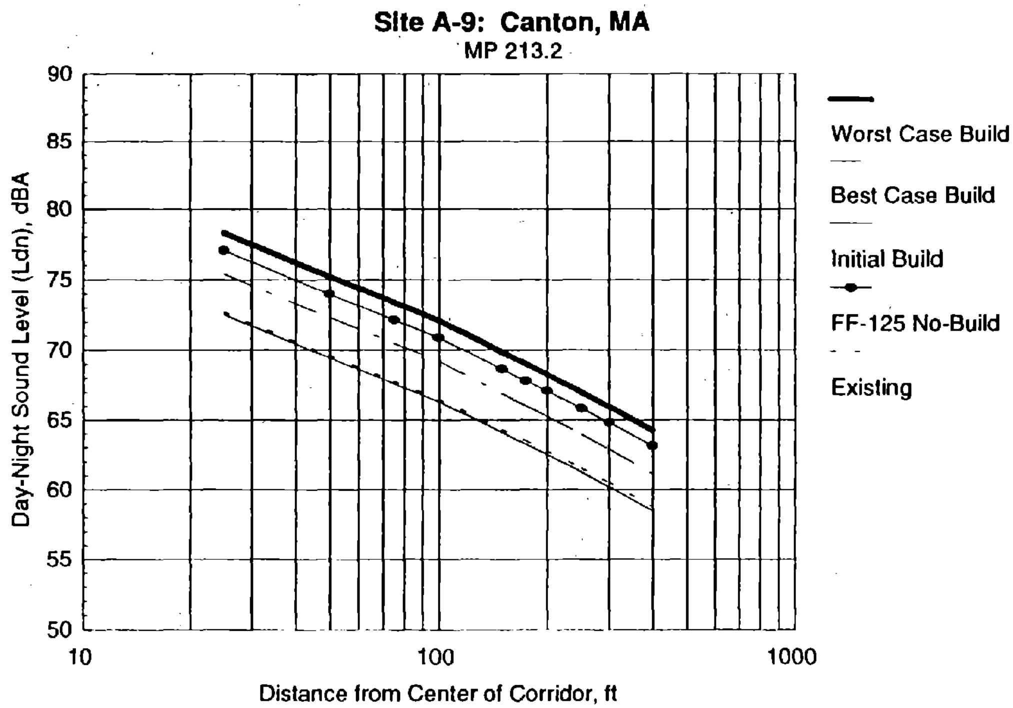


Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-8

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-11

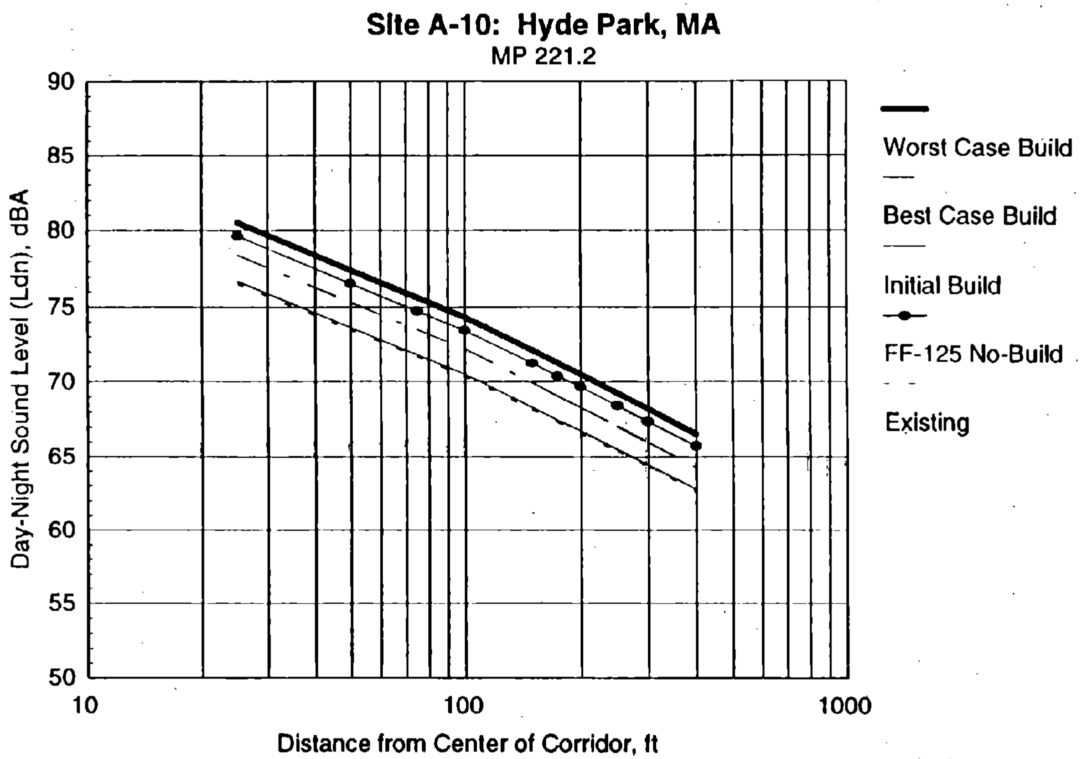


Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-9

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-12



Source: HMMH

PROJECTED TRAIN NOISE LEVELS NEAR SITE A-10

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-13

TABLE 4.4-6 Corridorwide Train Noise Impact Inventory

MUNICIPALITY	# RESIDENCES IN IMPACT ZONE				
	NO-BUILD		BUILD		
	AMD-103	FF-125	Initial	Best Case	Worst Case
New Haven	0	0	0	0	4
East Haven	0	0	0	0	0
Branford	0	31	0	5	37
Guilford	0	38	0	3	69
Madison	0	27	0	9	52
Clinton	0	7	0	6	26
Westbrook	0	11	0	7	11
Old Saybrook	0	6	0	2	9
Old Lyme	0	54	1	37	57
East Lyme	0	76	0	11	71
Waterford	0	9	0	0	11
New London	0	20	0	0	20
Groton	0	54	0	8	25
Stonington	0	91	0	54	139
TOTAL CT	**0**	**424**	**1**	**142**	**531**
Westerly	0	16	0	2	15
Hopkinton	0	0	0	0	0
Charlestown	0	20	0	6	20
Richmond	0	28	0	6	28
South Kingstown	17	25	6	45	58
Exeter	0	10	0	7	13
North Kingstown	7	70	0	41	89
East Greenwich	3	77	2	32	80
Warwick	40	360	3	252	412
Cranston	0	14	0	0	0
Providence	0	4	0	4	4
Pawtucket	0	11	0	1	11
Central Falls	0	11	0	0	11
TOTAL RI	**67**	**646**	**11**	**396**	**741**
Attleboro	0	185	1	155	336
Mansfield	0	112	0	77	195
Foxborough	0	9	0	9	63
Sharon	0	5	0	5	56
Canton	0	22	0	16	56
Westwood	0	0	0	0	0
Dedham	0	19	0	5	36
Boston	0	64	1	21	229
TOTAL MA	**0**	**416**	**2**	**288**	**971**
TOTAL CORRIDOR	**67**	**1,486**	**14**	**826**	**2,243**

Source: HMMH, Inc., 1994

TABLE 4.4-7 Potential Train Noise Impacts under No-Build Alternative - FF-125 Scenario

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
Branford	31	0	80.9	65	25
			82.7	100	25
			84.2-84.7	300	25
Guilford	38	0	86.6, 87.6, 87.9	100	25
			88.8, 89.1, 90.1	300	25
Madison	27	0	91.0, 91.3-91.6	150	25
			92.1, 92.4	100	25
			93.2, 93.5, 93.9, 94.7	125	25
Clinton	7	0	95.2, 96.8-96.9	150	25
			97.3	125	25
Westbrook	11	0	98.9, 100.6, 101.0	125	25
Old Saybrook	6	0	102.6, 103.7, 103.9	125	25
			105.3	100	25
Old Lyme	54	0	108.2, 109.2, 110.3	150	25
			108.7, 110.6, 111.0	175	25
			111.6	200	25
			111.9-112.2	500	25
East Lyme	76	0	114.3-115.0, 115.9	175	25
			115.0-115.5	150	25
			116.1	125	25
Waterford	9	0	117.8-118.0	150	25
			119.5	80	25
New London	20	1R[(1)]	121.2-121.8	125	25
Groton	54	1R[(2)]	124.8	150	25
			129.4	125	25
			129.9	100	25
			128.0, 130.2	175	25
			131.4-131.7	400	25
			132.2-132.5	800	40
Stonington	91	0	133.5	400	25
			134.1-134.3, 138.4, 139.5	150	25
			135.6-136.1, 136.5, 140.0-141.0	125	25
			136.2	80	25
			137.4, 139.7-140.0	175	25
TOTAL CT	**424**	**2R**			
Westerly	16	0	141.8	100	25
			142.4	150	25
			143.4	200	25
			146.0	175	25
Charlestown	20	0	148.3	125	25
			152.0-152.3	300	25
			153.2	200	25

Table 4.4-7 Potential Train Noise Impacts under No-Build Alternative - FF-125 Scenario (continued)

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
Richmond	28	0	149.8, 153.7-154.0, 154.4	125	25
			152.9-153.0	200	25
South Kingstown	25	0	159.3	400	40
			159.7-160.7	1100	50
Exeter	10	0	161.1-161.9	500	40
North Kingstown	70	0	161.9-162.6, 163.0	400	25
			165.1-165.9, 166.7, 168.1-168.7,	300	25
			170.3-170.5	175	25
East Greenwich	77	0	171.3-171.8	175	25
			171.8-172.1	300	25
Warwick	360	0	172.1-173.0, 173.7-174.4, 176.3-	300	25
			173.0-173.5	175	25
			174.7-175, 177.9-178.6	150	25
Cranston	14	0	180.4-180.6	150	25
Providence	4	0	181.9	100	25
Pawtucket	11	0	188.4	150	25
Central Falls	11	0	190.3	50	25
			190.6-190.9	150	25
TOTAL RI	**646**	**0**			
Attleboro	185	1C[3]	191.5-192.3, 195.9-196.0	150	25
			193.1-193.4, 196.7-197.0	300	25
			195.2-195.4, 197.0-198.2	125	25
			196.2-196.7	200	25
Mansfield	112	0	200.3, 200.9-201.4	125	25
			202.4-202.7	200	25
			203.3-203.7	400	25
			204.2-204.7	300	25
Foxborough	9	0	205.6, 206.2, 206.9	125	25
Sharon	5	0	208.0, 209.2	125	25
Canton	22	0	213.2-213.4	125	25
			213.4-213.7	150	25
Dedham	19	0	218.5-218.9	125	25
Boston	64	0	219.7, 221.8-222.3	100	25
			220.3-221.1	65	25
TOTAL MA	**416**	**1C**			
TOTAL CORRIDOR	**1,486**	**1C+2R**			

Notes: [1]Distance measured from centerline of all active tracks.
[2]"C" denotes Church and "R" denotes a recreational area.
(1)Caulkins Park
(2)Bluff Point State Park
(3)Second Congregational Church

Source: HMMH, Inc., 1994

TABLE 4.4-8 Potential Train Noise Impacts under Initial Build Alternative

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
Old Lyme	1	0	112.0	80	25
New London	0	1R[(1)]	121.6	25	25
Groton	0	1R[(2)]	128.0	25	25
TOTAL CT	**1**	**2R**			
South Kingstown	6	0	159.5-160.7	125	25
East Greenwich	2	0	172.0	40	25
Warwick	3	0	172.2, 172.6	40	25
TOTAL RI	**11**	**0**			
Attleboro	1	0	196.8	25	25
Boston	1	0	219.6	25	25
TOTAL MA	**2**	**0**			
TOTAL CORRIDOR	**14**	**2R**			

Notes: [1]Distance measured from centerline of all active tracks.
[2]"C" denotes Church and "R" denotes a recreational area.
[(1)]Caulkins Park
[(2)]Bluff Point State Park

Source: HMMH, Inc., 1994

TABLE 4.4-9 Potential Train Noise Impacts under Best-Case Build Alternative

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
Branford	5	0	84.4-84.6	100	25
Guilford	3	0	88.8	100	25
Madison	9	0	91.0, 91.3-91.6	125	25
Clinton	6	0	95.2, 96.8	150	25
			97.3	125	25
Westbrook	7	0	98.9, 100.6, 101.0	80	25
Old Saybrook	2	0	105.3	100	25
Old Lyme	37	0	108.2, 108.7	65	25
			109.2	125	25
			110.6-111.0	100	25
			111.9-112.2	500	25
East Lyme	11	0	114.3-115.0	80	25
			115.0-115.5	40	25
			116.1	65	25
New London	0	1R[(1)]	121.6	50	25
Groton	8	1R[(2)]	131.4-131.6, 128.0	150	25
			132.4	500	25
Stonington	54	0	133.5	400	25
			136.5, 137.4, 140.0-141.0	125	25
			139.7-140.0	100	25
TOTAL CT	**142**	**2R**			
Westerly	2	0	143.4	200	25
			146.0	175	25
Charlestown	6	0	152.0-152.3, 153.2	100	25
Richmond	6	0	152.9-153.0	100	25
South Kingstown	45	0	157.1, 157.3-158.7	300	25
			159.3	400	40
			159.7-160.7	800	40
Exeter	7	0	161.3-161.9	400	40
North Kingstown	41	0	161.9-162.6, 163.0	175	25
			165.1-165.9, 166.7, 168.1-168.7	300	25
East Greenwich	32	0	171.3-171.8	100	25
			171.8-172.1	175	25

TABLE 4.4-9 Potential Train Noise Impacts under Best-Case Build Alternative (continued)

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
Warwick	252	0	172.1-173.0	175	25
			173.7-174.4, 176.3-177	200	25
			174.7-175	125	25
			173.0-173.5, 177.9-178.6	100	25
Providence	4	0	181.9	100	25
Pawtucket	1	0	188.4	100	25
TOTAL RI	**396**	**0**			
Attleboro	155	1C[(3)]	191.5-192.3, 195.2-195.4, 197.4-198.0, 196.2-196.7	125	25
			193.1	100	25
			196.7-197.0	175	25
Mansfield	77	0	200.3, 200.9-201.4	125	25
			202.4-202.6	80	25
			203.3-203.6	120	25
			204.2-204.7	300	25
Foxborough	9	0	205.6, 206.2, 206.9	125	25
Sharon	5	0	208.0	125	25
Canton	16	0	213.2-213.4, 213.4-213.7	125	25
Dedham	5	0	218.5-218.9	50	25
Boston	21	0	219.7, 220.3-221.1, 221.8-222.3	65	25
TOTAL MA	**288**	**1C**			
TOTAL CORRIDOR	**826**	**1C+2R**			

Notes: [1]Distance measured from centerline of all active tracks.
[2]"C" denotes Church and "R" denotes a recreational area.
(1)Caulkins Park
(2)Bluff Point State Park
(3)Second Congregational Church

Source: HMMH, Inc., 1994

TABLE 4.4-10 Potential Train Noise Impacts under Worst-Case Build Alternative

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY (ft)	
	Resid.	Other[2]		Resid.	Other
New Haven	4	0	73.7-75.9	65	25
Branford	37	0	80.9	80	25
			82.7	125	25
			84.2-84.6	300	25
			85.1-86.0	200	25
Guilford	69	0	86.6	100	25
			87.6, 87.9	200	25
			88.7-88.9, 89.1, 89.9-90.1	400	25
Madison	52	0	90.8, 91.0-91.6	300	25
			92.1, 92.4	100	25
			93.2, 93.5, 93.9, 94.7	125	25
Clinton	26	0	95.2	300	25
			96.3, 96.8, 97.3, 98.6	200	25
Westbrook	11	0	98.9, 100.6, 101.0	125	25
Old Saybrook	9	0	102.6, 103.7, 103.9, 104.0	125	25
			105.3	200	25
Old Lyme	57	0	108.2, 109.2, 110.5	150	25
			108.7, 110.6-111.0, 111.6	200	25
			111.9-112.2	500	25
East Lyme	71	0	114.3-115.0, 115.9	200	25
			115.0-115.5, 116.1	125	25
Waterford	11	0	117.8-118.0, 119.0	200	25
New London	20	1R(1)	121.2-121.8	125	25
Groton	25	1R(2)	129.4	150	25
			129.9	65	25
			128.0, 130.2, 131.3-131.7	200	25
			132.2-132.5	500	40
Stonington	139	0	133.5	400	25
			134.1-134.3, 135.6-136.1	150	25
			138.4, 139.5	125	25
			136.2	100	25
			137.4-137.6, 139.7-140.0, 140.0-141.0	200	
			136.5	400	25
TOTAL CT	**531**	**2R**			
Westerly	15	0	141.8	100	25
			142.4	125	25
			143.4	300	25
			146.0	200	25
Charlestown	20	0	148.3	150	25
			152.0-152.3	300	25
			153.2	200	25
Richmond	28	0	149.8, 153.7-154.0, 154.4	150	25
			152.9-153.0	200	25
South Kingstown	58	0	157.1, 158.2-158.7	400	65
			157.3-158.2	300	40
			159.3	600	65
			159.7-160.7	1000	50

TABLE 4.4-10 Potential Train Noise Impacts under Worst-Case Build Alternative (continued)

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY (ft)	
	Resid.	Other[2]		Resid.	Other
Exeter	13	0	161.3-161.9	1000	40
North Kingstown	89	0	161.9-162.6, 163.0, 165.1-165.9, 166.7,	400	25
			170.3-170.5	200	25
East Greenwich	80	0	171.3-171.8	200	25
			171.8-172.1	300	25
Warwick	412	0	172.1-172.3, 173.7-174.1, 176.3-177.7	300	25
			172.3-173.0, 174.1-174.4	400	
			173.0-173.5, 174.7-175, 177.9-178.6	200	25
Providence	4	0	181.9	100	25
Pawtucket	11	0	188.4	150	25
Central Falls	11	0	190.3	50	25
			190.6-190.9	150	25
TOTAL RI	**741**	**0**			
Attleboro	336	1C[3]	191.5-192.3, 195.9-196.1, 193.1-193.4,	300	25
			195.2-195.4, 196.2-196.7, 196.7-197.0,	400	50
			193.7-193.9	200	25
Mansfield	195	0	200.3, 200.9-201.4, 202.4-202.7, 203.3-	400	25
			200.7	300	25
			204.2-204.7	600	25
Foxborough	63	0	205.1-205.5, 205.6, 206.2-206.5, 207.9,	400	25
Sharon	56	0	208.0-208.2, 209.8	400	25
			208.9-209.7	200	25
			211.2-211.7	150	25
			211.9	300	25
Canton	56	0	212.9-213.4, 213.4-213.7	300	25
Dedham	36	0	218.5-218.9	300	25
Boston	229	0	219.6-219.8, 220.0-221.1	300	25
			221.8-222.3	100	25
TOTAL MA	**971**	**1C**			
TOTAL CORRIDOR	**2,243**	**1C+2R**			

Notes: [1]Distance measured from centerline of all active tracks.
[2]"C" denotes Church and "R" denotes a recreational area.
(1)Caulkins Park
(2)Bluff Point State Park
(3)Second Congregational Church

Source: HMMH, Inc., 1994

4.4.3 Vibration Impact from Train Operations

Changes in train equipment, schedules, and speeds along the Northeast Corridor that are proposed as part of the project have the potential to affect the ground-borne vibration environment along the corridor. Vibration impact criteria, projections and assessment for the proposed changes in train operations are described below.

4.4.3(a) Train Vibration Impact Criteria

The significance of vibration impacts from train operations on the NEC are assessed based on the projected maximum root-mean square (RMS) ground vibration velocity level (V_{dB}), expressed in decibels relative to a reference velocity of one μinch per second (10^{-6} in/sec). The criteria are given in terms of velocity because the sensitivity of humans, buildings and mechanical equipment to vibration has typically been found to correspond to a constant level of vibration velocity amplitude within the low-frequency range of most concern for environmental vibrations (roughly 5 to 100 Hz).Although the peak particle velocity (PPV) is also commonly used to quantify vibration, it is more applicable to blast damage criteria, and response to train vibration is better related to the RMS amplitude. The RMS amplitude is defined as the average of the squared amplitude of the signal over a one-second time period.

Although velocity is normally described in units of inches per second in the U.S., the decibel notation, which acts to compress the range of numbers required to describe vibration, can also be used. In this notation, the vibration magnitude is expressed in terms of velocity level, in decibels, defined as follows:

$$V_{dB} = 20 \log_{10} \left(\frac{v}{v_{ref}} \right)$$

where: v = rms velocity, μin/sec
v_{ref} = 1 μin/sec

Absolute criteria for ground-borne vibration impact are based on those currently being proposed for adoption by the U.S. Federal Transit Administration.[19] These criteria, presented in Table 4.4-11, are evaluated in terms of the maximum ground vibration levels for a single event and account for land use as well as the frequency of events. For consistency, the absolute criterion based on the existing train frequency is used to assess impact for the future alternatives.

Because the project involves potential changes in train vibration along an existing rail corridor, significant impact is assessed only at locations where: (1) projected future alternative ground vibration levels exceed the absolute criteria and (2) there is a projected increase of at least 25 percent (2 dB) in the magnitude of train vibration, or at least a doubling in the number of daily train operations.

Another area of concern is damage to buildings located near the right-of-way. The criteria for vibration damage are 100 dB for buildings in general, and 95 dB for fragile, historic buildings. However, damage from normal train operations is extremely unlikely, except in unusual cases.

4.4.3(b) Train Vibration Projection Model

Because ground-borne vibration is a complex phenomenon that is difficult to model and predict accurately, most projection procedures used for train vibration rely on empirical data. This section summarizes the empirical model used to predict vibration generated by trains operating on the project corridor. The model is based on available data from measurements and provides a conservative yet reasonable basis for projection train vibration along the corridor for existing and future scenarios.

TABLE 4.4-11 Proposed FTA Criteria for Vibration Impact

LAND USE CATEGORY	GROUND-BORNE VIBRATION IMPACT LIMITS (rms Vibration Velocity Level in dB re 1 μin./sec)	
	Frequent Events[1]	Infrequent Events[2]
CATEGORY 1: Buildings where low ambient vibration is essential for interior operations.	65 dB	65 dB
CATEGORY 2: Residences and buildings where people normally sleep.	72 dB	80 dB
CATEGORY 3: Institutional land uses with primarily daytime use.	75 dB	83 dB

Notes: [1]"Frequent Events" is defined as more than 70 vibration events per day. Most transit systems fall into this category.
[2] "Infrequent Events" is defined as less than 70 vibration events per day. This category includes most commuter and inter-city rail systems.

Source: FTA, 1990

A comprehensive measurement program was carried out as part of the DEIS/R study to document vibration levels from existing train equipment at various locations on the NEC between New Haven and Boston. In addition, the ground vibration generated by prototypical equipment considered for the project in its future electrification and no-build scenarios were also measured for purposes of comparison with the existing equipment. These included the electric AEM7, X2000 and ICE trainsets operating on the electrified portion of the NEC south of New Haven, and the RTL in service on New York's Empire Corridor. Given the large geographic distribution of all of the gathered measurement data, there is a wide variation in both vibration 'levels generated by trains and their propagation characteristics. However, using statistical methods and generalized assumptions regarding factors such as attenuation with distance and speed-dependency, overall observations can be made from analysis of these data. These are summarized as follows:

- Diesel (F40PH), electric (AEM7), and gas turbine (RTL) locomotive-hauled Amtrak trains generate about the same overall level of vibration at similar speeds.

- Measurements of the ICE and X2000 trainsets tested on the NEC indicated that vibration levels generated by the ICE are 3 to 5 dB lower than those generated by the AEM-powered trains, but that the X2000 vibration levels are 6 to 10 dB lower than the AEM7 and 5 to 7 dB lower than the ICE. These observations were made based on comparison of measurements performed at a single measurement site in New Jersey; thus, site or track variations were eliminated and a valid comparison of the data could be made.

- Small differences of 3 to 5 dB may be attributable to the relatively new rolling stock of the European trainsets tested on the NEC compared with the standard revenue service fleet of AEM7s. However, major differences in equipment design may account for larger variations in vibration levels. Specifically, the X2000 is known to have a truck with a significantly lower unsprung weight per axle than either of the other electric trains, and this may account for lower dynamic loads and ground-borne vibration levels.

A 5 dB "degradation factor" is often applied to new equipment to account for the eventual wear and stabilization of the rolling stock after it has been in service for 1 year or more. The X2000 vibration propagation characteristic was adjusted with this 5 dB factor, and its rate of attenuation was calibrated to follow the rate obtained by an energy-average of the vibration measurement data obtained on the New Haven to Boston portion of the NEC. This curve was used as the baseline for predicting maximum vibration levels for express Amtrak trains under the Build alternative in the DEIS/R study, and was similarly applied to evaluate potential vibration impact for the Best-Case and Initial Build alternatives for the FEIS/R in a manner consistent with the DEIS/R. The same vibration propagation curve as used in the DEIS/R for the AEM7/diesel Amtrak trains (conventional Amtrak service) was used for projecting vibration under the FEIS Worst Case build and FF-125 no-build alternatives. The results are summarized in Figure 4.4-14, which shows the projected vibration level as a function of distance for the four future alternatives and corresponding Amtrak equipment type assumed.

The curves in Figure 4.4-14 apply to trains at 90 mph, and were used to project future build and no-build vibration levels along the project corridor. The following adjustment for speed was applied to account for variations in maximum operating speed:

$$\Delta L = 20 \log_{10} \left[\frac{v}{90} \right]$$

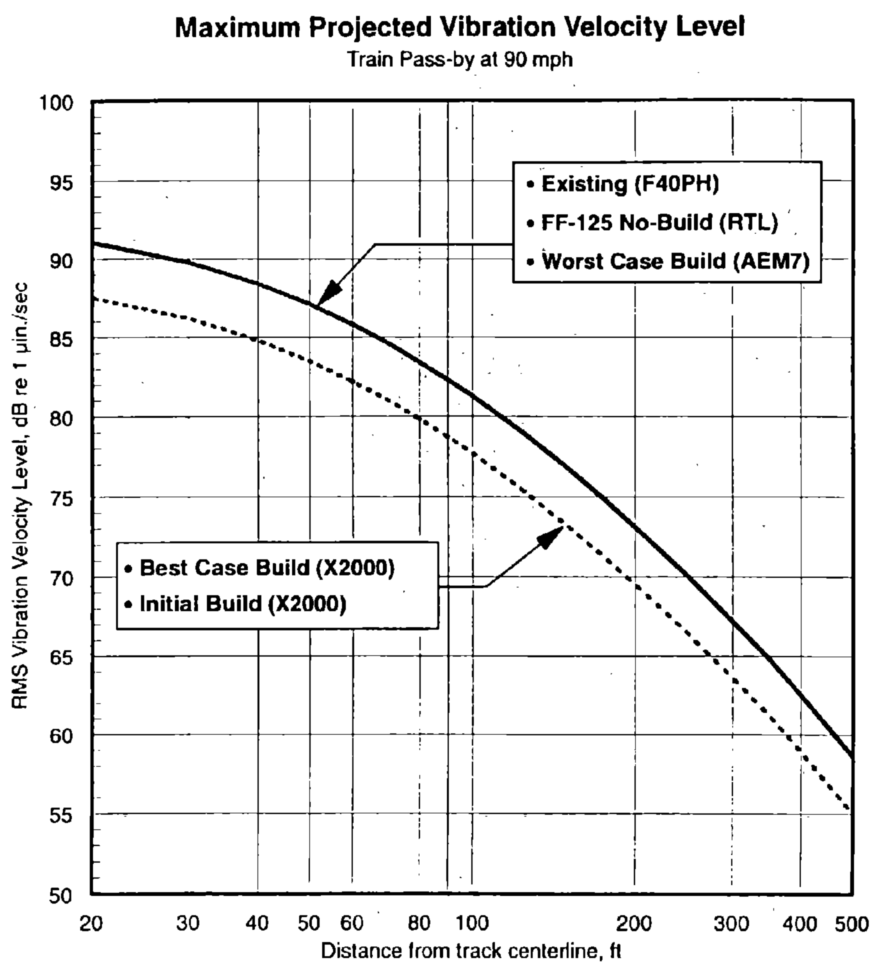
where v = train speed (mph)

As is the case for noise, special trackwork such as turnouts and crossovers can cause increases in ground-borne levels of 5 to 10 dB close to the track. However, because their effects are highly localized and because the project will not alter their locations, a detailed analysis of special trackwork is not required for a reasonable assessment of vibration impact.

4.4.3(c) Train Vibration Impact Assessment
The speed-corrected vibration propagation curve for each segment of the project corridor was used to determine impact screening distances within which impact from vibration is likely to occur. Table 4.4-12 provides a summary of the projected maximum vibration level from trains at each of the measurement sites for the existing, no-build and build alternatives. Table 4.4-13 then applies the site-specific vibration impact criteria to each of the sites, and demonstrates the use of these criteria in determining significant impact.

The absolute vibration criterion at each site was selected based on the total number of existing train operations per day. A criterion of 80 dB was found to apply at all but site A-10, which is the only of the eleven sites currently exposed to more than 70 trains per day. Out of the eleven sites, Table 4.4-12 indicates that projected train vibration levels exceed the absolute criterion at seven sites for the existing, AMD-103 no-build, Initial Build and Best-Case build alternatives, at nine sites for the No-Build Alternative - FF-125 Scenario and at ten sites for the Worst-Case build alternative.

Significant impact for the future alternatives was assessed when the absolute criterion would be exceeded, provided that there was also an increase of at least 2 dB in maximum vibration level or at least a doubling of train frequency. The results in Table 4.4-13 indicate that significant vibration impact is projected at two of the sites for the No-Build Alternative - AMD-103 Scenario, seven sites for the No-Build Alternative - FF-125 Scenario, one site for Initial build, six sites for Best-Case build, and nine of the sites for the Worst-Case build alternative.



Source: HMMH

MAXIMUM VIBRATION FOR EXISTING AND FUTURE AMTRAK SCENARIOS

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 4.4-14

A corridorwide inventory of train vibration impact is provided in Table 4.4-14. This table indicates the estimated number of vibration-sensitive locations within the vibration impact zone for the No-Build Alternatives - AMD-103 and FF-125 scenarios and three Build alternatives. The vibration impact zone for each case was determined by comparing the vibration projections with the project criteria along individual segments of the corridor based on speed, source level, and number of operations, and by estimating the distances within which impact would occur. These train vibration impact distances are given by corridor milepost segment in Appendix 4H. The numbers of vibration-sensitive sites located within the impact zone were then counted with the aid of land-use maps and aerial photographs of the project corridor. The approximate locations of each of these affected areas are indicated by milepost in Tables 4.4-15 through 4.4-18 for four of the future alternatives, respectively: No-Build Alternative - FF-125 Scenario, Initial Build, Best-Case Build and Worst-Case Build. Also listed in each of these tables is the distance to impact for both land use categories in the corresponding corridor segment.

The results project a total of 369 residences within the impact zone for the No-Build Alternative - AMD-103 Scenario, 746 for the No-Build Alternative - FF-125 Scenario, 1,255 for the Initial Build alternative; 1,390 for the Best-Case Build alternative; and 4,269 for the Worst-Case Build alternative. For the Build alternatives, most of the potential vibration impacts are in Massachusetts, and the least are in Connecticut. For the No-Build Alternatives, most of the potential vibration impacts are in Rhode Island.

Of note in Table 4.4-14 is the number of impacted residences in Massachusetts for the No-Build Alternative - FF-125 Scenario as compared to similar data for the build alternatives, particularly the Worst-Case Build alternative. Although train operations under the No-Build Alternative - FF-125 Scenario and Worst-Case Build alternative are assumed to generate the same vibration levels at any given speed, the speed assumptions are different for these two cases. The Worst-Case Build alternative assumes speeds up to 120 mph for conventional trains and up to 150 mph for express trains, while the No-Build Alternative - FF-125 Scenario assumes speeds up to 120 mph for all trains. The greater maximum speed under the Worst-Case Build alternative results in significantly greater impact for this alternative as compared to the No-Build Alternative - FF-125 scenario.

TABLE 4.4-12 Projected Vibration Levels at Measurement Sites

SITE NO.	SITE LOCATION	DIST. TO CORRIDOR C.L. (ft)	MAXIMUM RMS VIBRATION VELOCITY LEVEL (dB re: μin/sec)						
			Crit.	Exist.	NO-BUILD		BUILD		
					AMD-103	FF-125	Initial	Best Case	Worst Case
A-1	New Haven, CT	94	80	80	80	80	77	77	80
A-2	Westbrook, CT	111	80	79	79	80	78	78	81
A-3	Waterford, CT	86	80	79	79	82	78	78	82
A-3a	West Mystic, CT	42	80	85	85	86	84	84	88
A 4	Pawcatuck, CT	79	80	83	83	83	81	81	84
A-5	Charlestown, RI	59	80	84	84	86	83	83	87
A-6	Warwick, RI	69	80	84	84	86	84	84	88
A-7	Central Falls, RI	32	80	89	89	89	86	86	89
A-8	W. Mansfield, MA	125	80	79	79	81	79	79	82
A-9	Canton, MA	68	80	84	84	86	84	84	88
A-10	Hyde Park, MA	78	72	85	85	86	84	84	87

Source: HMMH, Inc., 1994

TABLE 4.4-13 Vibration Impact Assessment at Measurement Sites

SITE NO.	# TRAIN OPERATIONS PER DAY						INCREASE IN VIBRATION LEVEL (dB re: 1 μin/sec)					SIGNIFICANT VIBRATION IMPACT				
	Exist	% INCREASE					NO-BUILD		BUILD			NO-BUILD		BUILD		
		NO-BUILD		BUILD												
		AMD-103	FF-125	Initial	Best Case	Worst Case	AMD-103	FF-125	Initial	Best Case	Worst Case	AMD-103	FF-125	Initial	Best Case	Worst Case
A-1	52	23%	73%	15%	73%	73%	0	0	-3	-3	0	No	No	No	No	No
A-2	52	23%	73%	15%	73%	73%	0	1	-1	-1	2	No	No	No	No	No
A-3	24	75%	183%	58%	183%	183%	0	3	-1	-1	3	No	Yes	No	Yes	Yes
A-3a	20	30%	160%	10%	160%	160%	0	1	-1	-1	3	No	Yes	No	Yes	Yes
A-4	20	30%	160%	10%	160%	160%	0	0	-2	-2	1	No	Yes	No	Yes	Yes
A-5	20	30%	160%	10%	160%	160%	0	2	-1	-1	3	No	Yes	No	Yes	Yes
A-6	22	136%	255%	118%	255%	255%	0	2	0	0	4	Yes	Yes	Yes	Yes	Yes
A-7	30	103%	147%	47%	147%	147%	0	0	-3	-3	0	Yes	Yes	No	Yes	Yes
A-8	55	7%	67%	13%	67%	67%	0	2	0	0	3	No	Yes	No	No	Yes
A-9	53	8%	60%	4%	60%	60%	0	2	0	0	4	No	No	No	No	Yes
A-10	117	32%	56%	31%	56%	56%	0	1	-1	1	2	No	No	No	No	Yes

Source: HMMH, Inc., 1994

TABLE 4.4-14 Corridorwide Train Vibration Impact Inventory

MUNICIPALITY	# RESIDENCES IN IMPACT ZONE				
	NO-BUILD		BUILD		
	AMD-103	FF-125	Initial	Best Case	Worst Case
New Haven	0	12	0	0	19
East Haven	0	0	0	0	0
Branford	0	3	0	0	17
Guildford	0	0	0	0	0
Madison	0	0	0	0	29
Clinton	0	0	0	0	15
Westbrook	0	0	0	0	15
Old Saybrook	0	0	0	0	2
Old Lyme	0	20	0	10	20
East Lyme	0	57	0	21	59
Waterford	0	7	0	3	7
New London	0	12	0	8	16
Groton	0	13	0	8	14
Stonington	0	73	0	50	97
TOTAL CT	**0**	**197**	**0**	**100**	**310**
Westerly	0	9	0	6	11
Hopkinton	0	0	0	0	0
Charlestown	0	9	0	0	10
Richmond	0	21	0	16	24
South Kingstown	4	8	3	4	13
Exeter	0	0	0	0	0
North Kingstown	59	25	11	11	33
East Greenwich	32	50	29	29	51
Warwick	231	232	192	192	254
Cranston	0	0	0	0	0
Providence	5	4	4	4	6
Pawtucket	0	3	0	0	4
Central Falls	38	26	0	12	36
TOTAL RI	**369**	**387**	**239**	**274**	**442**
Attleboro	0	95	0	0	180
Mansfield	0	4	0	0	56
Foxborough	0	0	0	0	13
Sharon	0	0	0	0	26
Canton	0	19	0	0	67
Westwood	0	0	0	0	0
Dedham	0	44	0	0	45
Boston	0	0	1016	1016	3130
TOTAL MA	**0**	**162**	**1,016**	**1,016**	**3,517**
TOTAL CORRIDOR	**369**	**746**	**1,255**	**1,390**	**4,269**

Source: HMMH, Inc., 1994

TABLE 4.4-15 Potential Train Vibration Impacts under No-Build Alternative - FF-125 Scenario

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
New Haven	12	0	73.2	66	42
			74.0	97	70
Branford	3	0	81.8	85	60
			82.6	118	88
Old Lyme	20	0	1082-108.6, 108.8, 109.2	123	92
			110.6-111.0	118	88
			112.0	91	65
East Lyme	57	0	113.0-113.5, 114.3-115.5, 116.0	113	84
			116.1	100	75
Waterford	7	0	117.8-118.0, 119.5	103	46
New London	12	0	121.3-121.9	79	54
Groton	13	0	129.4, 131.5	90	65
			129.6, 129.9-130.2, 131.2	103	75
Stonington	73	1C(1)	132.8	66	42
			134.3, 135.6-136.1	99	72
			136.3	79	54
			136.5, 137.5, 137.6	122	91
			139.5, 139.7-140.9	108	79
TOTAL CT	**197**	**1C**			
Westerly	9	0	141.8, 142.5, 143.5, 146.0	113	84
Charlestown	9	1C(2)	148.4	118	88
			152.3, 153.0, 153.3	115	86
Richmond	21	0	149.8, 152.9, 153.8, 154.4	118	88
South Kingstown	8	0	159.8-160.6	145	111
North Kingstown	25	0	162.0-162.5, 166.7, 168.2-168.7	141	108
			170.3-170.4	132	0
East Greenwich	50	0	171.3-171.9	128	96
Warwick	232	0	172.1-172.3	129	97
			172.3-173.7, 173.9-175.0, 176.0, 176.3-177.0, 177.2-177.6	123	92
Providence	4	0	181.8	91	65
Pawtucket	3	0	188.4	97	70
Central Falls	26	0	190.0	79	54
			190.3	85	60
			190.7	113	84
TOTAL RI	**387**	**1C**			

TABLE 4.4-15 Potential Train Vibration Impacts Under No-Build Alternative - FF-125 Scenario (continued)

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
Attleboro	95	0	195.1-195.4, 195.8-196.1, 196.6-197.0, 197.3-198.1	146	112
Mansfield	4	0	200.3	146	112
Canton	19	0	214.1-214.3	227	182
Dedham	44	0	218.5-218.8	257	208
TOTAL MA	**162**	**0**			
TOTAL CORRIDOR	**746**	**2C**			

Notes: [1]Distance measured from centerline of outer track.
[2]"C" denotes Church
(1)Pentecostal Church of God
(2)Shannock Baptist Church

Source: HMMH, Inc., 1994

TABLE 4.4-16 Potential Train Vibration Impacts under Initial Build Alternative

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
TOTAL CT	**0**	**0**			
South Kingstown	3	0	160.2	117	87
North Kingstown	11	0	162.3-162.4, 166.7, 168.2-168.7	122	92
East Greenwich	29	0	171.4-171.9	98	71
Warwick	192	0	172.2	98	71
			172.3-173.7, 173.9-175.0, 176.0, 176.3-177.0, 177.2-177.6, 178.0-178.6	105	77
Providence	4	0	181.8	78	54
TOTAL RI	**239**	**0**			
Boston	1016	0	227.0-227.5	149	115
TOTAL MA	**1,016**	**0**			
TOTAL CORRIDOR	**1,255**	**0**			

Notes: [1]Distance measured from centerline of outer track.
[2]"C" denotes Church and "S" denotes School.

Source: HMMH, Inc., 1994

TABLE 4.4-17 Potential Train Vibration Impacts under Best-Case Build Alternative

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
Old Lyme	10	0	108.2, 108.6, 108.8, 109.2, 110.6-	87	61
			112.0	65	42
East Lyme	21	0	113.1, 114.3-114.5, 115.1-115.5,	78	54
			116.1	70	46
Waterford	3	0	117.9, 119.5	70	46
New London	8	0	121.6-121.9	60	38
Groton	8	0	129.4, 129.9-130.2	70	46
			131.2, 131.5	74	50
Stonington	50	0	132.8	65	42
			134.3, 135.6-136.1	70	46
			136.5, 139.5, 139.7-140.9	87	61
TOTAL CT	**100**	**0**			
Westerly	6	0	141.8, 142.5, 143.5, 146.0	87	61
Charlestown	0	1C[(1)]	153.3	91	64
Richmond	16	0	149.8, 153.8, 154.4	94	68
			152.9	87	61
South Kingstown	4	0	157.3	122	91
			160.2	117	87
North Kingstown	11	0	162.3-162.4, 166.7, 168.2-168.7	122	92
East Greenwich	29	0	171.4-171.9	98	71
Warwick	192	0	172.2	98	71
			172.3-173.7, 173.9-175.0, 176.0,	105	77
Providence	4	0	181.8	78	54
Central Falls	12	0	190.0, 190.3	60	38
			190.7	78	54
TOTAL RI	**274**	**1C**			
Boston	1016	0	227.0-227.5	149	115
TOTAL MA	**1,016**	**0**			
TOTAL	**1,390**	**1C**			

Notes: [1]Distance measured from centerline of outer track.
[2]"C" denotes Church and "S" denotes School.
[(1)]Shannock Baptist Church

Source: HMMH, Inc., 1994

TABLE 4.4-18 Potential Train Vibration Impacts under Worst-Case Build Alternative

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
New Haven	19	0	73.2	66	1
			73.5	72	22
			74.0	97	42
Branford	17	0	81.8	85	60
			82.6	123	92
			84.4-84.6	137	104
Madison	29	0	91.0-91.6	141	108
			92.0, 92.3	137	104
			93.5, 93.9, 94.6	128	96
Clinton	15	0	95.2	132	100
			96.4, 97.0, 97.1, 97.3, 98.8	140	108
Westbrook	15	0	98.9	137	104
Old Saybrook	2	0	104.0	123	92
Old Lyme	20	0	108.2, 108.6, 108.8, 109.2	123	92
			110.6-111.0	118	88
			112.0	97	70
East Lyme	59	0	113.0-113.5, 114.3-115.5, 116.0	113	84
			116.1	103	75
Waterford	7	0	117.8-118.0, 119.5	103	70
New London	16	0	121.3-121.9	91	65
Groton	14	0	129.4, 129.6, 129.9-130.2	103	75
			131.2, 131.5	108	79
Stonington	97	1C[(1)]	132.8, 134.3, 135.6-136.0	103	75
			136.3	91	65
			136.5, 137.5, 137.6, 139.5, 139.7-140.9	123	92
TOTAL CT	**310**	**1C**			
Westerly	11	0	141.8, 142.5, 143.5, 146.0	123	92
Charlestown	10	1C[(2)]	148.4, 153.0, 153.3	128	96
			152.0	123	92
Richmond	24	0	149.8, 153.8, 154.4	132	100
			152.9	123	92
South Kingstown	13	0	157.1, 157.3	165	128
			159.8-160.6	160	124
North Kingstown	33	0	162.0-162.5, 166.7, 168.1-168.7	166	129
			170.3-170.4	141	108
East Greenwich	51	0	171.3-171.0	137	104
Warwick	254	0	172.1-172.3	137	104
			172.3-173.7, 173.9-175.0, 176.3-177.0, 177.2-177.6, 178.0-178.6	146	112

TABLE 4.4-18 Potential Train Vibration Impacts under Worst-Case Build Alternative (continued)

MUNICIPALITY	POTENTIALLY AFFECTED RECEPTORS		POTENTIALLY AFFECTED AREAS (by milepost)	DISTANCE TO IMPACT ZONE BOUNDARY[1] (ft)	
	Resid.	Other[2]		Resid.	Other
Providence	6	0	181.8	113	84
Pawtucket	4	0	188.4	118	88
Central Falls	36	0	189.8-190.2, 190.3	91	65
			190.7	113	84
TOTAL RI	**442**	**1C**			
Attleboro	180	0	191.5-192.3	150	115
			195.1-195.4, 195.8-196.1, 196.6-197.0, 197.3-198.1	166	129
Mansfield	56	0	200.3, 201.0-201.6, 202.4-202.7, 203.3-203.5, 204.1-204.5	166	129
Foxborough	13	0	205.6, 206.2, 207.0, 207.1-207.2	158	122
Sharon	26	0	208.2, 208.6, 209.0, 209.7, 211.3, 211.4-211.7, 211.9	158	122
Canton	67	0	213.2-213.4, 213.5-213.7	148	114
			214.1-214.3	258	209
			214.5-215.2	238	192
Dedham	45	0	218.5-218.8	270	220
Boston	3130	4S[(3)]	219.5-219.7, 220.1-223.4	280	230
			223.4-224.6	270	220
			225.8-227.0	230	186
			227.0-227.5	198	157
TOTAL MA	**3,517**	**4S**			
TOTAL CORRIDOR	**4,269**	**2C+4S**			

Notes: [1]Distance measured from centerline of outer track.
[2]"C" denotes Church and "S" denotes School.
[(1)]Pentecostal Church of God
[(2)]Shannock Baptist Church
[(3)]Northeastern University, Roxbury Community College, English High School, Weld School

Source: HMMH, Inc., 1994

4.4.4 Summary of Impacts

4.4.4(a) Train Noise Impact

The train noise evaluation indicates that impacts are anticipated primarily at residential locations. Significant impacts at other noise-sensitive sites are expected to be limited to one church and two recreational areas for the No-Build Alternative - FF-125 Scenario and for the Best and Worst-Case Build alternatives. For the Initial Build alternative, noise impact at nonresidential sites is expected to be limited to two recreational areas.

In terms of residential noise impacts, the evaluation projects a total of only 14 residences within the impact zone for the Initial Build alternative, including one in Connecticut, 11 in Rhode Island, and two in Massachusetts. Noise impacts under the No-Build Alternative - AMD-103 Scenario are projected to occur at 67 residences, all in Rhode Island. However, with the anticipated increases in train lengths and frequency of operation, design-year noise impacts are projected at a minimum of 826 residences for the Best-Case Build alternative and at a maximum of 2,243 residences for the Worst-Case Build alternative. Impacts for the No-Build Alternative - FF-125 Scenario are expected to fall in the middle of the range for the three Build cases, with 1,486 residences subject to potentially significant noise impact. In terms of geographical distribution, the greatest percentage of the residential noise impacts are expected in Rhode Island under the No-Build Alternatives - AMD-103 and FF-125 scenarios, Initial Build and Best-Case Build conditions, and in Massachusetts under Worst-Case Build conditions.

4.4.4(b) Train Vibration Impact

The train vibration evaluation indicates that impacts are anticipated primarily at residential locations. Significant impacts at other noise-sensitive sites are expected to be limited to two churches and one school for the No-Build Alternative - FF-125 Scenario, one church for the Best-Case Build alternative, and two churches and four schools for the Worst-Case Build alternative.

In terms of residential vibration impacts, the evaluation projects a total of 369 residences within the impact zone for the No-Build Alternative - AMD-103 Scenario, with all of these located in Rhode Island. Under the No-Build Alternative - FF-125 Scenario, 746 residences are projected to be within the vibration impact zone, with about half of these in Rhode Island and roughly one-quarter each in Connecticut and Massachusetts. For the Initial Build alternative, a total of 1,255 residences are projected to be within the impact zone, including about 80 percent in Massachusetts, 20 percent in Rhode Island, and none in Connecticut. With the anticipated increases in train lengths and frequency of operation, design-year vibration impacts are projected at a minimum of 1,390 residences for the Best-Case Build alternative and at a maximum of 4,269 residences for the Worst-Case Build alternative. In terms of geographical distribution, about 70 to 80 percent of these are in Massachusetts, about 10 to 20 percent are in Rhode Island, and about 5 to 10 percent are in Connecticut.

4.5 MITIGATION MEASURES

This section provides a discussion of potential measures to mitigate the train noise and vibration impacts from the NECIP electrification identified in Section 4.4. While not the only source of noise and vibration impacts, trains do create the overwhelming bulk of the impacts. Mitigation measures capable of addressing noise from electrification facilities and construction-related noise and vibration are thoroughly discussed in Section 4.5 of Volume III of the DEIS/R.

While all of the recommended measures described below are physically possible, it should be noted that factors such as aesthetics and cost-effectiveness should be considered when determining the extent to which mitigation measures are implemented. Thus, more detailed studies should be undertaken during the final design phase of the project, and only those mitigation measures that are found to be reasonable and feasible should be implemented.

Due to the uncertainties in future train equipment and operations, only mitigation for the Initial Build case should be considered at the outset of the project. Beyond this initial mitigation, a train noise and vibration monitoring program should be undertaken to determine when additional mitigation is warranted once the project is underway. The monitoring program should involve performing baseline measurements at representative locations along the corridor, followed by periodic tests to document noise and vibration increases on an ongoing basis. If feasible, mitigation would be provided when these increases exceed the criteria used in this study, based on an implementation priority to be developed as part of the project design work. A representative noise and vibration monitoring program is included in Section 4.7.

4.5.1 Mitigation of Train Noise Impacts

As indicated in Section 4.4, the train noise evaluation projects a total of 14 residences and 2 recreational areas to be within the zone of significant noise impact for the Initial Build scenario; and 2,243 residences, one church, and two recreational areas for the Worst-Case Build scenario. The analysis also indicates that the primary sources of this impact under the Worst-Case are expected to be increased Amtrak train frequency and speed, while projected impact under the Initial Build scenario is primarily due to increased train speed. To address potential impact mitigation, source, path, and receiver noise control measures have been considered as described in the DEIS/R.

Train noise control measures that have been considered include source, path and receiver treatments of varying levels of effectiveness, cost and feasibility. Noise control at the *source* can involve equipment and track maintenance-related measures as well as operational modifications. Maintenance measures cannot always be relied upon to provide the required noise reduction, since the projections of impact are made based on the assumption of reasonably good equipment and track condition, and operational changes such as a reduction in train speed are contrary to the primary objectives of the project.

The installation of wayside noise barriers, designed to block the direct sound *path* between the trains and the noise-sensitive sites along the corridor, is likely to be the most effective measure to mitigate train noise impact. The physical dimensions of each such barrier need to be determined in order to ensure that sufficient noise reduction is attained.

Finally, although noise control at the *receiver* is usually least desirable, it provides an alternative approach in situations where path treatments are not feasible due to aesthetic, cost or other considerations. Potential mitigation measures at the receiver include property acquisition or the application of sound insulation treatment to noise-sensitive buildings within the impact zone. One disadvantage of sound insulation treatment is that it has no effect on noise in exterior areas. However, it may be the best choice for sites where noise barriers are not feasible, and for schools or churches where indoor noise control is most important.

Substantial improvements in building sound insulation (on the order of 5 to 10 dBA) can usually be achieved by adding an extra layer of glazing to the windows, by installing acoustical storm doors, by improving the weather stripping around doors and windows, by sealing any holes in exterior surfaces that act as sound leaks, and by providing forced ventilation and air conditioning so that windows do not need to be opened. Based on experience with residential sound-insulation projects near airports, the cost for such treatment is expected to range between $10,000 and $20,000 per home. If warranted, such treatments will be investigated during the final design phase of the project.

4.5.2 Mitigation of Train Vibration Impacts

As indicated in Section 4.4, the train vibration evaluation projects a total of 1,255 residences to be within the zone of significant impact for the Initial Build alternative, and a total of 4,269 residences, 2 churches, and 4 schools under the Worst-Case Build alternative. All of these impacts are related to annoyance effects and not to building damage effects. The analysis also indicates that the primary sources of this impact are expected to be the increased Amtrak train frequency and speed for the worst case, while increased train speeds only are projected to cause impact under the Initial Build scenario. As for train noise, source, path and receiver vibration impact mitigation measures have been considered as described in the DEIS/R.

Similar to train noise control, train vibration control can be achieved at the source, path or receiver. Since the source of ground-borne vibration is the wheel/rail interaction, vibration reduction at the *source* is essentially limited to equipment and track maintenance-related measures and operational modifications. However, as in the case of train noise mitigation, maintenance alone cannot be relied upon to provide the required vibration mitigation. A reduction in train frequency and speed would also reduce the vibration impact, but such operational measures are not feasible since increased speed and service are among the primary objectives of the project.

Potential *path* vibration control treatments include (1) ballast mats, (2) floating slabs, (3) the use of wood in place of concrete ties, and (4) trenches or underground barriers. These measures are discussed below:

- **Ballast Mats.** Ballast mats typically consist of a 2 to 3-inch-thick elastomer mat placed under the normal track ballast. Most ballast mat installations are supported on concrete foundations in subway tunnels, or on concrete railroad bridges. Although there are some examples of ballast mats being installed for at-grade track, there is limited data on the effectiveness of at-grade installation. However, the available information indicates that ballast mats could reduce vibration levels along the NEC by 3 to 6 dB in some locations, sufficient to eliminate much of the projected vibration impact in those areas.

  The main disadvantage of ballast mats is that they tend to be expensive, particularly for retrofit installations, and are not cost-effective to protect only a few houses.

- **Floating Slabs.** Floating slabs consist of 1-foot-thick or thicker concrete slabs supported by resilient pads on a concrete foundation. The tracks are mounted on top of the floating slabs. Most successful floating slab installations are in subways. To use them with at-grade track, a concrete foundation must first be constructed for the slab to work against.

  Construction of a floating slab track bed is much more expensive than tie and ballast at-grade track construction, even with ballast mats. Therefore, floating slabs are unlikely to be cost effective for this project.

- **Wood vs. Concrete Ties.** There is some evidence that ground vibration levels can be as much as 5 dB lower for trains operating on wood tie and ballast track compared to trains operating on concrete tie and ballast track. However, the measurements made for this project did not indicate any significant difference in ground vibration level based on track usage at NEC locations where one track had wood ties and the other track had concrete ties. Therefore, this is not likely to be an effective vibration impact mitigation measure for this project.

- **Trenches or Underground Barriers.** Although rarely used, a deep trench, 30 to 80 feet deep, can be an effective barrier to ground-borne vibration. The trench can be either open or filled with concrete or similar dense material. However, this is not likely to be a viable option for the NEC.

Of these options, only ballast mats appear to have the potential to provide reliable and effective train vibration impact mitigation.

Practical vibration mitigation measures at the *receiver* are generally limited to property acquisition or the purchase of vibration easements. In cases where ballast mats are not feasible or cost effective, such measures may provide the only possible means for train vibration impact mitigation.

4.6 ADDITIONAL NOISE CONSIDERATIONS

4.6.1 Potential Effectiveness of Noise Barriers

Noise barriers are walls designed to interrupt the path between a source of noise and a receiver, forcing the sound energy to take an indirect path which is longer and which may involve some energy-absorbing reflections. In order to be acoustically effective, a noise barrier must be a solid, unbroken wall with sufficient height and length to break the line of sight of the entire noise source, and must be made of material heavy enough to limit the transmission of sound energy. Breaking the line of sight of noise sources of a train requires the noise barrier to be high enough to hide the wheels and undercarriage of all cars in an electric train and the exhaust stack of the diesel locomotives, and long enough to hide a significant portion of the train consist.

Figure 4.6-1 shows how the height of a noise barrier is important in blocking the noise from a locomotive. As shown in the figure, a hypothetical noise barrier is interposed between the locomotive and a person. The barrier with height "A" blocks the sound from the wheels but allows the diesel exhaust sound to pass over the barrier, whereas the barrier with height "B" screens out both wheel/rail noise and the exhaust noise. Ideally, the barrier is located close to the source so that it can serve to block the sound from getting to upper stories of nearby buildings. In situations where the receiver is a first-floor residence, or is a person outdoors in his/her yard, a noise barrier would be effective if it could be placed at the receiving property line instead of along the tracks. The length of a barrier must be such that more than half the train length is hidden by a barrier, and that its endpoints are at a location that makes an angle of 60 degrees or more from the perpendicular line between the last protected building and the tracks. The "solid unbroken wall" requirement rules out many common privacy fences with gaps between boards, or between the ground and the lower edge.

The material requirements are generally met by wood, metal, or precast concrete panels with a minimum surface density of 4 lb/square foot. Special care must be taken to seal all joints, drainage gaps, and supports to prevent any direct openings that could compromise the sound transmission characteristics of the barrier. Additional strength and material requirements must be met to ensure the structure can withstand wind loads and other environmental effects.

Noise barriers typically reduce noise at the receiver by 5 to 15 decibels depending on the geometry of the source-receiver configuration. A barrier that just breaks the line of sight to the top of train wheels of an electric train (no diesel exhaust stack), for example, will provide about 5 dB reduction. Such a barrier is typically 6 to 8 feet above ground level at the ROW line, allowing for the height of the track bed. A full 15 dB reduction is possible only by hiding most of the height and length of the electric train, which would require a 12- to 15-foot-high structure. Shielding a diesel locomotive requires an even higher barrier, 15 to 17 feet tall to shield the exhaust stack, which is located approximately 15 feet above top-of-rail. Terrain features, limitations in ROWs, or unacceptable visual blockage are some factors that can make it difficult or impossible to place a noise barrier in an optimal location to achieve the desired noise reductions. In such cases, the choice is either to adopt a suboptimal design or to judge the mitigation infeasible.

4.6.2 Train Noise Evaluation Criteria

The noise impact criteria for train operations are based on comparison of projected future noise levels from NEC train operations with existing conditions at noise sensitive locations. These criteria are based on those proposed by the U.S. Federal Transit Administration (FTA) for assessing noise impact from rail transportation operations. The FTA criteria were developed from the considerable body of research on human response to community noise conducted by EPA and HUD.

The noise descriptors and associated impact criteria depend on land use. The noise descriptors used in this assessment are either the 24-hour equivalent sound level, $L_{eq}(24)$, or the day-night sound level, L_{dn}, depending on land use activity. These descriptors correlate well with the overall effects of noise on people and are the environmental noise measures recommended by EPA. Both of these measures represent the total dose of noise energy at a given outdoor location over a 24-hour period in terms of the A-weighted sound level (dBA). L_{eq} (24) is applied to noise-sensitive land uses where sensitivity does not depend on the time of occurrence, such as schools, places of worship, and recreational areas. L_{dn} includes an added 10-decibel weighting imposed on sound levels occurring during the nighttime and is used for residences, hospitals, and other buildings where people sleep.

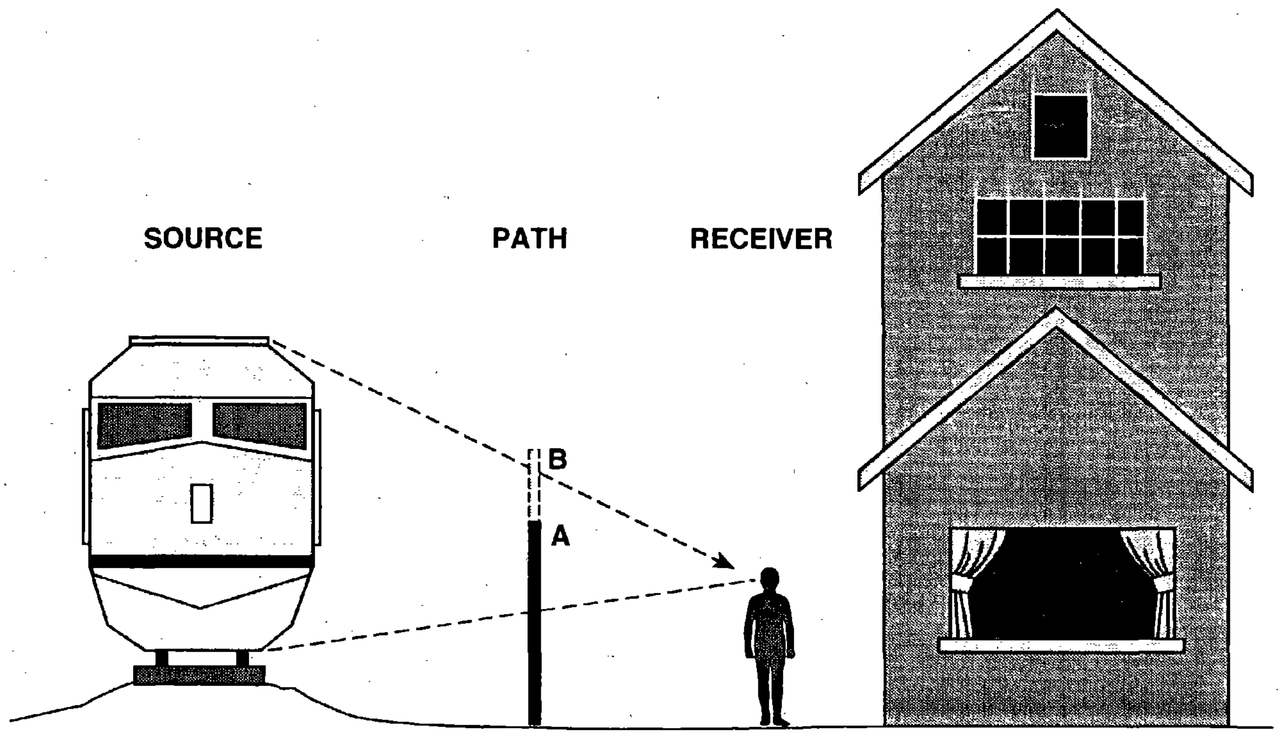
The criteria allow less of a noise increase in already noisy areas than in areas where the existing noise levels are lower. This concept is a result of research showing that people already exposed to high levels of noise will notice and be annoyed by even a small increase in the cumulative noise in their community; where existing noise levels are low, a greater change in the community noise will be required for the equivalent degree of annoyance. The allowable increases in $L_{eq}(24)$ are greater than the allowable increases in L_{dn}; this is to account for the lower noise sensitivity at sites with daytime use only, where $L_{eq}(24)$ would be applied as a measure of noise impact.

4.6.3 Potential Mitigation Measures for Facility Noise Impact

Noise from fixed facilities associated with the electrification emanates from transformers and ventilation equipment. Although the noise levels from these facilities are generally low compared with train-generated noise sources, they are nearly continuous and contain tonal components which can be obtrusive especially at night when ambient noise is low. Consequently, the siting of these facilities must take into account their proximity to noise-sensitive residential areas and, in special cases, individual homes. To minimize noise impact, the first step in final design is to orient the transformers and fan discharges away from noise-sensitive receivers, if possible. Where fan discharge orientation does not eliminate impact, fan silencers can be installed and exit ducts can be hidden behind baffles. Transformers out in the open radiate noise in all directions. Where there is expected to be noise impact in a particular direction, a sound barrier wall would be built along the boundary on that side, or around the perimeter, if necessary. Walls with special sound-absorptive surfaces are especially effective against the pure tones radiated by transformers and their cooling fans. These surfaces can be either sound-absorptive blanket material, suitably protected from the weather, or specially cast block surfaces with resonator absorbers tuned to the tonal frequencies generated by the transformers. Site-specific plans would be reviewed for application of these treatments during final design.

4.6.4 Potential Mitigation Measures for Construction Noise Impact

Although many of the construction activities associated with electrification of the NEC would generate short periods of high noise levels, only the longer-term activities, those that would last for 30 days or more, are considered as candidates for causing impact. For example, although setting the catenary poles and stringing wire would take place at night for the most part, these activities would remain in one place for only a few hours at a time, not long enough to be considered a noise impact. Advance notice would be given to all nearby residences when any nighttime construction takes place.



SCHEMATIC SHOWING REQUIRED HEIGHT OF NOISE BARRIER

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure
4.6-1

Activities that could have the potential for noise impact are identified for the construction of fixed facilities and for the modifications at bridges. The fixed facilities would be new electrical substations and paralleling stations. Construction of electrical substations is expected to last approximately 4 months at each site, with activities such as clearing, foundation work, equipment delivery and installation, and finishing. Equipment expected to be used includes graders and bulldozers for clearing, backhoes for foundation work, and cranes and trucks for equipment delivery and installation. Construction at paralleling stations would encompass similar activities over a shorter period of 2 to 3 months. No construction is expected during nighttime hours. Residential areas within 180 feet of the site are estimated to be exposed to an average workday L_{dn} noise level greater than the 75 dBA impact criterion.

Modifications are expected at numerous overhead bridge locations to provide the necessary clearance for catenary installation. Three types of modification would be required, depending on the location: (1) bridge raising, (2) bridge replacement, or (3) bridge undercutting. These are fairly major construction activities, ranging in time from 4 days for undercutting to 4.5 months for replacement. Construction activities associated with raising and replacement would be confined to daylight hours, but undercutting takes place within the rail ROW and would be done generally at night. Residential areas are projected to be exposed to an average workday L_{dn} noise level greater than the 75 dBA impact criterion if they are within 140 feet for bridge raising, 280 feet for bridge replacement, and 320 feet for bridge undercutting.

Noise abatement for construction activities falls into two categories: source control and path control. Noise control at the source of noise requires contractors to maintain equipment in good operating condition, to use the quietest available equipment that meets the requirements of the task, and to avoid working during the sensitive nighttime hours. Examples of source controls include providing effective mufflers on all internal combustion engines and installing covers and shields in place on stationary equipment. In all cases of fixed facility construction, the contractor would be required to meet noise specifications in the contract documents to ensure that the equipment would not be excessively noisy, and restrictions would be placed on operations during the nighttime hours of 10 PM and 7 AM where local ordinances prohibit such activity. For bridge undercutting, much of the work would be done at night. As with catenary pole setting and wire stringing, the activity would last for a period less than 30 days and therefore would not be considered for noise impact. However, advance warning would be given to all nearby residents preceding commencement of the work.

Noise control along the sound path between the source and the receiver involves breaking the path with a solid wall or earth berm to create a "shadow zone" where noise is reduced. In some locations, it may be practical for contractors to install temporary noise barriers to shield nearby residences from noisy construction activities. Contractors would be required to locate fixed equipment, such as air compressors and generators, as far away from residences as practical.

4.6.5 Effects of NECIP on Noise from Regional Air Traffic

NECIP, when complete, is projected to draw some of its ridership from air travelers along the NEC, causing a small decline in air traffic at several airports from Boston to New York. These effects on aircraft operations have been forecast separately for the air routes between Boston and New York and between Providence and New York and are reported in a document entitled *Northeast Corridor Improvement Project Electrification - New Haven, CT to Boston, MA*, subtitled *Aircraft Fleet Projections for the Boston-New York Corridor*.[20] Tables One and Two of the report summarize these forecasts for the year 2010 and indicate that jet operations between Boston and New York (LaGuardia and Newark Airports combined) are expected to decrease by 43 flights per day, while jet operations on the Providence-New York route are expected to be reduced by two flights per day. (An additional reduction of flights by quieter turboprop aircraft operated by commuter airlines is also forecast to occur on the Providence-New York route but does not materially affect any discussion of noise in this FEIS/R.)

To estimate the noise benefits of these reduced numbers of flights for residents in the vicinity of the affected airports along NECIP, these changes in aircraft operations must be viewed in the context of total airport activity at each facility. Four airports are addressed here: Boston's Logan International Airport, Providence's T.F. Greene Airport, and the two New York area airports -- LaGuardia and Newark. New York's Kennedy International Airport operates primarily as an international gateway and is not expected to lose significant numbers of air travelers due to improved train service. Of the others, the most straightforward to address is Logan.

In June 1993, the Massachusetts Port Authority (Massport) published a detailed series of forecasts for Logan Airport for the year 2010. Entitled *Logan Growth & Impact Control Study -- Phase II Final Report,*[21] the report identifies the most likely growth scenario, assuming no major improvement to the NEC rail lines. The forecast, included in Table 3-6 of the report, indicates that total jet traffic (passenger and cargo activity combined) is expected to reach 340,573 operations per year, or approximately 933 jet operations per day. Noise exposure from this activity was quantified this report using a metric known as the Cumulative Noise Index, or CNI, developed by Massport and codified in Logan's Noise Abatement Rules and Regulations. CNI is a measure of the total noise of the fleet of aircraft using the airport over the course of a year, and is directly proportional to the numbers of operations, the noisiness of each aircraft, and the number of night flights that occur during the period. Decreases in any one of these will cause the CNI to decrease, generally reflecting an overall improvement in the noise environment.

For the 2010 forecast operations in the Harris report, the projected CNI was computed to be 156.3 dB, one dB higher than the present (1993) level of 155.3 due to a combination of increased operations and increased activity at night projected over the next 15 to 20 years. In contrast, the projected reduction of 43 flights per day expected to occur in 2010 with improvements to the rail corridor decreases the CNI value to 156.1 decibels. The 0.2 dB reduction is considered minimal and probably an unnoticeable change in overall noise for people living near the airport. In essence this is because the total jet traffic on the Boston-New York route constitutes less than 15 percent of the total jet traffic in and out of Logan, and the change in flights attributable to NECIP is only about 3 percent of Logan's total traffic. Remaining aircraft will overshadow any benefit derived from decreased air traffic due to improved rail service.

This same conclusion is expected at T.F. Greene Airport and at LaGuardia and Newark. Although detailed forecasts for these facilities are not available for the year 2010, the reduction of two flights at Providence and 45 flights at the two New York airports from improved rail service on the NEC represent only small fractions of each airport's current total jet traffic. Considering future operations are only expected to increase, the overall benefit to noise exposure from the small reduction in air traffic at these airports would be minimal.

4.7 NOISE AND VIBRATION MONITORING AND TEST PROGRAMS

4.7.1 Introduction

This section outlines representative monitoring programs for noise and ground-borne vibration from train operations along the NEC, as well as a test program to evaluate the effectiveness of ballast mats as a measure to mitigate vibration impacts. A number of areas were identified where future noise and vibration levels may exceed the impact criteria for one or more of the alternatives that were evaluated. The alternative with the highest potential noise and vibration impact assumed use of existing electric train equipment as well as significant increases in train speed and volume on the NEC. Given the projected impacts from this alternative, it is deemed unlikely that FRA would permit such equipment to be utilized as envisioned. If this equipment were to be used, however, the projected levels of impacts would not be reached until sometime in the future.

Extensive noise and vibration mitigation measures may be needed when NEC operations approach the maximum projected volumes and speeds assumed in the Worst-Case Build alternative. However, initially the noise and vibration levels would be only marginally higher than they are now. The main purpose of the monitoring plans outlined here is to provide a method to determine when noise and vibration levels have reached the point where installing mitigation measures is warranted. Furthermore, although the proposed noise mitigation treatments (barriers or building sound insulation) are well-understood approaches to noise control, the proposed use of ballast mats for vibration impact mitigation is not a proven measure for at-grade railroad applications. Therefore, a test program to evaluate the effectiveness of at-grade ballast mats is also outlined below.

4.7.2 Noise Monitoring

The primary steps could be as follows:

- *Select Sites for Monitoring:* A reasonable approach is to select at least one site for each area where mitigation is expected to be needed, focusing on areas with the largest amount of potential impact. Where sites are close enough together, it will be possible to use one measurement location for several impact areas. Some type of cost effectiveness criterion should also be considered. For example, if only one residence is affected, and mitigation would probably require a 500-foot wall, it may be reasonable to eliminate the area from consideration because mitigation would clearly not be cost effective.

  A suggested guideline is to select sites along track segments with constant characteristics (i.e., train speed, schedule) where, for the worst-case conditions, noise impact is projected for more than 10 residences or other noise-sensitive land uses. Based on the FEIS/R assessment of noise impact, it is estimated that this would require approximately 50 monitoring sites.

- *Measure Baseline Noise Conditions:* This would consist of a series of measurements to establish the baseline noise before the electrification process is initiated. At each site, measurements should be made for a minimum of one 24-hour period during the week to determine the L_{dn} and $L_{eq}(24)$. The measurements should be made during a period when it can be verified that the train operations are normal. It would be an advantage to increase the duration of the measurements to 2 or more days to increase measurement accuracy. This could be particularly valuable if the levels are near the impact threshold.

  The measurement protocol should be designed to make sure that other noise sources do not contaminate the measurement of train noise; this is unlikely to be a problem as long as the measurement sites are close enough to the tracks and not immediately adjacent to major highways or other noise sources. Since train noise is of concern, the noise data should be correlated with the train passages, which could be a labor-intensive task. The measurement team should coordinate with Amtrak before the measurements to make sure that no unusual activities, such as track maintenance, are planned and to confirm after the measurements that the measurement period was representative.

- *Conduct Periodic Measurements:* It is recommended that noise measurements be done at least once every 12 to 18 months, using the same procedures as for the baseline measurements. In addition, measurements should be done after any modifications (change in train equipment, increase in scheduled trains, raising speed limit, etc.) that may cause increased noise levels.

- *Analyze Measurements and Prepare Summary Report:* This would include analyzing and reporting the field data, and determining whether the impact criteria are being exceeded based on a comparison with baseline noise levels. A summary report should be prepared at the end of each measurement phase that includes a table of the measured L_{dn} and $L_{eq}(24)$ values, highlighting any sites where the measured levels exceed the impact threshold. The detailed results of the measurements, including hourly L_{eq} and percentile levels, should also be included in the summary report.

4.7.3 Vibration Monitoring

A vibration monitoring program could be carried out in a manner similar to the noise monitoring program. The main difference between the two would be the measurement instrumentation and analysis procedure. It is recommended that seismograph-type vibration monitors be used at one representative location for each potential mitigation site. Vibration should be monitored in terms of either the component or vector-sum peak particle velocity for all train passages that occur over a minimum period of 24 hours. If the average peak particle velocity for trains over this time period exceeds the average baseline value by 25 percent or more, or if the number of train events exceeds the baseline number by 100 percent or more, then vibration mitigation would be warranted.

4.7.4 Tests to Evaluate Ballast Mat Effectiveness

4.7.4(a) Ballast Mat Testing

Tests of a ballast mat trial section should be made to evaluate the effectiveness of this treatment as a function of vibration frequency. The tests should be conducted somewhere on the NEC, or at a suitable test site such as the U.S. Department of Transportation Test Center at Pueblo, Colorado. The tests should include measurements of vibration levels before and immediately after the mat is installed. Following are specific recommendations for vibration testing of a ballast mat test installation:

- *Test Installation:* The minimum length of a test installation should be about 300 feet, and it should be located so there will be a suitable area for vibration testing near the center of the installation.

- *Test Site:* The ideal test site will have a relatively open area near the center of the test section so that vibration sensors can be located at various distances from the tracks. Although it is theoretically sufficient to measure at only one distance from the tracks, experience has shown that it is far preferable to have measurements at several distances. At least four positions are recommended with the closest position 15 to 25 feet from the near track and the far position 100 to 200 feet from the near track.

- *Test Procedure:* Because of the normal variability of ground-borne vibration, the best indication of ballast mat performance will be obtained if as many variables as possible are kept the same. These would include: measuring before and after in the same locations; making sure that the track condition including wear patterns, profile and gage are as similar as possible for both tests; and measuring a sufficient number of trains to give a statistically valid indication of the before-after vibration differences. Although a dedicated test train would allow doing the tests in a controlled fashion, the results could be skewed by a change in the wheel condition between tests. It is recommended that normal in-service trains be used for the vibration measurements. This will require a minimum of one day for each set of tests.

  Because of the difficulty in isolating the cause for changes in levels of ground-borne vibration, it is advantageous to measure at more than one location, even if the locations are relatively close together. This would mean measuring in two perpendicular lines from the tracks, with at least four accelerometers on each line. The two lines could either be on opposite sides of the track or on the same side separated by 50 to 100 feet.

The measurements would be made using accelerometers mounted vertically on the ground surface with the train vibration data recorded on magnetic tape for laboratory analysis. The recorded train data should be analyzed to obtain spectra for maximum rms train vibration velocity level in one-third octave bands in the frequency range of 5 Hz to 200 Hz. The rms averaging time should be about 20 percent less than the time it takes for trains to pass the measurement position.

- *Before Tests:* The vibration measurements before the installation of the ballast mat should be done within a couple of weeks of when the ballast mat is installed. At the same time, the track should be carefully inspected for wear, and the track gage and profile should be checked.

- *After Tests:* It would be ideal if the after tests could be done within a couple of weeks of completion of the installation. At the same time as the tests, the inspection and measurements of the track should be repeated. The purpose of this is to try to verify that track conditions are substantially the same for the before and after tests.

- *Evaluation of Results:* The effectiveness of the ballast mat installation should be evaluated in terms of the difference in the before and after vibration levels, normalized to the same train speed, in one-third octave frequency bands.

4.7.4(b) Site Vibration Testing

For any area where it is decided that vibration mitigation is warranted, a vibration test should be performed prior to installing the mat to determine whether the site conditions are such that the mat will be effective. The test procedure should be similar to that for the ballast mat tests described above. The effectiveness of ballast mats for a given site would be evaluated by applying the vibration reductions obtained from the ballast mat tests to the ground vibration levels obtained during the site tests, in one-third octave bands, and by combining the one-third octave band results to calculate the overall reduction in vibration velocity level. If the calculated overall reduction in vibration velocity level is less than 2 decibels, the use of ballast mats is not likely to be effective at the site.

ENDNOTES

1. Harris Miller Miller & Hanson Inc. *ICE Trainset Noise and Vibration Measurements*. Report No. 292340.07, December 1993.

2. Ibid.

3. U.S. Department of Transportation. *Draft Environmental Impact Statement/Report, Northeast Corridor Improvement Project Electrification - New Haven, CT to Boston, MA*, Volume III, Technical Study 4 - Noise and Vibration, Report No. DOT-FRA-RDV-93-01-C/DOT-VNTSC-FRA-93-9.111, Federal Railroad Administration, September 1993.

4. Rathe, E.J. "Railway Noise Propagation," *Journal of Sound and Vibration*, Vol. 51, No. 3, pp. 371-388. 1977.

5. Wilson, G.P., J.T. Nelson, and H.J. Saurenman. *Handbook of Urban Rail Noise and Vibration Control*. U.S. Department of Transportation, Urban Mass Transportation Administration Report No. UMTA-MA-06-0099-82-1 and DOT-TSC-UMTA-81-72, October 1982.

6. Harris Miller Miller & Hanson, Inc., op. cit.

7. The curve for AEM7 in Figure 4.1-8 differs slightly from that shown in Figure 4.1-9. The generalized model used in the DEIS (Figure 4.1-8) was a result of many data points obtained at several locations along the NEC, while the curve in Figure 4.1-9 represents data gathered at only one measurement site.

8. Harris Miller Miller & Hanson, Inc., op. cit.

9. U.S. Department of Transportation, op. cit.

10. Hanson, C.E. "Measurements of Noise from High Speed Electric Trains in the United States Northeast Railroad Corridor," *Journal of Sound and Vibration*, 66(3), 467-471. 1979.

11. Harris Miller Miller & Hanson, Inc. op. cit.

12. EPA. U.S. Environmental Protection Agency. *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*. Report No. 550/9-74-004, March 1974.

13. FTA. U.S. Department of Transportation. *DRAFT: Guidance Manual for Transit Noise and Vibration Impact Assessment*. Federal Transit Administration Report No. UMTA-DC-08-9091-90-1, July 1990.

14. The SEL is a time-integrated, A-weighted sound level for a single event that is equivalent in magnitude to a reference signal with a duration of 1 second. SEL provides a measure that accounts for both the magnitude and duration of a single noise event and that can be used to calculate the contribution of such events to the overall noise environment.

15. Rathe, E.J. "Railway Noise Propagation," *Journal of Sound and Vibration*, Vol. 51, No. 3, pp. 371-388, 1977.

Wilson, G.P.; J.T. Nelson; and H.J. Saurenman. op. cit.

16. FTA, op. cit.

17. Hanson, C.E. op. cit.

18. National Railroad Passenger Corporation (Amtrak). *Train Performance Calculations*. Computer simulations dated 28 April 1992, transmitted by J. Popoff of Amtrak to G. Goulet of the Volpe Center on October 3, 1992.

19. FTA, op. cit.

20. Dayl Cohen Associates. *Northeast Corridor Improvement Project Electrification -- New Haven, CT to Boston, MA,* subtitled *Aircraft Fleet Projections for the Boston-New York Corridor*. May 7, 1993.

21. F.R. Harris. *Logan Growth & Impact Control Study -- Phase II Final Report*. June 1993.

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Barry, T.M. and J.A. Reagan. *FHWA Highway Traffic Noise Prediction Mode.* U.S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-77-108, December 1978.

National Railroad Passenger Corporation (Amtrak). *Attachment IV, Power Systems Specifications, New Haven-Boston Electrification Project.* Issued on November 26, 1991, and revised on January 6, 1992.

U.S. Department of Transportation. *Northeast Corridor Improvement Project Final Programmatic Environmental Impact Statement.* Federal Railroad Administration, Document No. FRA-RNC-EIS-77-01-F, June 30, 1978.

APPENDIX 4A

TABLE 4A-1 Summary of A-Weighted Noise Level Results

SITE	DATE	TIME	TRAIN NO.	TYPE	DIR	TRACK	SPEED	COMMENTS	DIST	RIGHT SIDE OF TRAIN			LEFT SIDE OF TRAIN		
										SEL	Lfmax	Lsmax	SEL	Lfmax	Lsmax
1	3/30/94	06:24	242	RTL	SB	2	43		50	90.2	87.5	84.0	--	--	--
1	3/30/94	07:05	246	RTG-II	SB	1	42	horn	36	--	--	--	--	97.5	--
									86	--	--	--	99.7	92.9	91.0
1	3/30/94	07:49	248	RTL	SB	2	44		50	--	--	--	--	90.5	--
									100	--	--	--	90.1	84.0	82.1
1	3/30/94	09:11	250	RTL	SB	1	32		36	--	--	--	--	93.5	--
									86	--	--	--	90.1	83.8	82.1
1	3/30/94	10:31	284	RTL	SB	2	44	horn @ start	50	--	--	--	--	89.0	--
									100	--	--	--	87.9	82.3	80.6
2	3/30/94	19:42	287	RTL	NB	0	83		50	--	96.5	--	--	--	--
									100	90.7	86.6	84.6	--	--	--
2	3/30/94	20:15	265	RTL	NB	0	81		50	--	92.5	--	--	--	--
									100	87.7	84.0	81.6	--	--	--
3	3/31/94	06:25	242	RTL	SB	2	40		50	--	87.0	--	--	--	--
									100	88.7	85.3	82.5	--	--	--
3	3/31/94	07:06	246	RTL	SB	2	45		50	--	85.0	--	--	--	--
									100	85.9	82.6	79.7	--	--	--
3	3/31/94	07:50	248	RTL	SB	2	45		50	--	87.0	--	--	--	--
									100	86.2	81.4	79.1	--	--	--
3	3/31/94	09:09	250	RTG-II	SB	2	44		50	--	95/5	--	--	--	--
									100	87.9	82.1	81.4	--	--	--
3	3/31/94	10:39	284	RTL	SB	2	36		50	--	84.5	--	--	--	--
									100	86.3	83.3	80.2	--	--	--

TABLE 4A-1 Summary of A-weighted Noise Level Results (Continued)

SITE	DATE	TIME	TRAIN NO.	TYPE	DIR	TRACK	SPEED	COMMENTS	DIST	RIGHT SIDE OF TRAIN			LEFT SIDE OF TRAIN		
										SEL	Lfmax	Lsmax	SEL	Lfmax	Lsmax
4	3/31/94	17:20	255	RTL	NB	1	67	Right side n.g.	50	--	--	--	93.1	89.9	87.5
									100	--	--	--	--	--	--
4	3/31/94	18:40	263	RTL	NB	1	56		50	--	--	--	96.3	95.1	91.0
									100	92.6	88.7	86.7	--	--	--
4	3/31/94	19:21	287	RTG-II	NB	1	56		50	--	97.5	--	99.1	89.9	87.5
									100	94.2	88.7	86.7	--	--	--
4	3/31/94	19:55	265	RTL	NB	1	57		50	--	94.5	--	94.5	91.2	89.3
									100	89.7	86.3	83.8	--	--	--
4	4/1/94	06:30	242	RTL	SB	2	38		50	88.0	84.6	82.5	87.8	88.0	83.8
									100	--	--	--	87.3	83.4	81.7
4	4/1/94	07:09	246	RTL	SB	2	46	horn after	50	96.3	95.6	91.7	93.4	89.6	87.2
									100	--	--	--	90.3	86.1	84.7
4	4/1/94	07:51	248	RTL	SB	2	50		50	94.6	90.7	88.8	91.8	89.1	86.7
									100	--	--	--	88.7	86.2	83.5
4	4/1/94	09:12	250	RTL	SB	2	52		50	92.0	87.4	85.5	89.7	87.1	84.7
									100	--	--	--	84.2	80.6	78.6
4	4/1/94	10:23	284	RTG-II	SB	2	55		50	100.0	96.6	94.8	97.3	93.3	91.8
									100	--	--	--	91.3	86.8	85.5

Note: Track 1 is NB track (land side)
Track 2 is SB track (river side)
Single track at Site 2

Source: HMMH, Inc., 1993

APPENDIX 4B
TRAIN NOISE MODEL

This appendix summarizes the mathematical model used to develop a general model of train noise that is based on available measurements. The same basic model can be used for all types of trains including the diesel-hauled Amtrak, commuter and freight trains, the electric locomotive-hauled trains (AEM7, X2000, ICE) and the gas turbine-powered RTL trainset. Given the L_{Smax} of a train passby under a specific set of reference conditions, the model allows for estimating L_{Smax}, SEL and other energy-based noise metrics for varying distance from the track, train speeds, train consists and schedules. The standard approach is to model rail cars as moving, incoherent, dipole line sources. This model is described by the following equations:

$$L_{Smax} = K + 10\log\left[\alpha + \frac{\sin(2\alpha)}{2}\right] - 10\log(y) + K_s - c_g - c_a - c_s$$

$$K = L_{Smax\text{-}ref} - 10\log\left[\frac{\alpha + \sin(2\alpha_{ref})}{2y_{ref}}\right]$$

$$SEL = L_{Smax} + 10\log\left[\frac{len}{v}\right] - 10\log\left(2\alpha + \sin(2\alpha)\right) + 3.3$$

For locomotives, which can be modeled as moving monopole point sources, the corresponding equations are as follows:

$$L_{Smax} = K + 10\log(2\alpha) - 10\log(y) + K_s\log\left[\frac{s}{s_{ref}}\right] - c_g - c_a - c_s$$

$$K = L_{Smax\text{-}ref} - 10\log\left[\frac{2\alpha_{ref}}{y_{ref}}\right]$$

$$SEL = L_{Smax} + 10\log\left[\frac{len}{v}\right] - 10\log(2\alpha) - 3.3$$

The parameters which apply to the equations above are:

y	=	*observer distance from track centerline, feet*
y_{ref}	=	*reference observer distance from track centerline, feet*
len	=	*train length, feet*
len_{ref}	=	*reference train length, feet*
α	=	$\tan^{-1}(len/2/y)$
α_{ref}	=	$\tan^{-1}(len_{ref}/2/y_{ref})$
s	=	*train speed, feet/second*
s_{ref}	=	*reference train speed, feet/second*
v	=	*train velocity, mph*
L_{Smax}	=	*maximum sound level during train passby, dBA*
$L_{Smax\text{-}ref}$	=	L_{Smax} *during train passby with reference conditions, dBA*
K_s	=	*speed-dependency coefficient (dimensionless)*
c_g	=	*excess ground attenuation, dBA*

c_a = *excess air absorption, dBA*
c_s = *excess shielding attenuation, dBA*

Standard reference source levels were developed for locomotives and rail cars based on the source noise measurements of each equipment type performed for this project. The above model was first used to predict the L_{Smax} and SEL for the observed trains, using available reference level data from the literature and/or other sources wherever possible. The reference levels were then adjusted to minimize the discrepancies between energy-average predicted and measured noise levels. The results of this procedure yielded the source reference levels given in Table 4.B-1.

The above discussion has concentrated on noise levels for single train passages. However, to project the overall daily noise exposure, the noise from all train operations that occur over a 24-hour period must be combined. The SEL, which is a measure of the total sound energy received from a single event such as a train passage, is used as the basis for computing the Day-Night Sound Level (L_{dn}) and the 24-hour Sound Level ($L_{eq}24$). These are given by the following equations:

$$L_{dn} = SEL + 10 \log (N_d + 10 N_n) - 49.4$$

$$L_{eq}(24) = SEL + 10 \log (N_d + N_n) - 49.4$$

where:
N_d = *number of daytime trains per day*
N_n = *number of nighttime trains per day*

The basic train noise model described in this Appendix provides a means for projecting train noise at close range under standard conditions. However, it does not take into account the excess sound attenuation at greater distances due to ground effects, atmospheric absorption or shielding. Furthermore, it does not account for the additional noise generated by trains in the vicinity of grade crossings or special trackwork.

TABLE 4B-1 Source Reference Levels for Train Noise Model

TYPE OF TRAIN	TYPE OF VEHICLE	TRAIN NOISE SOURCE REFERENCE QUANTITIES				
		Distance y_{ref} (ft)	Length len_{ref} (ft)	Speed s_{ref} (ft/sec)	Noise Level $L_{Smax\text{-}ref}$ (dBA)	Speed Coeff. K_s
Amtrak F40PH (Diesel)	Locomotive	50	56	73.3	91	10
	Rail Car	50	85	73.3	81	30
Commuter (Diesel)	Locomotive	50	60	73.3	91	10
	Rail Car	50	85	73.3	84	30
Freight (Diesel)	Locomotive	50	60	73.3	86	10
	Rail Car	50	70	73.3	81	30
Amtrak AEM7 (Electric)	Locomotive	50	51	73.3	85	35
	Rail Car	50	85	73.3	81	30
X2000 (Electric)	Locomotive	50	58	73.3	82	35
	Rail Car	50	80	73.3	80	30
ICE (Electric)	Locomotive	50	68	73.3	78	35
	Rail Car	50	87	73.3	78	30
RTL (Gas Turbine)	Locomotive	50	57	73.3	87	25
	Rail Car	50	84	73.3	80	30

Source: HMMH, Inc., 1993

APPENDIX 4C
SUMMARY OF RMS VIBRATION VELOCITY LEVEL RESULTS

TABLE 4C-1 Summary of rms Vibration Velocity Level Results - Re 1μ in/sec

SITE	DATE	TIME	TRAIN NO.	TYPE	DIR	TRACK	SPEED	DIST	LV-MAX (dB)
2	3/30/94	19:42	287	RTL	NB	0	83	25	86.1
2	3/30/94	19:42	287	RTL	NB	0	83	50	89.9
2	3/30/94	19:42	287	RTL	NB	0	83	75	83.9
2	3/30/94	19:42	287	RTL	NB	0	83	100	84.1
2	3/30/94	19:42	287	RTL	NB	0	83	150	78.5
2	3/30/94	20:15	265	RTL	NB	0	81	25	86.2
2	3/30/94	20:15	265	RTL	NB	0	81	50	90.0
2	3/30/94	20:15	265	RTL	NB	0	81	75	83.5
2	3/30/94	20:15	265	RTL	NB	0	81	100	85.0
2	3/30/94	20:15	265	RTL	NB	0	81	150	78.2
4	3/31/94	17:20	255	RTL	NB	1	67	25	89.2
4	3/31/94	17:20	255	RTL	NB	1	67	50	86.6
4	3/31/94	17:20	255	RTL	NB	1	67	75	81.4
4	3/31/94	17:20	255	RTL	NB	1	67	100	76.9
4	3/31/94	17:20	255	RTL	NB	1	67	150	72.6
4	3/31/94	18:40	263	RTL	NB	1	56	25	89.0
4	3/31/94	18:40	263	RTL	NB	1	56	50	86.9
4	3/31/94	18:40	263	RTL	NB	1	56	75	82.8
4	3/31/94	18:40	263	RTL	NB	1	56	100	79.8
4	3/31/94	18:40	263	RTL	NB	1	56	150	73.3
4	3/31/94	19:21	287	RTG-II	NB	1	56	25	87.9
4	3/31/94	19:21	287	RTG-II	NB	1	56	50	83.4
4	3/31/94	19:21	287	RTG-II	NB	1	56	75	79.5
4	3/31/94	19:21	287	RTG-II	NB	1	56	100	76.5
4	3/31/94	19:21	287	RTG-II	NB	1	56	150	71.3
4	3/31/94	19:55	265	RTL	NB	1	57	25	88.6
4	3/31/94	19:55	265	RTL	NB	1	57	50	86.5
4	3/31/94	19:55	265	RTL	NB	1	57	75	81.7
4	3/31/94	19:55	265	RTL	NB	1	57	100	76.6
4	3/31/94	19:55	265	RTL	NB	1	57	150	72.7
4	4/1/94	06:30	242	RTL	SB	2	38	25	--
4	4/1/94	06:30	242	RTL	SB	2	38	50	--
4	4/1/94	06:30	242	RTL	SB	2	38	75	--
4	4/1/94	06:30	242	RTL	SB	2	38	100	--
4	4/1/94	06:30	242	RTL	SB	2	38	150	--

TABLE 4C-1 Summary of RMS Vibration Velocity Level Results - Re 1μ in/sec (Continued)

SITE	DATE	TIME	TRAIN NO.	TYPE	DIR	TRACK	SPEED	DIST	LV-MAX (dB)
4	4/1/94	07:09	246	RTL	SB	2	46	25	83.0
								50	81.1
								75	77.5
								100	76.1
								150	--
4	4/1/94	07:51	248	RTL	SB	2	50	25	83.8
								50	80.9
								75	75.8
								100	72.7
								150	--
4	4/1/94	09:12	250	RTL	SB	2	52	25	83.2
								50	79.0
								75	75.2
								100	73.5
								150	--
4	4/1/94	10:23	284	RTG-II	SB	2	55	25	83.6
								50	79.1
								75	76.6
								100	74.9
								150	--

Note: Track 1 is NB track (land side)
Track 2 is SB track (river side)
Single track at Site 2

Source: HMMH, Inc., 1993

APPENDIX 4D
TRAIN NOISE DATA

TABLE 4D-1 Train Noise Data

A-WEIGHTED SOUND LEVELS - Plainsboro, NJ - 11/10/93 to 11/11/93										
						Speed		Meas.	Noise Level (dBA)	
Tape	run	Type	track	#loco	#cars	(mph)	ch.	dist. (ft)	SEL	Lmax(fast)
1-N	4	ICE	2	2	6	128	L	76	93.6	89.1
1-N	4	ICE	2	2	6	128	R	100	90.6	86.2
1-N	30	ICE	3	2	6	126	L	63	98.0	93.6
1-N	30	ICE	3	2	6	126	R	100	94.6	89.5
2-N	10	ICE	2	2	6	129	L	76	94.4	90.2
2-N	10	ICE	2	2	6	129	R	100	91.4	87.2
2-N	28	ICE	3	2	6	129	L	63	98.1	93.9
2-N	28	ICE	3	2	6	129	R	100	94.4	89.5
1-N	3	AEM7	1	1	8	111	L	89	95.2	92.7
1-N	3	AEM7	1	1	8	111	R	113	93.0	90.2
1-N	6	AEM7	4	1	5	103	L	50	98.3	96.9
1-N	6	AEM7	4	1	5	103	R	74	94.9	92.9
1-N	7	AEM7	2	1	4	99	L	76	97.8	95.5
1-N	7	AEM7	2	1	4	99	R	100	94.9	92.7
1-N	8	AEM7	4	1	6	98	L	50	101.4	98.5
1-N	8	AEM7	4	1	6	98	R	74	97.9	94.1
1-N	11	AEM7	4	1	16	82	L	50	108.6	102.6
1-N	11	AEM7	4	1	16	82	R	74	105.4	99.3
1-N	13	AEM7	2	1	5	113	L	76	96.3	94.3
1 N	13	AEM7	2	1	5	113	R	100	93.5	90.2
1-N	17	AEM7	2	1	6	116	L	76	97.6	95.3
1-N	17	AEM7	2	1	6	116	R	100	95.4	91.9
1-N	19	AEM7	2	1	8	106	L	76	99.2	96.3
1-N	19	AEM7	2	1	8	106	R	100	96.7	94.4
1-N	20	AEM7	3	1	6	96	L	63	100.8	99.5
1-N	20	AEM7	3	1	6	96	R	100	97.6	95.2
1-N	23	AEM7	3	1	5	113	L	63	97.5	94.6
1-N	23	AEM7	3	1	5	113	R	100	93.2	89.5
1-N	24	AEM7	2	1	6	114	L	76	98.6	95.3
1-N	24	AEM7	2	1	6	114	R	113	95.7	91.3
1-N	25	AEM7	3	1	9	102	L	63	98.9	93.3
1-N	25	AEM7	3	1	9	102	R	100	94.7	88.7
1-N	26	AEM7	2	1	5	98	L	76	95.3	93.7
1-N	26	AEM7	2	1	5	98	R	113	92.3	89.8
1-N	28	AEM7	4	1	10	63	L	50	94.6	88.2
1-N	28	AEM7	4	1	10	63	R	87	90.3	83.5
2-N	2	AEM7	2	1	14	89	L	76	103.4	98.5
2-N	2	AEM7	2	1	14	89	R	100	100.7	95.0
2-N	4	AEM7	2	1	6	120	L	76	99.9	97.2
2-N	4	AEM7	2	1	6	120	R	100	98.0	94.9

TABLE 4D-1 Train Noise Data (Continued)

A-WEIGHTED SOUND LEVELS - Plainsboro, NJ - 11/10/93 to 11/11/93										
Tape	run	Type	track	#loco	#cars	Speed (mph)	ch.	Meas. dist. (ft)	Noise Level (dBA) SEL	Lmax(fast)
2-N	5	AEM7	2	1	5	107	L	76	96.2	94.4
2-N	5	AEM7	2	1	5	107	R	100	92.7	90.8
2-N	6	AEM7	3	1	3	99	L	63	99.6	98.6
2-N	6	AEM7	3	1	3	99	R	87	96.2	95.1
2-N	7	AEM7	3	2	11	113	L	63	101.8	98.1
2-N	7	AEM7	3	2	11	113	R	87	97.9	93.5
2-N	8	AEM7	2	1	2	100	L	76	92.8	91.3
2-N	8	AEM7	2	1	2	100	R	100	89.3	87.8
2-N	9	AEM7	3	2	12	103	L	63	105.8	100.8
2-N	9	AEM7	3	2	12	103	R	87	102.7	97.6
2-N	11	AEM7	1	1	8	107	L	89	94.6	91.6
2-N	11	AEM7	1	1	8	107	R	113	91.7	88.2
2-N	12	AEM7	4	1	16	85	L	50	108.0	101.8
2-N	12	AEM7	4	1	16	85	R	74	104.6	98.6
2-N	13	AEM7	3	1	6	116	L	63	99.9	96.1
2-N	13	AEM7	3	1	6	116	R	87	96.0	92.7
2-N	14	AEM7	2	1	4	101	L	76	94.4	91.8
2-N	14	AEM7	2	1	4	101	R	100	91.4	88.8
2-N	15	AEM7	2	1	4	116	L	76	96.5	94.2
2-N	15	AEM7	2	1	4	116	R	100	93.8	91.8
2-N	16	AEM7	3	1	8	104	L	63	98.4	93.8
2-N	16	AEM7	3	1	8	104	R	100	93.7	89.1
2-N	17	AEM7	2	1	6	118	L	76	98.0	95.6
2-N	17	AEM7	2	1	6	118	R	113	94.0	91.2
2-N	18	AEM7	2	1	9	109	L	76	97.3	91.9
2-N	18	AEM7	2	1	9	109	R	113	93.4	87.9
2-N	19	AEM7	3	1	8	108	L	63	99.3	95.5
2-N	19	AEM7	3	1	8	108	R	100	94.6	90.6
2-N	20	AEM7	3	1	6	116	L	63	102.4	99.5
2-N	20	AEM7	3	1	6	116	R	100	98.0	94.6
2-N	23	AEM7	2	1	6	117	L	76	99.1	96.0
2-N	23	AEM7	2	1	6	117	R	113	95.5	91.8
2-N	24	AEM7	3	1	8	101	L	63	99.1	95.3
2-N	24	AEM7	3	1	8	101	R	100	94.9	90.0
2-N	25	AEM7	2	1	7	104	L	76	94.7	92.4
2-N	25	AEM7	2	1	7	104	R	113	91.7	89.3
2-N	27	AEM7	4	1	9	63	L	50	96.1	90.8
2-N	27	AEM7	4	1	9	63	R	87	91.9	85.3

Source: HMMH, Inc., 1993

APPENDIX 4E
GROUND-BORNE TRAIN VIBRATION DATA

TABLE 4E-1 Ground-Borne Train Vibration Data

PLAINSBORO, NJ: AMTRAK TRAIN VIBRATION DATA 11/93									
Tape	run	Type	track	#loco	#cars	Speed (mph)	ch.	Meas. dist. (ft)	Max. rms Vib. Vel. Level (dB)
1-V	4	ICE	2	2	6	128	1	51	85.8
							2	76	79.6
							3	101	79.3
							4	126	79.0
							5	176	70.6
1-V	30	ICE	3	2	6	126	1	38	94.4
							2	63	85.9
							3	88	83.5
							4	113	86.0
							5	163	77.6
2-V	10	ICE	2	2	6	129	1	51	85.3
							2	76	80.3
							3	101	79.0
							4	126	78.8
							5	176	70.0
2-V	28	ICE	3	2	6	129	1	38	94.0
							2	63	86.0
							3	88	83.6
							4	113	85.7
							5	163	78.0
1-V	3	AEM7	1	1	8	111	1	64	90.0
							2	89	86.1
							3	114	84.9
							4	139	84.7
							5	189	78.4
1-V	6	AEM7	4	1	5	103	1	25	97.8
							2	50	89.5
							3	75	91.6
							4	100	90.0
							5	150	80.4
1-V	7	AEM7	2	1	4	99	1	51	86.4
							2	76	80.5
							3	101	82.0
							4	126	81.5
							5	176	71.6
1-V	8	AEM7	4	1	6	98	1	25	96.9
							2	50	89.3
							3	75	89.7
							4	100	89.0
							5	150	79.7

TABLE 4E-1 Ground-Borne Train Vibration Data (Continued)

PLAINSBORO, NJ: AMTRAK TRAIN VIBRATION DATA 11/93									
Tape	run	Type	track	#loco	#cars	Speed (mph)	ch.	Meas. dist. (ft)	Max. rms Vib. Vel. Level (dB)
1-V	11	AEM7	4	1	16	82	1	25	95.5
							2	50	87.2
							3	75	86.9
							4	100	85.1
							5	150	76.5
1-V	13	AEM7	2	1	5	113	1	51	86.4
							2	76	81.0
							3	101	81.1
							4	126	80.2
							5	176	73.0
1-V	15	AEM7	3	1	6	112	1	38	93.4
							2	63	88.5
							3	88	86.6
							4	113	87.9
							5	163	76.1
1-V	17	AEM7	2	1	6	116	1	51	87.0
							2	76	83.3
							3	101	84.2
							4	126	81.6
							5	176	74.8
1-V	19	AEM7	2	1	8	106	1	51	86.6
							2	76	83.3
							3	101	83.8
							4	126	81.8
							5	176	74.8
1-V	20	AEM7	3	1	6	96	1	38	93.2
							2	63	89.0
							3	88	86.7
							4	113	87.4
							5	163	76.0
1-V	23	AEM7	3	1	5	113	1	38	93.8
							2	63	89.5
							3	88	86.0
							4	113	87.5
							5	163	77.2
1-V	24	AEM7	2	1	6	114	1	51	87.5
							2	76	82.5
							3	101	82.8
							4	126	80.8
							5	176	72.0

TABLE 4E-1 Ground-Borne Train Vibration Data (Continued)

PLAINSBORO, NJ: AMTRAK TRAIN VIBRATION DATA 11/93									
Tape	run	Type	track	#loco	#cars	Speed (mph)	ch.	Meas. dist. (ft)	Max. rms Vib. Vel. Level (dB)
1-V	25	AEM7	3	1	9	102	1	38	95.4
							2	63	89.9
							3	88	87.7
							4	113	90.8
							5	163	81.1
1-V	26	AEM7	2	1	5	98	1	51	85.9
							2	76	80.8
							3	101	82.4
							4	126	81.9
							5	176	74.2
1-V	28	AEM7	4	1	10	63	1	25	92.2
							2	50	85.9
							3	75	86.0
							4	100	84.6
							5	150	76.0
2-V	2	AEM7	2	1	14	89	1	51	89.4
							2	76	83.0
							3	101	82.5
							4	126	81.7
							5	176	73.6
2-V	4	AEM7	2	1	6	120	1	51	88.0
							2	76	82.5
							3	101	82.8
							4	126	80.0
							5	176	73.7
2-V	5	AEM7	2	1	5	107	1	51	87.0
							2	76	81.5
							3	101	82.5
							4	126	82.9
							5	176	76.0
2-V	6	AEM7	3	1	3	99	1	38	91.7
							2	63	83.8
							3	88	82.3
							4	113	84.3
							5	163	77.5
2-V	7	AEM7	3	2	11	113	1	38	95.4
							2	63	89.3
							3	88	87.2
							4	113	90.0
							5	163	81.5

TABLE 4E-1 Ground-Borne Train Vibration Data (Continued)

PLAINSBORO, NJ: AMTRAK TRAIN VIBRATION DATA 11/93									
Tape	run	Type	track	#loco	#cars	Speed (mph)	ch.	Meas. dist. (ft)	Max. rms Vib. Vel. Level (dB)
2-V	8	AEM7	2	1	2	100	1	51	84.8
							2	76	78.0
							3	101	78.6
							4	126	78.0
							5	176	69.9
2-V	9	AEM7	3	2	12	103	1	38	92.8
							2	63	85.0
							3	88	83.8
							4	113	85.4
							5	163	79.9
2-V	11	AEM7	1	1	8	107	1	64	89.4
							2	89	86.0
							3	114	85.0
							4	139	83.4
							5	189	77.5
2-V	12	AEM7	4	1	16	85	1	25	95.2
							2	50	87.3
							3	75	87.0
							4	100	85.4
							5	150	76.5
2-V	13	AEM7	3	1	6	116	1	38	93.7
							2	63	87.8
							3	88	86.5
							4	113	87.3
							5	163	75.7
2-V	14	AEM7	2	1	4	101	1	51	85.1
							2	76	80.5
							3	101	81.5
							4	126	81.6
							5	176	71.9
2-V	15	AEM7	2	1	4	116	1	51	86.5
							2	76	81.1
							3	101	81.9
							4	126	80.1
							5	176	72.0
2-V	16	AEM7	3	1	8	104	1	38	94.8
							2	63	89.1
							3	88	87.3
							4	113	89.0
							5	163	71.9

TABLE 4E-1 Ground-Borne Train Vibration Data (Continued)

PLAINSBORO, NJ: AMTRAK TRAIN VIBRATION DATA 11/93									
Tape	run	Type	track	#loco	#cars	Speed (mph)	ch.	Meas. dist. (ft)	Max. rms Vib. Vel. Level (dB)
2-V	17	AEM7	2	1	6	118	1	51	86.0
							2	76	81.7
							3	101	82.9
							4	126	81.2
							5	176	73.6
2-V	18	AEM7	2	1	9	109	1	51	86.6
							2	76	81.6
							3	101	84.1
							4	126	82.9
							5	176	75.5
2-V	19	AEM7	3	1	8	108	1	38	95.1
							2	63	89.5
							3	88	87.8
							4	113	90.0
							5	163	81.6
2-V	20	AEM7	3	1	6	116	1	38	93.7
							2	63	88.6
							3	88	86.2
							4	113	87.8
							5	163	77.5
2-V	21	AEM7	3	1	4	107	1	38	94.0
							2	63	88.4
							3	88	85.8
							4	113	87.1
							5	163	74.4
2-V	23	AEM7	2	1	6	117	1	51	86.5
							2	76	82.0
							3	101	83.0
							4	126	80.5
							5	176	73.2
2-V	24	AEM7	3	1	8	101	1	38	95.3
							2	63	89.2
							3	88	87.7
							4	113	90.1
							5	163	82.0
2-V	25	AEM7	2	1	7	104	1	51	86.2
							2	76	81.1
							3	101	83.5
							4	126	82.0
							5	176	73.5

TABLE 4E-1 Ground-Borne Train Vibration Data (Continued)

PLAINSBORO, NJ: AMTRAK TRAIN VIBRATION DATA 11/93									
Tape	run	Type	track	#loco	#cars	Speed (mph)	ch.	Meas. dist. (ft)	Max. rms Vib. Vel. Level (dB)
2-V	27	AEM7	4	1	9	63	1	25	93.8
							2	50	86.1
							3	75	85.5
							4	100	87.0
							5	150	77.0

Source: HMMH, Inc., 1993

APPENDIX 4F
SOURCE REFERENCE LEVELS USED IN TRAIN NOISE ANALYSES

The results of the empirical noise model development procedure yields the source reference levels given in Table 4F-1 below. These reference levels, used in conjunction with the theoretical model detailed in Appendix 4.3-B, provide a quantitative means for comparing the overall noise exposure of the various future project alternatives.

TABLE 4F-1 Source Reference Levels for Train Noise Model

TYPE OF TRAIN	TYPE OF VEHICLE	TRAIN NOISE SOURCE REFERENCE QUANTITIES				
		DISTANCE y_{ref} (ft)	UNIT LENGTH len_{ref} (ft)	SPEED s_{ref} (ft/sec)	NOISE LEVEL $L_{max\text{-}ref}$ (dBA)	SPEED COEFF. K_s
Amtrak F40PH (Diesel)	Locomotive	50	56	73.3	91	10
	Rail Car	50	85	73.3	81	30
Commuter (Diesel)	Locomotive	50	60	73.3	91	10
	Rail Car	50	85	73.3	84	30
Freight (Diesel)	Locomotive	50	60	73.3	86	10
	Rail Car	50	70	73.3	81	30
Amtrak AEM7 (Electric)	Locomotive	50	51	73.3	85	35
	Rail Car	50	85	73.3	81	30
X2000 (Electric)	Locomotive	50	58	73.3	82	35
	Rail Car	50	80	73.3	80	30
ICE (Electric)	Locomotive	50	68	73.3	78	35
	Rail Car	50	87	73.3	78	30
RTL (Gas Turbine)	Locomotive	50	87	73.3	87	25
	Rail Car	50	84	73.3	80	30

Source: HMMH, Inc., 1994

APPENDIX 4G
EXCESS SOUND ATTENUATION

All assumptions made in determining excess sound attenuation are consistent with those developed for the DEIS, and are described as follows:

Ground effect or attenuation over flat ground depends on such factors as the relative heights of the source and receiver above ground level, the type and surface condition of the soil, and the presence of any temperature or wind gradients. *Air absorption* of sound energy depends on temperature and humidity, as well as on sound frequency and distance. Conservative assumptions were used to calculate the ground attenuation and atmospheric absorption, based on simplified models in the literature.[22]

Shielding attenuation depends primarily on geometrical factors relating the noise source, receiver and intervening terrain or structures. Information regarding these factors was obtained from visual surveys and aerial photographs of the project corridor. Generalized assumptions for shielding attenuation were made using typical track configurations and standard sound diffraction modeling techniques.[23] These assumptions are summarized as follows:

- Deep Cut: Where the tracks are in a deep cut or trench of 15 to 20 feet, shielding attenuations of 11 dBA and 6 dBA were assumed for rail car (wheel/rail) and locomotive (exhaust, fan) noise, respectively.

- Sloped Trench: Where the tracks are in sloped trenches (typically about 5 feet deep), a shielding attenuation of 8 dBA was assumed for rail car noise only.

- Transitions: In areas of transition between at-grade and cut sections, a shielding attenuation of 4 dBA was assumed for rail car noise.

- Embankment: Where the tracks are on embankment, a small (1 dBA) attenuation was assumed to account for the shielding of rail car noise by the edge of the embankment.

Finally, the shielding attenuation due to intervening rows of buildings was estimated based on the procedure outlined in the FHWA Traffic Noise Prediction Model (FHWA, 1978).

Grade Crossings. Noise exposure near at-grade crossings is typically dominated by horns that are sounded by trains as they approach the crossing. Therefore, the noise from grade crossing signal bells was neglected for the purpose of the noise projections. Based on the measurements done for this study, a reference source noise level of 108 dBA at a distance of 50 feet was determined for locomotive horns. Furthermore, FRA regulations stipulate that a "whistle post," fixed at 0.25 mile before each grade crossing, signifies the horn to begin a standard signaling sequence of two long horn blasts, followed by one short blast and one long blast over the 0.25-mile stretch. Observations made during noise measurements near grade crossings suggest that horn noise occurring at these locations was within the FRA standard. These conditions are also consistent with assumptions made during the noise studies performed for both the NEC PEIS and the DEIS/R.

Based on the above assumptions, the train horn SEL was calculated for representative locations, taken to be along a line perpendicular to the tracks, 100 feet before each grade crossing. The SEL was calculated by modelling the horns as moving, monopole point sources as follows:

$$SEL = L_{max-ref} + 10\log\left[\frac{y_{ref}^{2}(\alpha_2-\alpha_1)}{s\,y}\right] - c_g - c_a - c_s$$

where: $L_{max-ref}$ = 108 dBA at y_{ref}

y_{ref} = 50 feet
α_1 = $\tan^{-1}(-1220/y)$
α_2 = $\tan^{-1}(100/y)$
y = distance between track centerline and receiver, feet
s = train speed, feet/sec
c_g = excess ground attenuation, dBA
c_a = excess atmospheric attenuation, dBA
c_s = excess shielding attenuation, dBA

The Northeast Corridor Transportation Plan recommends the closing of five grade crossings. Such actions could eliminate significant noise impact in the communities where these grade crossings are located. For example, if the grade crossings in Old Lyme, CT, and in South Kingstown, RI, would eliminate seven residences from the total of noise-impacted residences, reducing the total impacted residences from 14 to seven.

Special Trackwork. Special trackwork, associated with switches and crossovers, generates additional noise due to wheel impacts when trains pass over discontinuities or gaps in these track sections. Although the noise increase near special trackwork can be significant, on the order of 5 to 10 dBA at 50 feet, the noise effect becomes less pronounced at greater distances. This is because the impacts are point sources, with a distance attenuation rate twice that of the train's wheel/rail noise, which acts as a line source.

As suggested by the above discussion, the noise effects of special trackwork are highly localized. Because special trackwork will only affect noise levels in localized areas, and because the project will not alter their locations, a detailed analysis of special trackwork would not significantly change the overall results of the train noise assessment. Therefore, a detailed assessment of the noise effects at each special trackwork location is not required for a reasonable assessment of overall noise impact.

APPENDIX 4H
NOISE AND VIBRATION IMPACT DISTANCE SUMMARY TABLES

TABLE 4H-1 Train Noise Impact Distance Summary

MUNICIPALITY	MILEPOST MARKER		RESIDENTIAL LAND USE (Ldn)					INSTITUTIONAL LAND USE (Leq24)				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best case	Worst case	AMD-103	FF-125	Initial	Best case	Worst case
New Haven	72.2	72.5	25	25	25	25	25	25	25	25	25	25
New Haven	72.5	73.3	25	25	25	25	25	25	25	25	25	25
New Haven	73.3	73.7	25	25	25	25	25	25	25	25	25	25
New Haven	73.7	74.2	25	40	25	25	25	25	25	25	25	25
New Haven	74.2	74.7	25	25	25	25	25	25	25	25	25	25
New Haven	74.7	76.0	25	40	25	25	40	25	25	25	25	25
New Haven	76.0	76.3	25	50	25	25	65	25	25	25	25	25
New Haven	76.3	76.6	25	25	25	25	25	25	25	25	25	25
New Haven	76.6	76.8	25	25	25	25	25	25	25	25	25	25
New Haven	76.8	77.0	25	25	25	25	25	25	25	25	25	25
East Haven	77.0	77.6	25	50	25	25	65	25	25	25	25	25
East Haven	77.6	78.1	25	25	25	25	25	25	25	25	25	25
East Haven	78.1	79.0	25	25	25	25	25	25	25	25	25	25
Branford	79.0	79.5	25	50	25	25	65	25	25	25	25	25
Branford	79.5	80.0	25	25	25	25	25	25	25	25	25	25
Branford	80.0	81.2	25	65	25	25	80	25	25	25	25	25
Branford	81.2	82.0	25	40	25	25	25	25	25	25	25	25
Branford	82.0	82.7	25	100	25	25	100	25	25	25	25	25
Branford	82.7	83.9	25	100	25	25	125	25	25	25	25	25
Branford	83.9	84.7	25	300	25	100	300	25	25	25	25	25
Branford	84.7	85.1	25	25	25	25	50	25	25	25	25	25
Branford	85.1	86.0	25	100	25	25	200	25	25	25	25	25
Guilford	86.0	86.5	25	80	25	25	80	25	25	25	25	25
Guilford	86.5	87.4	25	100	25	25	100	25	25	25	25	25
Guilford	87.4	88.3	25	100	25	25	200	25	25	25	25	25
Guilford	88.3	90.5	25	300	25	100	400	25	25	25	25	25
Madison	90.5	91.0	25	175	25	125	300	25	25	25	25	25
Madison	91.0	91.3	25	150	25	125	300	25	25	25	25	25
Madison	91.3	91.7	25	150	25	125	300	25	25	25	25	25
Madison	91.7	93.0	25	100	25	25	100	25	25	25	25	25
Madison	93.0	94.6	25	125	25	40	125	25	25	25	25	25
Madison	94.6	94.9	25	125	25	25	125	25	25	25	25	25
Clinton	94.9	95.3	25	125	25	40	125	25	25	25	25	25
Clinton	95.3	95.9	25	150	25	125	300	25	25	25	25	25
Clinton	95.9	96.0	25	80	25	25	80	25	25	25	25	25
Clinton	96.0	96.5	25	150	25	125	200	25	25	25	25	25
Clinton	96.5	97.1	25	150	25	65	200	25	25	25	25	25
Clinton	97.1	98.9	25	125	25	125	200	25	25	25	25	25
Westbrook	98.9	99.6	25	125	25	80	150	25	25	25	25	25
Westbrook	99.6	100.5	25	80	25	25	80	25	25	25	25	25
Westbrook	100.5	101.3	25	125	25	25	125	25	25	25	25	25
Westbrook	101.3	102.0	25	125	25	25	125	25	25	25	25	25

TABLE 4H-1 Train Noise Impact Distance Summary (Continued)

MUNICIPALITY	MILEPOST MARKER		RESIDENTIAL LAND USE (Ldn)					INSTITUTIONAL LAND USE (Leq24)				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best case	Worst case	AMD-103	FF-125	Initial	Best case	Worst case
Westbrook	102.0	102.5	25	65	25	25	100	25	25	25	25	25
Old Saybrook	102.5	102.8	25	125	25	25	125	25	25	25	25	25
Old Saybrook	102.8	103.6	25	125	25	25	125	25	25	25	25	25
Old Saybrook	103.6	103.9	25	125	25	25	125	25	25	25	25	25
Old Saybrook	103.9	104.7	25	25	25	25	125	25	25	25	25	25
Old Saybrook	104.7	105.1	25	25	25	25	50	25	25	25	25	25
Old Saybrook	105.1	105.9	25	100	25	65	200	25	25	25	25	25
Old Saybrook	105.9	106.6	40	80	25	40	80	25	25	25	25	25
Old Lyme	106.6	107.3	25	100	25	40	100	25	25	25	25	25
Old Lyme	107.3	107.5	25	200	25	125	200	25	25	25	25	25
Old Lyme	107.5	108.8	25	150	25	65	150	25	25	25	25	25
Old Lyme	108.8	109.2	25	175	25	125	200	25	25	25	25	25
Old Lyme	109.2	109.6	25	150	25	40	150	25	25	25	25	25
Old Lyme	109.6	110.0	25	175	25	100	200	25	25	25	25	25
Old Lyme	110.0	110.6	25	150	25	40	150	25	25	25	25	25
Old Lyme	110.6	111.4	25	175	25	100	200	25	25	25	25	25
Old Lyme	111.4	111.7	25	200	25	100	200	25	25	25	25	25
Old Lyme	111.7	111.9	25	40	25	25	40	25	25	25	25	25
Old Lyme (H)	111.9	112.3	75	500	80	500	500	25	25	25	25	25
East Lyme	112.3	112.8	40	125	25	50	150	25	25	25	25	25
East Lyme	112.8	113.0	25	175	25	65	200	25	25	25	25	25
East Lyme	113.0	113.5	25	40	25	25	40	25	25	25	25	25
East Lyme	113.5	113.8	25	200	25	100	200	25	25	25	25	25
East Lyme	113.8	115.0	25	175	25	80	200	25	25	25	25	25
East Lyme	115.0	115.5	25	150	25	40	125	25	25	25	25	25
East Lyme	115.5	116.0	25	175	25	80	200	25	25	25	25	25
East Lyme	116.0	116.5	25	125	25	65	125	25	25	25	25	25
East Lyme	116.5	116.7	25	50	25	25	50	25	25	25	25	25
Waterford	116.7	116.9	25	50	25	25	50	25	25	25	25	25
Waterford	116.9	117.2	25	80	25	25	40	25	25	25	25	25
Waterford	117.2	118.2	25	150	25	50	200	25	25	25	25	25
Waterford	118.2	119.1	25	150	25	50	200	25	25	25	25	25
Waterford	119.1	119.9	25	80	25	25	50	25	25	25	25	25
Waterford (H)	119.9	120.5	25	100	25	100	125	25	25	25	25	25
Waterford	120.5	120.7	25	125	25	40	125	25	25	25	25	25
Waterford	120.7	121.1	25	40	25	25	40	25	25	25	25	25
New London	121.1	122.0	25	125	25	50	125	25	25	25	25	25
New London	122.0	122.5	40	100	25	40	100	25	25	25	25	25
New London (H)	122.5	123.0	50	125	40	125	300	25	25	25	25	25
New London (H)	123.0	123.5	25	40	25	25	25	25	25	25	25	25
New London	123.5	123.9	25	25	25	25	25	25	25	25	25	25
Groton	123.9	124.3	25	150	25	40	125	25	25	25	25	25

TABLE 4H-1 Train Noise Impact Distance Summary (Continued)

MUNICIPALITY	MILEPOST MARKER		RESIDENTIAL LAND USE (Ldn)					INSTITUTIONAL LAND USE (Leq24)				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best case	Worst case	AMD-103	FF-125	Initial	Best case	Worst case
Groton	124.3	124.5	25	150	25	40	125	25	25	25	25	25
Groton	124.5	124.7	25	150	25	100	125	25	25	25	25	25
Groton	124.7	125.0	25	150	25	100	125	25	25	25	25	25
Groton	125.0	126.0	25	40	25	25	25	25	25	25	25	25
Groton	126.0	127.0	25	100	25	40	100	25	25	25	25	25
Groton	127.0	127.3	25	150	25	40	150	25	25	25	25	25
Groton	127.3	128.9	25	175	25	40	200	25	25	25	25	25
Groton	128.9	129.5	25	125	25	40	150	25	25	25	25	25
Groton	129.5	130.2	25	100	25	25	65	25	25	25	25	25
Groton	130.2	131.3	25	175	25	40	200	25	25	25	25	25
Groton (H)	131.3	131.7	25	400	25	150	200	25	25	25	25	25
Groton	131.7	132.0	25	40	25	40	80	25	25	25	25	25
Groton	132.0	132.2	25	25	25	25	40	25	25	25	25	25
Groton (H)	132.2	132.5	25	800	25	500	500	25	40	25	25	25
Stonington	132.5	132.8	25	40	25	25	40	25	25	25	25	25
Stonington	132.8	133.2	25	80	25	40	100	25	25	25	25	25
Stonington	133.2	133.6	25	400	25	400	400	25	25	25	25	25
Stonington	133.6	133.8	25	40	25	25	25	25	25	25	25	25
Stonington	133.8	134.7	25	150	25	40	150	25	25	25	25	25
Stonington	134.7	135.2	25	200	25	100	200	25	25	25	25	25
Stonington	135.2	135.5	25	150	25	40	150	25	25	25	25	25
Stonington	135.5	136.1	25	125	25	40	150	25	25	25	25	25
Stonington	136.1	136.5	25	80	25	40	100	25	25	25	25	25
Stonington	136.5	137.2	25	125	25	125	400	25	25	25	25	25
Stonington	137.2	137.6	25	175	25	125	200	25	25	25	25	25
Stonington	137.6	138.5	25	150	25	25	125	25	25	25	25	25
Stonington	138.5	139.1	25	175	25	100	200	25	25	25	25	25
Stonington	139.1	139.7	25	150	25	25	125	25	25	25	25	25
Stonington	139.7	140.0	25	175	25	100	200	25	25	25	25	25
Stonington	140.0	141.0	25	125	25	125	200	25	25	25	25	25
Westerly	141.0	141.3	25	100	25	65	100	25	25	25	25	25
Westerly	141.3	141.8	25	100	25	65	100	25	25	25	25	25
Westerly	141.8	142.5	25	150	25	40	125	25	25	25	25	25
Westerly	142.5	144.6	25	200	25	100	300	25	25	25	25	25
Westerly	144.6	146.1	25	175	25	65	200	25	25	25	25	25
Hopkinton	146.1	147.2	25	175	25	80	200	25	25	25	25	25
Charlestown	147.2	147.9	25	175	25	25	200	25	25	25	25	25
Charlestown	147.9	148.5	25	125	25	25	150	25	25	25	25	25
Charlestown	148.5	149.3	25	200	25	100	300	25	25	25	25	25
Richmond	149.3	150.3	25	125	25	25	150	25	25	25	25	25
Charlestown	150.3	151.8	25	125	25	25	150	25	25	25	25	25
Charlestown	151.8	152.3	25	300	25	100	300	25	25	25	25	25

TABLE 4H-1 Train Noise Impact Distance Summary (Continued)

MUNICIPALITY	MILEPOST MARKER		RESIDENTIAL LAND USE (Ldn)					INSTITUTIONAL LAND USE (Leq24)				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best case	Worst case	AMD-103	FF-125	Initial	Best case	Worst case
Richmond	152.3	153.0	25	200	25	100	25	25	25	25	25	25
Charlestown	153.0	153.4	25	200	25	100	25	25	25	25	25	25
Charlestown	153.4	153.6	25	125	25	25	25	25	25	25	25	25
Richmond	153.6	154.5	25	125	25	25	25	25	25	25	25	25
Richmond	154.5	155.8	25	300	25	300	25	25	25	25	40	65
S. Kingstown	155.8	157.3	25	125	25	300	25	25	25	25	25	65
S. Kingstown	157.3	157.9	25	40	25	300	25	25	25	25	25	40
S. Kingstown	157.9	158.2	40	25	25	300	25	25	25	25	25	40
S. Kingstown	158.2	159.2	50	125	25	300	25	25	25	25	25	40
S. Kingstown	159.2	159.5	50	400	25	400	25	25	40	25	40	65
S. Kingstown (H)	159.5	160.7	280	1100	125	800	25	25	50	25	40	50
Exeter	160.7	161.9	40	500	40	400	25	25	40	25	40	65
N. Kingstown	161.9	165.0	50	400	25	175	25	25	25	25	25	40
N. Kingstown	165.0	166.1	50	300	25	300	25	25	25	25	25	50
N. Kingstown	166.1	168.8	50	300	25	300	25	25	25	25	25	65
N. Kingstown	168.8	170.3	50	300	40	200	25	25	25	25	25	50
N. Kingstown	170.3	170.8	40	175	25	100	25	25	25	25	25	25
E. Greenwich	170.8	171.3	50	300	40	200	25	25	25	25	25	40
E. Greenwich	171.3	171.8	40	175	25	100	25	25	25	25	25	25
E. Greenwich	171.8	172.1	50	300	40	175	25	25	25	25	25	40
Warwick	172.1	172.3	40	300	40	175	25	25	25	25	25	40
Warwick	172.3	173.0	40	300	40	200	25	25	25	25	25	40
Warwick	173.0	173.7	40	175	25	100	200	25	25	25	25	25
Warwick	173.7	174.1	40	300	40	200	300	25	25	25	25	40
Warwick	174.1	174.6	40	300	40	200	400	25	25	25	25	40
Warwick	174.6	176.3	40	150	25	125	200	25	25	25	25	25
Warwick	176.3	177.8	75	300	25	200	300	25	25	25	25	50
Warwick	177.8	178.8	40	150	25	100	200	25	25	25	25	25
Cranston	178.8	179.7	40	150	25	150	200	25	25	25	25	25
Cranston	179.7	180.3	40	150	25	125	150	25	25	25	25	25
Cranston	180.3	180.6	40	150	25	125	125	25	25	25	25	25
Cranston	180.6	181.0	25	80	25	40	80	25	25	25	25	25
Providence	181.0	181.9	40	100	25	100	100	25	25	25	25	25
Providence	181.9	182.7	25	65	25	25	40	25	25	25	25	25
Providence	182.7	183.2	40	100	25	80	100	25	25	25	25	25
Providence	183.2	183.9	25	65	25	25	65	25	25	25	25	25
Providence	183.9	184.9	25	80	25	65	80	25	25	25	25	25
Providence	184.9	185.2	25	25	25	25	25	25	25	25	25	25
Providence	185.2	185.6	25	25	25	25	25	25	25	25	25	25
Providence	185.6	186.1	25	25	25	25	25	25	25	25	25	25
Providence	186.1	186.7	25	125	25	65	125	25	25	25	25	25
Providence	186.7	187.5	25	150	25	100	150	25	25	25	25	25

TABLE 4H-1 Train Noise Impact Distance Summary (Continued)

MUNICIPALITY	MILEPOST MARKER		RESIDENTIAL LAND USE (Ldn)					INSTITUTIONAL LAND USE (Leq24)				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best case	Worst case	AMD-103	FF-125	Initial	Best case	Worst case
Pawtucket	187.5	188.5	25	150	25	100	150	25	25	25	25	25
Pawtucket	188.5	189.8	25	25	25	25	25	25	25	25	25	25
Central Falls	189.8	190.2	25	25	25	25	25	25	25	25	25	25
Central Falls	190.2	190.6	25	50	25	25	50	25	25	25	25	25
Central Falls	190.6	190.9	25	150	25	65	150	25	25	25	25	25
Attleboro	190.9	191.5	25	25	25	25	25	25	25	25	25	25
Attleboro	191.5	192.3	25	150	25	125	300	25	25	25	25	25
Attleboro	192.3	193.0	25	125	25	40	200	25	25	25	25	25
Attleboro	193.0	193.4	25	300	25	100	300	25	25	25	25	25
Attleboro	193.4	195.0	25	40	25	40	200	25	25	25	25	25
Attleboro	195.0	195.7	25	125	25	125	400	25	25	25	25	25
Attleboro	195.7	196.2	25	150	25	40	300	25	25	25	25	25
Attleboro	196.2	196.7	25	200	25	125	400	25	25	25	25	25
Attleboro	196.7	197.0	25	300	25	175	400	25	25	25	25	50
Attleboro	197.0	198.2	25	125	25	125	400	25	25	25	25	25
Attleboro	198.2	198.9	25	200	25	80	300	25	25	25	25	25
Attleboro (H)	198.9	199.7	25	125	40	100	300	25	25	25	25	25
Mansfield	199.7	200.4	100	125	25	125	400	25	25	25	25	25
Mansfield	200.4	200.9	25	200	25	80	300	25	25	25	25	25
Mansfield	200.9	202.4	25	125	25	125	400	25	25	25	25	25
Mansfield	202.4	203.1	25	200	25	80	400	25	25	25	25	25
Mansfield	203.1	204.2	25	400	25	125	400	25	25	25	25	25
Mansfield	204.2	204.9	25	300	25	300	600	25	25	25	25	25
Foxboro	204.9	205.5	25	125	25	125	400	25	25	25	25	25
Foxboro	205.5	207.6	25	125	25	125	400	25	25	25	25	25
Sharon	207.6	209.3	25	125	25	125	400	25	25	25	25	25
Sharon	209.3	209.7	25	80	25	25	200	25	25	25	25	25
Sharon	209.7	211.0	25	150	25	125	400	25	25	25	25	25
Sharon	211.0	211.7	25	100	25	25	150	25	25	25	25	25
Sharon	211.7	212.7	25	125	25	125	300	25	25	25	25	25
Canton	212.7	213.4	25	125	25	125	300	25	25	25	25	25
Canton	213.4	214.0	25	150	25	125	300	25	25	25	25	25
Canton	214.0	214.6	25	25	25	25	40	25	25	25	25	25
Canton	214.6	215.2	25	25	25	25	40	25	25	25	25	25
Canton	215.2	216.2	25	25	25	25	50	25	25	25	25	25
Westwood	216.2	217.2	25	25	25	25	40	25	25	25	25	25
Dedham	217.2	217.5	25	25	25	25	25	25	25	25	25	25
Dedham	217.5	218.5	25	125	25	80	300	25	25	25	25	25
Dedham	218.5	218.7	25	125	25	50	300	25	25	25	25	25
Dedham	218.7	218.9	25	125	25	50	300	25	25	25	25	25
Boston	218.9	219.2	25	125	25	125	300	25	25	25	25	25
Boston	219.2	219.8	25	100	25	65	300	25	25	25	25	25

TABLE 4H-1 Train Noise Impact Distance Summary (Continued)

MUNICIPALITY	MILEPOST MARKER		RESIDENTIAL LAND USE (Ldn)					INSTITUTIONAL LAND USE (Leq24)				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best case	Worst case	AMD-103	FF-125	Initial	Best case	Worst case
Boston	219.8	220.0	25	80	25	25	200	25	25	25	25	25
Boston	220.0	221.1	25	65	25	65	300	25	25	25	25	25
Boston	221.1	221.8	25	40	25	25	125	25	25	25	25	25
Boston	221.8	222.3	25	100	25	65	100	25	25	25	25	25
Boston	222.3	223.4	25	25	25	25	25	25	25	25	25	25
Boston	223.4	223.8	25	25	25	25	25	25	25	25	25	25
Boston	223.8	224.7	25	25	25	25	25	25	25	25	25	25
Boston	224.7	225.7	25	25	25	25	25	25	25	25	25	25
Boston	225.7	227.0	25	25	25	25	25	25	25	25	25	25
Boston	227.0	227.5	25	25	25	25	25	25	25	25	25	25
Boston	227.5	227.6	25	25	25	25	25	25	25	25	25	25
Boston	227.6	227.7	25	25	25	25	25	25	25	25	25	25
Boston	227.7	228.3	25	25	25	25	25	25	25	25	25	25
Boston	228.3	228.5	25	25	25	25	25	25	25	25	25	25
Boston	228.5	228.8	25	25	25	25	25	25	25	25	25	25

Source: HMMH, Inc., 1994

TABLE 4H-2 Train Vibration Impact Distance Summary

MUNICIPALITY	MILEPOST		DISTANCE TO SIGNIFICANT IMPACT (ft)									
			RESIDENTIAL LAND USE					INSTITUTIONAL LAND USE				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best Case	Worst Case	AMD-103	FF-125	Initial	Best Case	Worst Case
New Haven	72.2	72.5	No impact	66	No impact	No impact	66	No impact	42	No impact	No impact	42
New Haven	72.5	73.3	No impact	66	No impact	No impact	66	No impact	42	No impact	No impact	42
New Haven	73.3	73.7	No impact	No impact	No impact	No impact	72	No impact	No impact	No impact	No impact	49
New Haven	73.7	74.2	No impact	97	No impact	No impact	97	No impact	70	No impact	No impact	70
New Haven	74.2	74.7	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
New Haven	74.7	76.0	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
New Haven	76.0	76.3	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
New Haven	76.3	76.6	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
New Haven	76.6	76.8	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
New Haven	76.8	77.0	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
East Haven	77.0	77.6	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
East Haven	77.6	78.1	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
East Haven	78.1	79.0	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Branford	79.0	79.5	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Branford	79.5	80.0	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Branford	80.0	81.2	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Branford	81.2	82.0	No impact	85	No impact	No impact	85	No impact	60	No impact	No impact	60
Branford	82.0	82.7	No impact	118	No impact	No impact	123	No impact	88	No impact	No impact	92
Branford	82.7	83.9	No impact	No impact	No impact	No impact	137	No impact	No impact	No impact	No impact	104
Branford	83.9	84.7	No impact	No impact	No impact	No impact	137	No impact	No impact	No impact	No impact	104
Branford	84.7	85.1	No impact	No impact	No impact	No impact	131	No impact	No impact	No impact	No impact	99
Branford	85.1	86.0	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Guilford	86.0	86.5	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Guilford	86.5	87.4	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Guilford	87.4	88.3	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Guilford	88.3	90.5	No impact	137	No impact	No impact	141	No impact	104	No impact	No impact	108
Madison	90.5	91.0	No impact	132	No impact	No impact	141	No impact	100	No impact	No impact	108
Madison	91.0	91.3	No impact	No impact	No impact	No impact	141	No impact	No impact	No impact	No impact	108
Madison	91.3	91.7	No impact	No impact	No impact	No impact	141	No impact	No impact	No impact	No impact	108
Madison	91.7	93.0	No impact	No impact	No impact	No impact	137	No impact	No impact	No impact	No impact	104
Madison	93.0	94.6	No impact	No impact	No impact	No impact	128	No impact	No impact	No impact	No impact	96
Madison	94.6	94.9	No impact	No impact	No impact	No impact	113	No impact	No impact	No impact	No impact	84
Clinton	94.9	95.3	No impact	No impact	No impact	No impact	132	No impact	No impact	No impact	No impact	100
Clinton	95.3	95.9	No impact	No impact	No impact	No impact	141	No impact	No impact	No impact	No impact	108
Clinton	95.9	96.0	No impact	No impact	No impact	No impact	134	No impact	No impact	No impact	No impact	102
Clinton	96.0	96.5	No impact	No impact	No impact	No impact	137	No impact	No impact	No impact	No impact	104
Clinton	96.5	97.1	No impact	No impact	No impact	No impact	139	No impact	No impact	No impact	No impact	106
Clinton	97.1	98.9	No impact	No impact	No impact	No impact	141	No impact	No impact	No impact	No impact	108
Westbrook	98.9	99.6	No impact	No impact	No impact	No impact	137	No impact	No impact	No impact	No impact	104
Westbrook	99.6	100.5	No impact	No impact	No impact	No impact	123	No impact	No impact	No impact	No impact	92
Westbrook	100.5	101.3	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Westbrook	101.3	102.0	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Westbrook	102.0	102.5	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Old Saybrook	102.5	102.8	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Old Saybrook	102.8	103.6	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Old Saybrook	103.6	103.9	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Old Saybrook	103.9	104.7	No impact	No impact	No impact	No impact	123	No impact	No impact	No impact	No impact	92
Old Saybrook	104.7	105.1	No impact	No impact	87	87	123	No impact	No impact	61	61	92

TABLE 4H-2 Train Vibration Impact Distance Summary (Continued)

MUNICIPALITY	MILEPOST		DISTANCE TO SIGNIFICANT IMPACT (ft)									
			RESIDENTIAL LAND USE					INSTITUTIONAL LAND USE				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best Case	Worst Case	AMD-103	FF-125	Initial	Best Case	Worst Case
Old Saybrook	105.1	105.9	No impact	85	No impact	83	118	No impact	60	No impact	57	88
Old Saybrook	105.9	106.6	No impact	79	No impact	50	79	No impact	54	No impact	28	54
Old Lyme	106.6	107.3	No impact	85	No impact	55	85	No impact	60	No impact	33	60
Old Lyme	107.3	107.5	No impact	115	No impact	87	123	No impact	86	No impact	61	92
Old Lyme	107.5	108.8	No impact	123	No impact	87	123	No impact	92	No impact	61	92
Old Lyme	108.8	109.2	No impact	123	No impact	87	123	No impact	92	No impact	61	92
Old Lyme	109.2	109.6	No impact	119	No impact	87	123	No impact	89	No impact	61	92
Old Lyme	109.6	110.0	No impact	118	No impact	83	118	No impact	88	No impact	57	88
Old Lyme	110.0	110.6	No impact	118	No impact	83	118	No impact	88	No impact	57	88
Old Lyme	110.6	111.4	No impact	113	No impact	83	118	No impact	84	No impact	57	88
Old Lyme	111.4	111.7	No impact	105	No impact	83	118	No impact	77	No impact	57	88
Old Lyme	111.7	111.9	No impact	102	No impact	80	115	No impact	74	No impact	55	86
Old Lyme	111.9	112.3	No impact	91	No impact	65	97	No impact	65	No impact	42	70
East Lyme	112.3	112.8	No impact	91	No impact	70	103	No impact	65	No impact	46	75
East Lyme	112.8	113.0	No impact	100	No impact	78	113	No impact	73	No impact	54	84
East Lyme	113.0	113.5	No impact	111	No impact	78	113	No impact	82	No impact	54	84
East Lyme	113.5	113.8	No impact	113	No impact	78	113	No impact	84	No impact	54	84
East Lyme	113.8	115.0	No impact	113	No impact	78	113	No impact	84	No impact	54	84
East Lyme	115.0	115.5	No impact	113	No impact	78	113	No impact	84	No impact	54	84
East Lyme	115.5	116.0	No impact	103	No impact	78	113	No impact	75	No impact	54	84
East Lyme	116.0	116.5	No impact	94	No impact	70	103	No impact	67	No impact	46	75
East Lyme	116.5	116.7	No impact	79	No impact	50	79	No impact	54	No impact	28	54
Waterford	116.7	116.9	No impact	79	No impact	55	85	No impact	54	No impact	33	60
Waterford	116.9	117.2	No impact	97	No impact	65	97	No impact	70	No impact	42	70
Waterford	117.2	118.2	No impact	103	No impact	70	103	No impact	75	No impact	46	75
Waterford	118.2	119.1	No impact	97	No impact	70	103	No impact	70	No impact	46	75
Waterford	119.1	119.9	No impact	97	No impact	70	103	No impact	70	No impact	46	75
Waterford	119.9	120.5	No impact	103	No impact	70	103	No impact	75	No impact	46	75
Waterford	120.5	120.7	No impact	91	No impact	65	97	No impact	65	No impact	42	70
Waterford	120.7	121.1	No impact	79	No impact	60	91	No impact	54	No impact	38	65
New London	121.1	122.0	No impact	79	No impact	60	91	No impact	54	No impact	38	65
New London	122.0	122.5	No impact	72	55	55	85	No impact	49	33	33	60
New London	122.5	123.0	No impact	42	No impact	1	42	No impact	19	No impact	1	19
New London	123.0	123.5	No impact	45	No impact	24	50	No impact	23	No impact	1	28
New London	123.5	123.9	No impact	50	38	38	66	No impact	28	1	1	42
Groton	123.9	124.3	No impact	79	55	55	85	No impact	54	33	33	60
Groton	124.3	124.5	No impact	85	55	55	85	No impact	60	33	33	60
Groton	124.5	124.7	No impact	97	70	70	103	No impact	70	46	46	75
Groton	124.7	125.0	No impact	91	70	70	103	No impact	65	46	46	75
Groton	125.0	126.0	No impact	79	No impact	55	85	No impact	54	No impact	33	60
Groton	126.0	127.0	No impact	89	No impact	65	97	No impact	63	No impact	42	70
Groton	127.0	127.3	No impact	108	No impact	74	108	No impact	79	No impact	50	79
Groton	127.3	128.9	No impact	108	No impact	74	108	No impact	79	No impact	50	79
Groton	128.9	129.5	No impact	91	No impact	65	97	No impact	65	No impact	42	70
Groton	129.5	130.2	No impact	100	No impact	70	103	No impact	73	No impact	46	75
Groton	130.2	131.3	No impact	103	No impact	74	108	No impact	75	No impact	50	79
Groton	131.3	131.7	No impact	89	No impact	74	108	No impact	63	No impact	50	79
Groton	131.7	132.0	No impact	70	No impact	65	97	No impact	46	No impact	42	70

TABLE 4H-2 Train Vibration Impact Distance Summary (Continued)

MUNICIPALITY	MILEPOST		DISTANCE TO SIGNIFICANT IMPACT (ft)									
			RESIDENTIAL LAND USE					INSTITUTIONAL LAND USE				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best Case	Worst Case	AMD-103	FF-125	Initial	Best Case	Worst Case
Groton	132.0	132.2	No impact	50	No impact	50	79	No impact	28	No impact	28	54
Groton	132.2	132.5	No impact	42	No impact	50	79	No impact	19	No impact	28	54
Stonington	132.5	132.8	No impact	66	No impact	65	97	No impact	42	No impact	42	70
Stonington	132.8	133.2	No impact	85	No impact	68	100	No impact	60	No impact	44	73
Stonington	133.2	133.6	No impact	87	No impact	65	97	No impact	61	No impact	42	70
Stonington	133.6	133.8	No impact	85	No impact	65	97	No impact	60	No impact	42	70
Stonington	133.8	134.7	No impact	99	No impact	70	103	No impact	72	No impact	46	75
Stonington	134.7	135.2	No impact	103	No impact	70	103	No impact	75	No impact	46	75
Stonington	135.2	135.5	No impact	100	No impact	70	103	No impact	73	No impact	46	75
Stonington	135.5	136.1	No impact	91	No impact	70	103	No impact	65	No impact	46	75
Stonington	136.1	136.5	No impact	79	No impact	60	91	No impact	54	No impact	38	65
Stonington	136.5	137.2	No impact	113	No impact	87	123	No impact	84	No impact	61	92
Stonington	137.2	137.6	No impact	122	No impact	87	123	No impact	91	No impact	61	92
Stonington	137.6	138.5	No impact	113	No impact	87	123	No impact	84	No impact	61	92
Stonington	138.5	139.1	No impact	108	No impact	87	123	No impact	79	No impact	61	92
Stonington	139.1	139.7	No impact	108	No impact	87	123	No impact	79	No impact	61	92
Stonington	139.7	140.0	No impact	108	No impact	87	123	No impact	79	No impact	61	92
Stonington	140.0	141.0	No impact	108	No impact	87	123	No impact	79	No impact	61	92
Westerly	141.0	141.3	No impact	118	No impact	87	123	No impact	88	No impact	61	92
Westerly	141.3	141.8	No impact	113	No impact	87	123	No impact	84	No impact	61	92
Westerly	141.8	142.5	No impact	108	No impact	83	119	No impact	79	No impact	58	89
Westerly	142.5	144.6	No impact	113	No impact	87	123	No impact	84	No impact	61	92
Westerly	144.6	146.1	No impact	113	No impact	87	123	No impact	84	No impact	61	92
Hopkinton	146.1	147.2	No impact	123	No impact	94	132	No impact	92	No impact	68	100
Charlestown	147.2	147.9	No impact	113	No impact	87	123	No impact	84	No impact	61	92
Charlestown	147.9	148.5	No impact	116	No impact	91	128	No impact	86	No impact	64	96
Charlestown	148.5	149.3	No impact	118	No impact	94	132	No impact	88	No impact	68	100
Richmond	149.3	150.3	No impact	118	No impact	94	132	No impact	88	No impact	68	100
Charlestown	150.3	151.8	No impact	118	No impact	87	123	No impact	88	No impact	61	92
Charlestown	151.8	152.3	No impact	115	No impact	87	123	No impact	86	No impact	61	92
Richmond	152.3	153.0	No impact	116	No impact	87	123	No impact	86	No impact	61	92
Charlestown	153.0	153.4	No impact	118	No impact	91	128	No impact	88	No impact	64	96
Charlestown	153.4	153.6	No impact	118	No impact	91	128	No impact	88	No impact	64	96
Richmond	153.6	154.5	No impact	118	No impact	91	128	No impact	88	No impact	64	96
Richmond	154.5	155.8	No impact	123	No impact	122	166	No impact	92	No impact	92	129
S. Kingstown	155.8	157.3	No impact	113	No impact	122	166	No impact	84	No impact	92	129
S. Kingstown	157.3	157.9	No impact	79	No impact	122	165	No impact	54	No impact	91	128
S. Kingstown	157.9	158.2	103	1	120	120	163	75	1	90	90	127
S. Kingstown	158.2	159.2	113	91	120	120	163	84	65	89	89	126
S. Kingstown	159.2	159.5	113	137	119	119	162	84	104	89	89	126
S. Kingstown	159.5	160.7	113	145	117	117	160	84	111	87	87	124
Exeter	160.7	161.9	123	144	122	122	166	92	110	92	92	129
N. Kingstown	161.9	165.0	128	141	122	122	166	96	108	92	92	129
N. Kingstown	165.0	166.1	128	139	119	119	162	96	106	89	89	126
N. Kingstown	166.1	168.8	123	139	116	116	158	92	106	86	86	122
N. Kingstown	168.8	170.3	118	135	109	109	150	88	103	80	80	115
N. Kingstown	170.3	170.8	113	132	102	102	141	84	100	74	74	108
E. Greenwich	170.8	171.3	113	130	102	102	141	84	98	74	74	108

TABLE 4H-2 Train Vibration Impact Distance Summary (Continued)

MUNICIPALITY	MILEPOST		DISTANCE TO SIGNIFICANT IMPACT (ft)									
			RESIDENTIAL LAND USE					INSTITUTIONAL LAND USE				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best Case	Worst Case	AMD-103	FF-125	Initial	Best Case	Worst Case
E. Greenwich	171.3	171.8	113	128	98	98	137	84	96	71	71	104
E. Greenwich	171.8	172.1	113	128	98	98	137	84	96	71	71	104
Warwick	172.1	172.3	108	128	98	98	137	79	96	71	71	104
Warwick	172.3	173.0	108	129	105	105	146	79	97	77	77	112
Warwick	173.0	173.7	108	125	105	105	146	79	94	77	77	112
Warwick	173.7	174.1	108	123	105	105	146	79	92	77	77	112
Warwick	174.1	174.6	108	126	105	105	146	79	95	77	77	112
Warwick	174.6	176.3	113	128	105	105	146	84	96	77	77	112
Warwick	176.3	177.8	118	128	105	105	146	88	96	77	77	112
Warwick	177.8	178.8	123	128	105	105	146	92	96	77	77	112
Cranston	178.8	179.7	118	128	105	105	146	88	96	77	77	112
Cranston	179.7	180.3	113	118	99	99	138	84	88	71	71	105
Cranston	180.3	180.6	103	112	91	91	128	75	83	64	64	96
Cranston	180.6	181.0	91	108	87	87	123	65	79	61	61	92
Providence	181.0	181.9	72	91	78	78	113	49	65	54	54	84
Providence	181.9	182.7	63	72	55	55	85	40	49	33	33	60
Providence	182.7	183.2	66	88	70	70	103	42	62	46	46	75
Providence	183.2	183.9	61	79	70	70	103	39	54	46	46	75
Providence	183.9	184.9	58	72	70	70	103	36	49	46	46	75
Providence	184.9	185.2	No impact	32	No impact	1	32	No impact	1	No impact	1	1
Providence	185.2	185.6	No impact	75	46	46	75	No impact	51	25	25	51
Providence	185.6	186.1	No impact	72	55	55	85	No impact	49	33	33	60
Providence	186.1	186.7	No impact	97	74	74	108	No impact	70	50	50	79
Providence	186.7	187.5	No impact	108	87	87	123	No impact	79	61	61	92
Pawtucket	187.5	188.5	No impact	97	No impact	83	118	No impact	70	No impact	57	88
Pawtucket	188.5	189.8	No impact	79	No impact	55	85	No impact	54	No impact	33	60
Central Falls	189.8	190.2	97	79	No impact	60	91	70	54	No impact	38	65
Central Falls	190.2	190.6	103	85	No impact	60	91	75	60	No impact	38	65
Central Falls	190.6	190.9	108	113	No impact	78	113	79	84	No impact	54	84
Attleboro	190.9	191.5	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Attleboro	191.5	192.3	No impact	No impact	No impact	No impact	150	No impact	No impact	No impact	No impact	115
Attleboro	192.3	193.0	No impact	No impact	No impact	No impact	150	No impact	No impact	No impact	No impact	115
Attleboro	193.0	193.4	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Attleboro	193.4	195.0	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Attleboro	195.0	195.7	No impact	146	No impact	No impact	160	No impact	112	No impact	No impact	124
Attleboro	195.7	196.2	No impact	146	No impact	No impact	166	No impact	112	No impact	No impact	129
Attleboro	196.2	196.7	No impact	146	No impact	No impact	166	No impact	112	No impact	No impact	129
Attleboro	196.7	197.0	No impact	145	No impact	No impact	166	No impact	111	No impact	No impact	129
Attleboro	197.0	198.2	No impact	146	No impact	No impact	166	No impact	112	No impact	No impact	129
Attleboro	198.2	198.9	No impact	146	No impact	No impact	166	No impact	112	No impact	No impact	129
Attleboro	198.9	199.7	No impact	146	No impact	No impact	166	No impact	112	No impact	No impact	129
Mansfield	199.7	200.4	No impact	146	No impact	No impact	166	No impact	112	No impact	No impact	129
Mansfield	200.4	200.9	No impact	No impact	No impact	No impact	166	No impact	No impact	No impact	No impact	129
Mansfield	200.9	202.4	No impact	No impact	No impact	No impact	166	No impact	No impact	No impact	No impact	129
Mansfield	202.4	203.1	No impact	No impact	No impact	No impact	166	No impact	No impact	No impact	No impact	129
Mansfield	203.1	204.2	No impact	No impact	No impact	No impact	162	No impact	No impact	No impact	No impact	126
Mansfield	204.2	204.9	No impact	No impact	No impact	No impact	162	No impact	No impact	No impact	No impact	126
Foxboro	204.9	205.5	No impact	141	No impact	No impact	158	No impact	108	No impact	No impact	122

TABLE 4H-2 Train Vibration Impact Distance Summary (Continued)

MUNICIPALITY	MILEPOST		DISTANCE TO SIGNIFICANT IMPACT (ft)									
			RESIDENTIAL LAND USE					INSTITUTIONAL LAND USE				
			NO-BUILD		BUILD			NO-BUILD		BUILD		
	From	To	AMD-103	FF-125	Initial	Best Case	Worst Case	AMD-103	FF-125	Initial	Best Case	Worst Case
Foxboro	205.5	207.6	No impact	No impact	No impact	No impact	156	No impact	No impact	No impact	No impact	121
Sharon	207.6	209.3	No impact	No impact	No impact	No impact	158	No impact	No impact	No impact	No impact	122
Sharon	209.3	209.7	No impact	No impact	No impact	No impact	157	No impact	No impact	No impact	No impact	122
Sharon	209.7	211.0	No impact	No impact	No impact	No impact	156	No impact	No impact	No impact	No impact	121
Sharon	211.0	211.7	No impact	No impact	No impact	No impact	155	No impact	No impact	No impact	No impact	120
Sharon	211.7	212.7	No impact	No impact	No impact	No impact	153	No impact	No impact	No impact	No impact	118
Canton	212.7	213.4	No impact	No impact	No impact	No impact	148	No impact	No impact	No impact	No impact	114
Canton	213.4	214.0	No impact	No impact	No impact	No impact	146	No impact	No impact	No impact	No impact	112
Canton	214.0	214.6	No impact	227	No impact	No impact	258	No impact	182	No impact	No impact	209
Canton	214.6	215.2	No impact	No impact	No impact	No impact	238	No impact	No impact	No impact	No impact	192
Canton	215.2	216.2	No impact	No impact	No impact	No impact	204	No impact	No impact	No impact	No impact	163
Westwood	216.2	217.2	No impact	No impact	No impact	No impact	203	No impact	No impact	No impact	No impact	161
Dedham	217.2	217.5	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Dedham	217.5	218.5	No impact	257	No impact	No impact	269	No impact	208	No impact	No impact	219
Dedham	218.5	218.7	No impact	257	No impact	No impact	269	No impact	208	No impact	No impact	219
Dedham	218.7	218.9	No impact	256	No impact	No impact	269	No impact	207	No impact	No impact	219
Boston	218.9	219.2	No impact	256	No impact	No impact	284	No impact	207	No impact	No impact	232
Boston	219.2	219.8	No impact	No impact	No impact	No impact	281	No impact	No impact	No impact	No impact	229
Boston	219.8	220.0	No impact	No impact	No impact	No impact	280	No impact	No impact	No impact	No impact	228
Boston	220.0	221.1	No impact	No impact	No impact	No impact	276	No impact	No impact	No impact	No impact	225
Boston	221.1	221.8	No impact	No impact	No impact	No impact	282	No impact	No impact	No impact	No impact	230
Boston	221.8	222.3	No impact	No impact	No impact	No impact	282	No impact	No impact	No impact	No impact	230
Boston	222.3	223.4	No impact	No impact	No impact	No impact	282	No impact	No impact	No impact	No impact	230
Boston	223.4	223.8	No impact	No impact	No impact	No impact	270	No impact	No impact	No impact	No impact	220
Boston	223.8	224.7	No impact	No impact	No impact	No impact	270	No impact	No impact	No impact	No impact	220
Boston	224.7	225.7	No impact	No impact	No impact	No impact	252	No impact	No impact	No impact	No impact	204
Boston	225.7	227.0	No impact	No impact	No impact	No impact	231	No impact	No impact	No impact	No impact	186
Boston	227.0	227.5	No impact	No impact	149	149	198	No impact	No impact	115	115	157
Boston	227.5	227.6	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Boston	227.6	227.7	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Boston	227.7	228.3	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Boston	228.3	228.5	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
Boston	228.5	228.8	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact

Source: HMMH

CHAPTER 5
ELECTROMAGNETIC FIELDS

In response to comments on the DEIS/R further technical information was compiled to evaluate electromagnetic field effects in the immediate vicinity of the proposed Roxbury Substation, at four alternative Roxbury crossing sites, on fish migration, and on children's health. In addition, studies of EMF effects on workers (including some railway workers) in Norway, Sweden, and Denmark were also used to identify potential effects on workers in the Northeast Corridor, and an analysis of EMF impacts related to Amtrak design modifications.

An EMF measurement survey was conducted to determine the field strengths in the immediate vicinity of the Massachusetts Bay Transportation Authority's Roxbury and Proposed Action Roxbury substations. It was concluded that no discernible EMF levels were encountered above commonly found background levels and that the Proposed Action would not directly influence these levels near the Roxbury substations.

Potential EMF exposure to the nearby local population was considered at four alternative Roxbury substation locations. It was concluded that the Canton, Hyde Park, Terrace Street, and South Station alternative substation sites could potentially expose four, 693, 95, and zero persons to EMF, respectively.

EMF emissions from submarine cables at the Connecticut, Thames, Niantic, and Mystic Rivers, and Shaw's Cove moveable bridges were considered for their potential impact on aquatic life. Although the literature does indicate a possible correlation between migration and magnetic fields, the field strengths from the Proposed Action would be so low that there would be no adverse EMF impacts on fish.

The potential impact of EMF on children was reviewed to assess potential health effects. Based on epidemiologic studies, the literature concludes that the scientific data presently do not support a limitation on the levels of fields encountered in our ordinary environment. The EMF emitted by the Proposed Action would not be expected to have a significant impact on children's health, based upon the results of studies presently available.

EMF exposure studies over the past 2 years on Norwegian, Swedish, and Danish workers were reviewed to identify potential health impacts to workers. Although recent studies have improved upon the design of older studies, consistent associations have not been reported relating EMF exposure to worker cancer.

Since preparation of the DEIS/R, several site refinements were made to the Proposed Action. The reasons for the modifications are various and encompass engineering, real estate, and environmental considerations. All site refinements, except the New London feeder line route, resulted in no net change to the population estimates provided in the DEIS/R. The New London feeder line route resulted in an increase in potentially exposed residents, but a decrease in the industrial/commercial potentially exposed population.

Potential EMF safety issues from electromagnetic induction was analyzed. Limiting exposure lengths were identified for the close-by communication and signaling circuits, underground and above-ground pipes, large objects, and fences. The analysis indicated that there could be an impact from induced voltages to long and parallel structures, such as fences and guardrails. In addition, the potential impact of EMF on local communications systems was examined. It was estimated through computer simulation that the Proposed Action could have an impact on telephone lines.

Several comments on the DEIS/R raised questions regarding the potential impact of EMF on wildlife. While the potential for exposure of wildlife to EMF generated by the proposed electrification is relatively limited, there are certain locations along the NEC in which exposure of wildlife could occur. Therefore, existing research on EMF impacts on wildlife was reviewed. The studies concluded that no effects could be attributed to electromagnetic fields.

5.1 EMF IMPACTS IN THE VICINITY OF THE ROXBURY SUBSTATION

The location of the proposed Roxbury Substation is a vacant lot directly across Halleck Street from the MBTA Substation. The DEIS/R comments raised concerns that the two substations in close proximity might represent a high EMF burden to their environs. The results of the survey, in conjunction with EMF projections for the proposed substation, will be used to evaluate these concerns. The locations of the MBTA Substation and the proposed Amtrak Substation are presented in Figure 5.1-1. The MBTA Substation is a one-story concrete walled building with approximate dimensions of 60 feet along Station Street and 90 feet along Halleck Street. The building is directly attached to an adjoining warehouse to the northwest along Station Street. There are two sections to the substation, separated by an interior wall. One section is an approximate 60-foot by 60-foot square at the corner of Station Street and Halleck Street which houses rectifiers, and the other is a 20-foot by 60-foot section which houses transformers. Alternating current power input and direct current power output by underground cables are depicted on Figure 5.1-1.

The two substations would be located in an industrial area with no residences in the immediate vicinity. A warehouse/distribution facility is located directly northwest separated from the MBTA Substation by an interior wall, a distribution/manufacturing facility is located across Station Street to the northeast, and the remaining land around the MBTA Substation for hundreds of feet consists of parking lots and vacant lots. The nearest residential area is approximately 300 feet to the west-northwest. The rail corridor is approximately 250 feet to the southeast, parallel to Halleck Street.

5.1.1 Measurement Locations, Measurement Descriptions, And Instruments Used

EMF measurements were taken at 22 locations in the vicinity of the MBTA and proposed Amtrak substations. One of the locations was inside the MBTA Substation and the remainder were at accessible locations in the vicinity of the substations. A vacant lot adjoining the MBTA Substation and the vacant lot that is the proposed Amtrak Substation were both fenced off and therefore inaccessible.

Measurements were taken at the three accessible corners of the substations and at the midpoints of their two accessible walls. Measurements were also taken at measured 50-foot intervals along each of the nearby streets.

As is described more completely in the DEIS/R, EMF levels will vary with the levels of electric current being drawn at a specific location at any specific time. Therefore, EMF levels change frequently in the vicinity of substations, since current loads vary when trains go by and when power use changes in local industrial facilities. In order to estimate representative conditions, EMF measurements were taken in 10-second intervals over a 5-minute duration at each survey location, except for the measurement inside the substation which was conducted at 1-second intervals over a 12-minute duration. Single points for taking EMF measurements were selected rather than taking measurements while moving from point to point. This was done to eliminate the uncertainty about whether changes in EMF levels were due to changes in location or the time-varying nature of the EMF. The EMF values are presented herein as discrete readings for each measurement interval and as averages over the selected time duration.

The measurements were conducted on Thursday, April 21, 1994, between 9:30 AM and 12:30 PM. Trains went by during all but two of the exterior measurements; it is not known whether trains went by during the substation interior sampling, but it is likely that they did because of the relatively long measurement duration.

The measurements were taken using an Emdex C hand-held meter manufactured by Electric Field Measurements Company. The Emdex C is a three axis magnetic field data logger, which acquires 50 to 60 hertz magnetic field data. The magnetic field intensities were calculated as the root mean square of the three axial components of the magnetic fields. As with all other EMF data presented in the DEIS/R, only the magnetic field component of EMF was measured.

All measurements were taken at 60 centimeters above ground level with the instrument oriented with the x axis aligned north-south, the y axis aligned vertically, and the z axis aligned east-west.

5.1.2 Results of Field Intensity Measurements

The measured magnetic field intensities at each survey point are presented graphically in Appendix 5A. At least 30 measurements of magnetic field intensity were taken at each location. The measured field intensity demonstrates the significant fluctuation that takes place as the nearby sources of EMF vary with varying current.

The average of all readings at each survey location are presented in Table 5.1-1 and are shown on Figure 5.1-1, next to the survey location. The values directly around the substation range from 0.7 to 1.9 milligauss (mG) and are generally between 0.4 mG and 1.1 mG elsewhere, except for locations S05 and S06, which are under utility power distribution lines; S04 which is under a power distribution line and over the electric service line to the building shown on Figure 5.1-1; and S07 whose EMF source is unknown, but may be related to an underground electric conduit at the north corner of Halleck and Station Streets. The maximum values were generally between 0.6 and 2.6 mG in the neighborhood around the substation, 2 to 5 mG on the sidewalk next to the substation, 6.5 mG at S04 (over building utility feed line), 3.5 at S07 (across the street from the substation), and 95 at S13 (inside the substation).

5.1.3 Population Assessment for Proposed Substation Location

The numbers of potentially exposed persons around the MBTA substation and the proposed Amtrak substation have been estimated in accordance with the procedures and exposure zones established in the DEIS/R. The three zones represent the areas 0 to 50 feet (Zone 1), 50 to 100 feet (Zone 2), and 100 to 150 feet (Zone 3) away from the boundary of the proposed Amtrak substation. The projected values are for the year 2010. The results are summarized below:

	Zone 1	Zone 2	Zone 3
Commercial/Industrial Population (Current)	2	8	8
Commercial/Industrial Population (Projected)	3	9	9
Residential Population (Current)	0	0	0
Residential Population (Projected)	0	0	0

TABLE 5.1-1 Average Magnetic Field Intensity

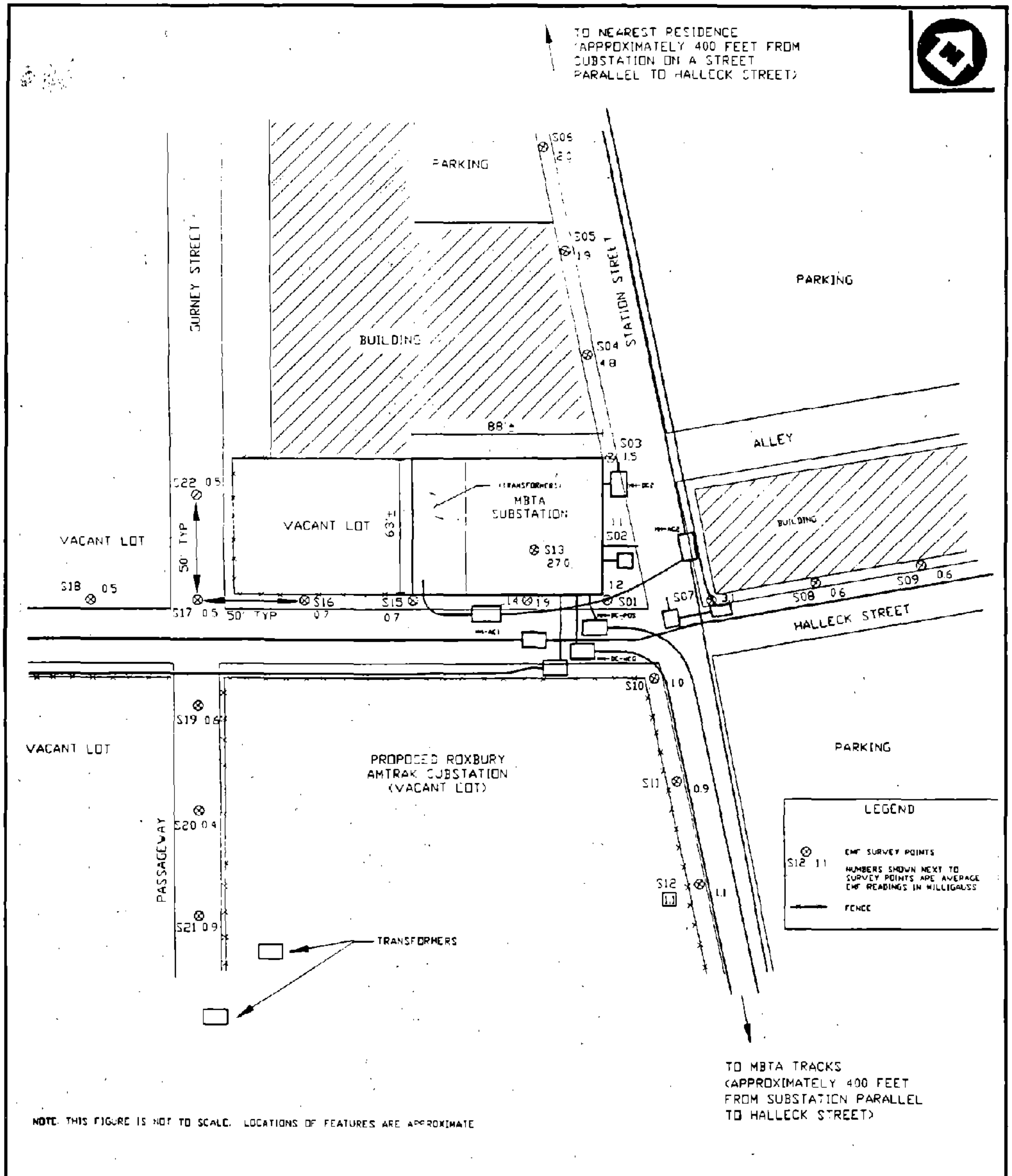
LOCATION	FIELD INTENSITY (mG)	LOCATION	FIELD INTENSITY (mG)
S01	1.2	S12	1.1
S02	1.1	S13 (Inside)	27.0
S03	1.5	S14	1.9
S04	4.8	S15	0.7
S05	1.9	S16	0.7
S06	2.0	S17	0.5
S07	3.1	S18	0.5
S08	0.6	S19	0.6
S09	0.6	S20	0.4
S10	1.0	S21	0.9
S11	0.9	S22	0.5

Source: Roy F. Weston, Inc., 1994

5.1.4 Conclusions of Field Intensity Measurements

Typical urban EMF values are reported in Figure 5.1-2 from Volume III of the DEIS/R, Section 5.4.3 of the Technical Study for Electromagnetic Field Impacts. These were obtained over a 6-mile travel distance from the city streets of Providence, RI, which contain representative urban-area EMF generating sources such as power distribution lines, building feed lines, signage, dedicated power lines, traffic control signals, lighting, building heating, ventilation, and air conditioning; and electrical motors and devices associated with office, commercial, manufacturing, and institutional use. The following conclusions were drawn from the data:

- the measured EMF ranges from 0 to 26 mG
- the highest sustained readings are around 10 mG; readings higher than 10 mG occurred as instantaneous "spikes" indicative of a narrow source of power such as a power line
- the average of the data appears to be around 4 mG



Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION EMF SURVEY LOCATIONS

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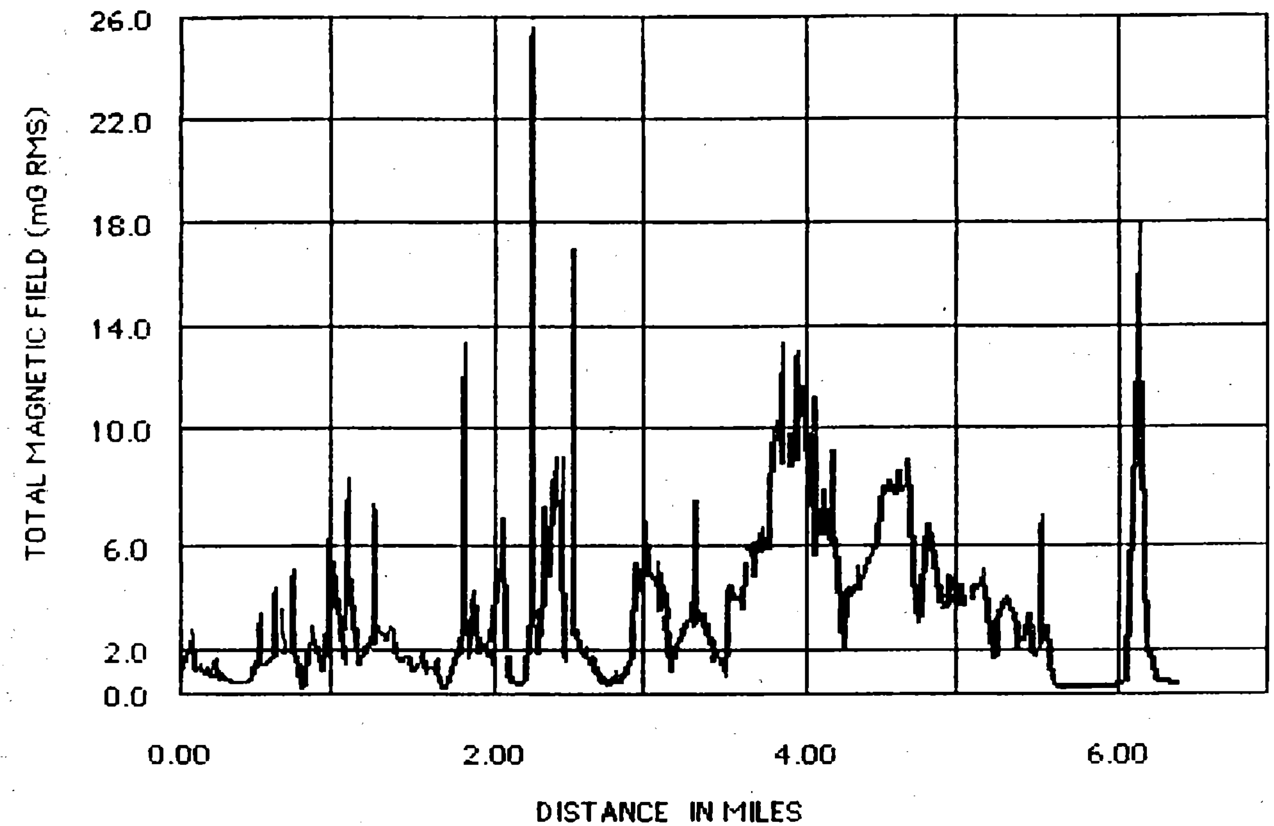
Figure 5.1-1



Source: Electric Research & Management, Inc., 1992

AMBIENT EMF MEASUREMENTS RECORDED DURING DRIVE FROM MANCHESTER STREET AND ALONG CITY STREETS AND U.S. 6, PROVIDENCE, RHODE ISLAND

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5.1-2

Based on the results of the survey described in this chapter and on the Providence survey described above, the following conclusions can be made:

- the EMF values immediately adjacent to the substation are equal to or less than EMF values elsewhere in the same neighborhood generated by other sources
- all EMF values measured (except for inside the substation) have an average intensity of 1.3 mG which is significantly lower than the 4.0 mG urban average obtained during the Providence survey
- all EMF values (except for inside the substation) are within the ranges typically encountered within and around residences (as described in more detail in the DEIS/R section referenced earlier)
- the MBTA Substation has no discernible EMF levels above what would be considered background levels for either urban areas or for residential units in any setting
- the MBTA Substation EMF levels will have no direct influence on the levels projected for the proposed Amtrak Substation since they cannot be discerned from other background levels

This last point is critical in that it relates to the potential for combined or cumulative impacts from the existing MBTA Substation and the proposed Amtrak Substation, which is one of the concerns raised in comments on the DEIS/R. Since the EMF levels surrounding the MBTA Substation are consistent with the levels encountered in urban environments, the EMF impacts associated with the proposed Amtrak Substation would be expected to be essentially the same whether the substation were located at the proposed location near the MBTA Substation or at any other location in an urban environment. Thus, no site-specific analysis of cumulative EMF impacts is warranted.

5.2 POPULATION ASSESSMENT FOR ALTERNATIVE SUBSTATION LOCATIONS

In response to concerns raised regarding the proposed location of the substation in Roxbury, four alternative locations for that substation have been identified. These four alternative locations have been evaluated in terms of the number of people residing and working within 150 feet of the locations. A discussion of each alternative location is presented below. Current populations' potential exposure to EMF resulting from the alternative location have been based on either visual assessments or, if the potentially affected area was large, zoning criteria. Populations for 2010 were then calculated based on the Massachusetts projected growth rate of 6.4 percent presented in the 1990 United States Census. The three zones represent the areas 0 to 50 feet (Zone 1), 50 to 100 feet (Zone 2), and 100 to 150 feet (Zone 3) away from the boundary of the proposed Amtrak Substation.

5.2.1 Canton Alternative Location - Milepost 212.9

The Canton alternative substation location is located south of High Street and west of Thayer Road along a Boston Edison transmission line. Houses along Thayer Street parallel the Boston Edison right-of-way, but are separated from the ROW by approximately 300 to 400 feet of woods and are, therefore, outside of the study limit. A single residence is located off the access to the ROW directly north of the alternative substation location. Based on the indicated alternative location, it would appear that this residence would be over 150 feet away from the substation. However, actual design may involve the placement of tie lines and other electrical system components nearer this residence; therefore, it has been included in the Zone 3 population estimates with an assumed population of four.

Due to power requirements, it is expected that this alternative location would require additional paralleling stations at the proposed Roxbury site and the alternate South Station site. The populations associated with these other sites are not included in the population estimates for this alternative. The numbers of potentially exposed persons around the Canton alternative location are as follows:

	Zone 1	Zone 2	Zone 3
Commercial/Industrial Population (Current)	0	0	0
Commercial/Industrial Population (Projected)	0	0	0
Residential Population (Current)	0	0	4
Residential Population (Projected)	0	0	4

5.2.2 Hyde Park Alternative Location - Milepost 220.5

The Hyde Park alternative substation location is located west of Hyde Park Avenue, slightly north of Dacy Street. Adjacent to the site are several industrial buildings and a multifamily residence. The substation would require a 115 kV feeder line which would extend north along Hyde Park Avenue approximately 11,000 feet to the existing Boston Edison 115 kV power source. Due to the length of the feeder line and the densely populated neighborhoods, a significant increase in the population potentially exposed to EMF would result from placing the substation at this alternative location.

Due to the large area potentially affected by this alternative, population estimates were established via zoning criteria. Estimates of existing residential and non-rail employee populations within each zone are made based upon current zoning districts along the corridor and tie-lines. To supplement this information, specific buildings having an occupancy higher than the estimates based on zoning districts and/or in particularly close proximity to the ROW were identified based upon review of aerial photographs, a slow-speed rail trip along the NEC, and discussions with officials from each town/city. This allowed individual estimates of employment for these particular buildings. Increases in residential and non-rail employee populations expected by the year 2010 were then estimated via state growth rates presented in the 1990 United States Census. Estimates for rail employee populations and for ridership populations are based on information provided by U.S. DOT, Amtrak, the MBTA, and ConnDOT. These estimates are described separately from the residential and non-rail employee estimates. The method used is discussed in greater detail in Technical Study 5 on EMF in the DEIS/R. Due to power requirements, it is expected that this alternative location would require additional paralleling stations at the proposed Roxbury site and the alternate South Station site. The populations associated with these other sites are not included in the population estimates for this alternative. The numbers of potentially exposed persons around the Hyde Park alternative location are as follows:

	Zone 1	Zone 2	Zone 3
Commercial/Industrial Population (Current)	25	529	529
Commercial/Industrial Population (Projected)	27	563	563
Residential Population (Current)	130	260	260
Residential Population (Projected)	139	277	277

5.2.3 Terrace Street Alternative Location - Milepost 225.2

According to the latest design information provided, the Terrace Street alternative substation is located at the southern end of Terrace Street at the intersection of Terrace Place. Current population estimates assume that the abandoned factory will be utilized for the substation and, therefore, will not be occupied. The feeder is anticipated to tie into Boston Edison on Tremont Street approximately 2,000 feet to the north. Population estimates are based on an inspection of the area and aerial photographs. The numbers of potentially exposed persons around the Terrace Street alternative location are as follows:

	Zone 1	Zone 2	Zone 3
Commercial/Industrial Population (Current)	24	48	48
Commercial/Industrial Population (Projected)	26	51	51
Residential Population (Current)	18	36	36
Residential Population (Projected)	19	38	38

5.2.4 South Station Alternative Location - Milepost 228.8

The South Station alternative substation location is located south of the railroad tracks adjacent to and north of Broadway Bridge. No residential structures are within the vicinity of this site. The only industrial/commercial building is an abandoned factory immediately south of Broadway Bridge. It was assumed that this factory will be demolished as part of the Central Artery/Tunnel (CA/T) construction project.

Due to power requirements, it is expected that this alternative location would require an additional substation at the alternative Canton site and a switching station at the proposed Roxbury site. The populations associated with sites are identified above. It was found that there are no potentially exposed persons within 150 feet of the South Station alternative location.

5.3 ANALYSIS OF EMF IMPACTS ON FISH MIGRATION

5.3.1 Introduction

This study examines the effects of EMF on the migration of fish in the rivers where there would be submarine cables carrying power for the proposed electrification project. Submarine cables would be present at five moveable bridges crossing the Connecticut, Thames, Niantic, and Mystic Rivers, and Shaw's Cove. The submarine cables would function as the feeder cable, as well as maintain full current flow along the traction circuit during the times that the bridges are open to allow the passage of river traffic. During normal operations, the moveable bridges are closed when trains are operating in their vicinity. At these times, current flow would apportion itself between the catenary and the submarine cable, so that there would always be current flowing through the cable when a train activates the local section of the catenary.

Based on Amtrak information, the average current in the submarine cables was estimated to be typically around 166 amps when the bridge is open, and approximately one-half that value when the bridge is closed.[1] On the other hand, the current specifications for the cable's design call for a 30-minute maximum value of 599 amps, and it is this current magnitude that has been used to model EMF levels, as described below. The cable specifications also list a 10-second maximum of 961 amps and a 15-minute maximum of 686 amps. The 599 amp value was selected for modeling because it is more consistent with the 166 amp expected average current level, while utilizing the conservative assumption of a peak condition.

5.3.2 Assessment of Potential Electric and Magnetic Field Exposure from Submarine Cables

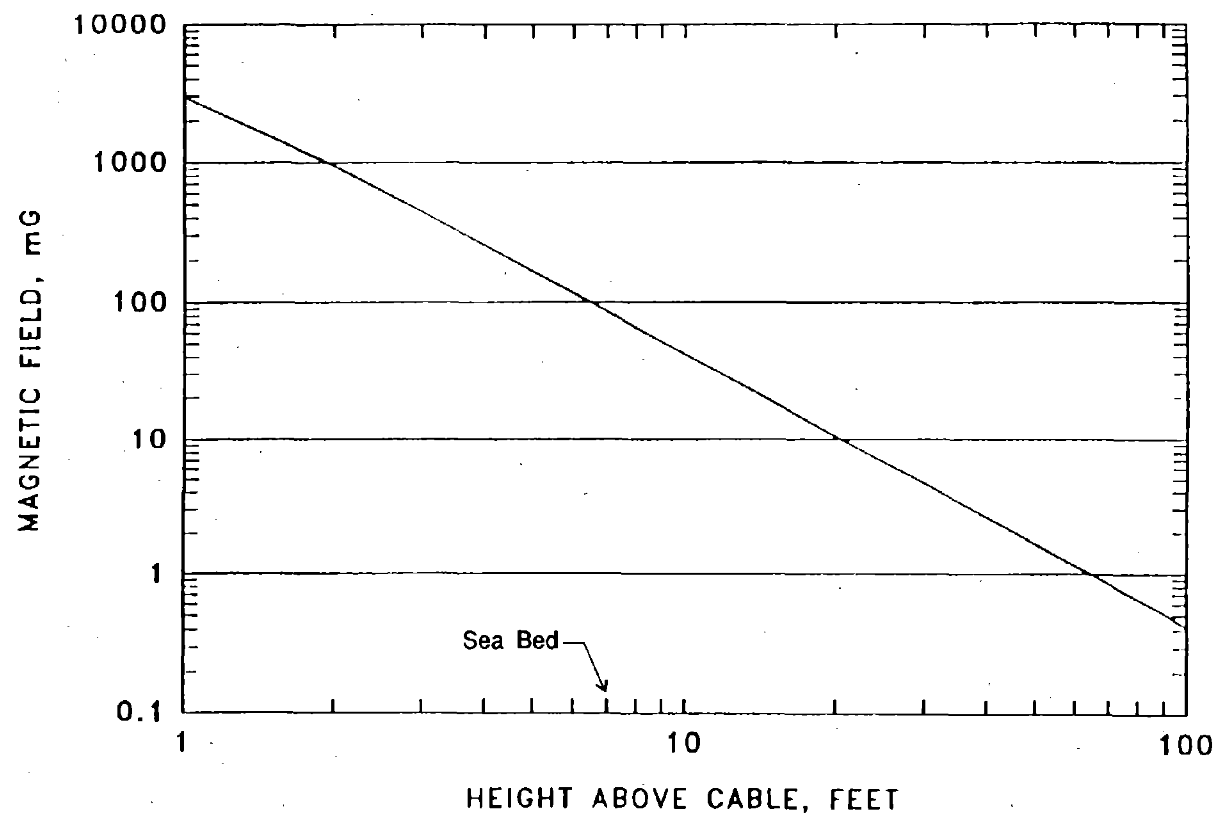
The submarine cables would not be a source of electric field exposure to fish and other aquatic organisms because of shielding by the metal anchor covering the cable. Hence, the only potential field exposure of significance would be magnetic. The submarine cable would be buried at a depth of 7 feet below the sea floor. The magnetic field intensities for a 599 amp current as a function of distance away from the submarine cable are presented in Figure 5.3-1. This figure was prepared based on the current design of the submarine cable and conduit configurations. The figure can be used to estimate the instantaneous maximum magnetic field exposure likely to be encountered at the moveable bridge crossings during short duration, peak power loadings. Magnetic field calculations, based upon the maximum 30-minute design current flow of 599 amps, project that the magnetic field levels would be about 12 mG at the surface of the shallowest river, the Niantic, or 15 feet above the cable. The mid-depth magnetic field value, 11 feet above the cable, for this river is approximately 28 mG. Since the Niantic River has the shallowest channel compared to the channels at the other four water bodies, the values described here are maximum values. Estimated magnetic field intensities from the submarine cables and catenaries at all moveable bridge crossings are presented in Table 5.3-1. It is important to note that when assessing potential exposure to aquatic life, the Niantic River submarine cable and the other cable crossings span less than half the width of their associated water bodies.

TABLE 5.3-1 EMF Intensity (mG) from Catenary and Submarine Cable at River/Cove Crossings

RIVER/COVE CROSSING	LOCATION	SUBMARINE CABLE		CATENARY	
		Distance To (ft)	Intensity (mG)	Distance To (ft)	Intensity (mG)
Connecticut River	Water Surface	22	7.8	52	1.6
	Mid-depth	14	13.0	60	1.2
Mystic River	Water Surface	22	7.8	44	2.6
	Mid-depth	14	13.0	52	1.6
Shaw's Cove	Water Surface	22	7.8	39	3.6
	Mid-depth	14	13.0	46	2.3
Niantic River	Water Surface	15	12.0	42	3.0
	Mid-depth	11	28.0	46	2.3
Thames River	Water Surface	47	2.0	55	1.4
	Mid-depth	27	5.7	75	< 1

Source: Roy F. Weston, Inc., 1994

Assuming that EMF values are a linear function of current, the average magnetic fields (based on an expected average current flow of 166 amps rather than the maximum design flow of 599 amps) that will be encountered at the Niantic River when the bridge is open are on the order of 4 mG at the surface, 8 mG at mid-depth, and 20 mG at the channel bottom. When the bridge is closed, these values will be approximately halved (to account for current apportioned between the catenary and the cable).



Source: Roy F. Weston, Inc.

MAGNETIC FIELD INTENSITY ABOVE SUBMARINE CABLE

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Figure 5.3-1

The overhead catenary system is also a potential source of magnetic fields in the water column. The magnitude of the magnetic fields from the catenary system can be estimated using the railside "EMF falloff" curve presented in Figure 5.3-2 from Volume III of the DEIS/R. (Figure 5.3-1 of this chapter is not used for the catenary because it is specific to the configuration of the submarine cable.) Figure 5.3-2 presents magnetic field intensity generated by the catenary and feeder line as a function of distance from the side of the rail along the ground surface. The catenary would be 23 feet above the rail, and the distance from the rail to mean low water for the Niantic River crossing is approximately 19 feet, for a total distance of 42 feet. Using Figure 5.3-2, the magnetic field intensity at the water surface would be the same magnetic field intensity as being 35 feet from the side of the rail, or approximately 3 mG.[2] The value at mid-depth for the Niantic River (4 feet below MLW or 44 feet below the catenary) is similarly estimated to be 2.3 mG. These magnetic field levels are likely to be experienced only when the train is actually on the bridge, causing current flow primarily through the catenary and not through the submarine cables. At other times, the magnetic field intensities will be diminished by half, reflecting the apportionment of current between the catenary and the submarine cable.

5.3.3 Connecticut Inshore Finfish

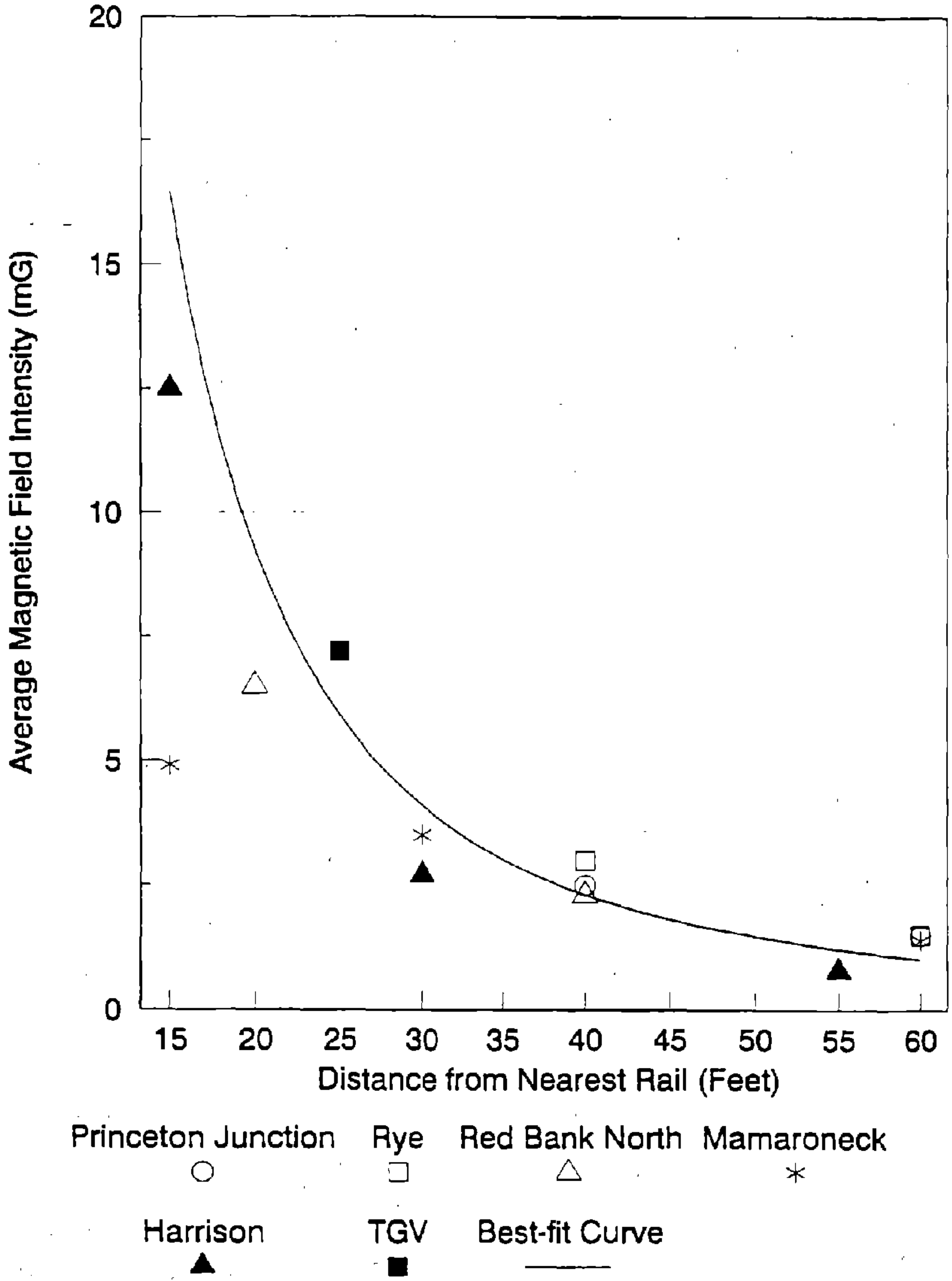
Of the anticipated submarine cables, four will be under estuaries and one will be under a saltwater cove. These estuaries and the saltwater cove provide habitat for a diversity of plant and animal life. Table 5.3-2 presents four types of finfish whose species are associated with these Connecticut aquatic environments. One type of finfish, estuarine, inhabits these aquatic environments throughout their life cycle, while the three other types of finfish will pass through these aquatic environments at different stages of their life cycle.

The three finfish types which pass through these aquatic environments during various stages of their life cycles include anadromous, catadromous, and euryhaline. Anadromous are those species which mature in salt water and migrate upstream to freshwater to spawn. Catadromous are those species which mature in freshwater and migrate to the sea to spawn. The last type of species are known as euryhaline. These species are able to tolerate a wide range of salinities and thus can be found in both saltwater and freshwater environments.

5.3.4 Use of the DC Geomagnetic Field by Fish for Navigational Cues

There has been ongoing interest in the possibility that exposure to manmade electric and magnetic fields could alter an organism's ability to navigate if the Earth's DC magnetic field is relied upon as a stable signal. Kirschvink reviews several studies that describe tests of different organisms' abilities to orient themselves with the aid of geomagnetic cues. Marine organisms reportedly able to orient themselves with geomagnetic cues include: magnetotactic bacteria and algae, sharks and rays, sockeye salmon, tuna, eels, and cetaceans. It is hypothesized that these organisms are geomagnetically sensitive because they possess magnetite.[3]

Magnetite is a ferromagnetic compound that is enclosed by a membrane.[4] In a recent report Kirschvink et al. reported that "there is a substantial concentration [of magnetite] in the well-defined dermal tissues of the dermethmoid region of the head of coho salmon."[5] It can be inferred from this that coho like sockeye salmon have the ability to orient themselves with geomagnetic cues. It was shown by Walker et al. that fin whales observed at sea have the ability to discriminate geomagnetic field gradients during migrations. These researchers were also able to train yellowfin tuna and honeybees to discriminate between a "spatially varying magnetic field from the ambient Hawaiian field" in the laboratory, although they were unable to pinpoint the location of magnetoreceptors.[6]



Source: DMJM/Harris, DEIS 1993

EMF FIELD STRENGTH AS A FUNCTION OF DISTANCE FROM RAIL

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Figure 5.3-2

TABLE 5.3-2 Finfish in Connecticut Estuaries and Saltwater Coves

FISH SPECIES	FISH TYPE			
	Estuarine	Anadromous	Catadromous	Euryhaline
Striped Killifish				X
Winter Flounder	X			
Three-Spine Stickleback	X			
Blueback Herring		X		
Alewife		X		
Naked Goby				X
American Shad		X		
Sea Run Brown Trout		X		
Rainbow Smelt		X		
American Eel			X	
Shortnose Sturgeon*		X		
Atlantic Salmon**		X		

Notes: *Endangered Species
**Is being reintroduced into the Connecticut River

Source: Adapted by Weston, Inc., from State of Connecticut, DEP, Fisheries Division, Habitat Conservation and Enhancement. *Inshore Finfish of Connecticut.* 1994.

5.3.5 Sensitivity to Electric Fields

In addition to reports that indicate that some marine animals are able to detect magnetic fields, it has been well documented that weak electric fields can also be detected by certain fish, which in turn use them as a means of orientation and prey location.[7] In electrosensitive fish such as elasmobranches (sharks, skates, rays, etc.) the ampullae of lorenzini serve as electroreceptors. The ampullae of lorenzini are jelly-filled canals which enable the fish to detect weak electric fields. Miller reported that "electrosensitive fish will readily respond to DC and AC fields, particularly to 1, 2, and 4 Hz fields but as the frequency increases the intensity of the field must be increased to be effective. In essence, the organs are responsive to fields ranging from DC to about 8 Hz." According to Kalmijn, "elasmobranch fishes detect DC and low frequency electric fields as weak as 5 nV/cm, which represents the highest electrical sensitivity known in the animal kingdom."[8] Although understanding of the mechanisms used by animals to assist in navigation is far from complete, the available information does not suggest that 60 Hz fields such as those associated with overhead AC transmission lines or underwater cables would impact marine species at crossings. In fact, those mechanisms that have been identified suggest that sensitivity is limited to direct current not 60 Hz alternating current fields. In addition, most of the species mentioned in the research literature do not inhabit the four rivers and estuaries associated with the proposed electrification.

5.3.6 Embryo Development and Fertilization

Several studies have been conducted to assess the effects of magnetic fields on the development of embryos in aquatic environments. One study of fish embryogenesis investigated the effects of electric (300 mA/m^2) and magnetic fields (1.0 G), designed to simulate those beneath a high-voltage transmission line, on Medaka fish eggs.[9] Cameron et al. reported that no gross abnormalities were observed in any of the embryos as they developed, but development delays of an average of 18 hours were seen in those embryos exposed to magnetic fields and 5 hours when exposed to combined electromagnetic fields. Delays were not seen in the embryos exposed to the electrical field alone. It was suggested by these researchers that magnetic fields like those produced by 60 Hz transmission lines retard development of Medaka fish embryos.[10] In another study, Cameron et al. found that 60 Hz magnetic fields caused delays in the early stages of sea urchin embryogenesis.[11] Conversely, Strand et al. demonstrated that magnetic field exposures of around 10,000 mG actually enhanced the fertilization success of rainbow trout under three exposure scenarios: ova alone, sperm alone, and both ova and sperm.[12]

The studies on embryo development and fertilization to date are insufficient to draw firm conclusions. However, a wealth of information on nonhuman mammalian species (e.g., rats) does not indicate that 60 Hz fields adversely affect reproduction and development process.

5.3.7 Upstream Migration and Movement

A question has been raised as to whether the electric and magnetic fields associated with the submarine cables would impede the upstream migration of anadromous and other migrating fish species. Although this question has not been a specific topic of research, there are some relevant data available. The U.S. Navy has been monitoring the possible effects of electric and magnetic fields on biological organisms in Michigan and Wisconsin since 1969. The source of these fields is an above-ground military communications antenna operating at 76 Hz. This antenna produces electric and magnetic fields similar to those produced by high-voltage transmission lines. Although there are some differences in frequencies and field strength between the antenna and submarine cables, the ecological study mentioned here provides a point of comparison to the potential effects of electric and magnetic fields on fish which inhabit the Thames, Connecticut, Niantic, and Mystic Rivers. One element of the Navy's ecological monitoring program was to assess the potential impact of electric and magnetic fields on brook trout movement patterns and rates. It was concluded by researchers Burton et al. that no differences in either mean daily movement rate or number of days between tagging and recapture were detected when the pre-transitional and post-operational periods of the antenna were compared.[13] In addition, many direct observations were made of brook trout passing directly under the antenna.

Poddubny observed that sturgeon (*Acipenser güldenstadtii*) appeared to alter their swimming direction and rate when they passed beneath a high-voltage transmission line.[14] While it was noted that the magnetic field strength in the water was about 600 mG, no information was provided on the transmission line configuration or its location respective to the field observations and measurements. Estimated magnetic field intensities at the five cable crossings are one to two orders-of-magnitude less than those associated with Poddubny's observations.

Although these two studies provide some additional information, they are of limited relevance for the following reasons. First, the study by Burton et al. is of a freshwater species and thus the results may not hold true for species in a marine environment.[15] Second, observation of a few single sturgeon under field conditions is of limited value. The observation was not made under controlled conditions and may not apply to other sturgeon species. Furthermore, no response sufficiently strong to predict a likely adverse impact was noted.

5.3.8 Conclusions

Assuming that the use of the Earth's direct current magnetic field by fish or other marine organisms as a navigational cue is mediated by magnetoreceptors, one would expect no interference by the proposed project for two reasons. First, the obvious sensitivity of the species is to DC magnetic fields, not 60 Hz AC magnetic fields. Second, analyses and calculations made by Adair[16] and Kirschvink et al.[17] suggest that it is unlikely that detection of 60 Hz AC fields by mechanisms based upon magnetite would operate at field strengths below 50 mG. Such field strengths would not be encountered at distances greater than 10 feet from the cable or 3 feet above the bottom of the channel. As shown by Figure 5.4-1, the maximum estimated magnetic field intensity at 10 feet above the submarine cable is approximately 42 mG (based on 599 amps). This means that if fish swim close enough to detect the field, they will have an opportunity to swim above the perceived field, in order to avoid field strengths greater than 50 mG. Furthermore, none of the proposed submarine cables would span more than half the width of the water body being crossed, thus leaving the major portion of water bodies exposed to only the very low magnetic field intensities resulting from the catenary systems. Finally, the expected average magnetic field intensity (at 166 amps) 10 feet above the cable would be on the order of 12 mG while the bridge is open and 6 mG while it is closed (far less than 50 mG), the latter condition being its predominant configuration. For these reasons, the EMF from the Proposed Action would not be expected to have adverse impacts on fish at the river and cove crossings.

5.4 ANALYSIS OF EMF IMPACTS ON CHILDREN'S HEALTH

5.4.1 Introduction

The proposed electrification of the rail line between New Haven and Boston constitutes a source of environmental electric and magnetic fields at power frequencies (60 Hz) similar to other existing electric transportation catenaries (e.g., the 11 kV line on the NEC south of New Haven). Comments on the DEIS/R have requested information on recent epidemiological studies of exposure to electric and magnetic fields at power frequencies and different types of cancer in children. As a result, this analysis is designed to supplement information presented in the DEIS/R by evaluating and summarizing the implications of the recent epidemiologic studies for potential impacts of these fields on human health, and relating these studies to the exposures estimated to be associated with the proposed electrification project. In addition, this section includes a discussion of assessments prepared by groups of scientists convened to evaluate the scientific research on electric and magnetic fields and health.

In the standard scientific approach to assess the potential health effects of any environmental exposure, both epidemiologic studies and laboratory studies are considered. Taken together these studies provide complementary information; epidemiology studies provide information on humans in their natural environments, and laboratory studies provide information on animals, cells, and tissues in carefully controlled laboratory environments. This technical study addresses those recent epidemiologic studies from Sweden and other Scandinavian countries that were the subject of comments; however, the DEIS/R, Volume III, considered the laboratory research (Section 5.2.4) as well as the epidemiologic research (Section 5.2.3) relevant to EMF and cancer in reaching its conclusions (Section 5.2.5).

Epidemiological studies of residential exposures to magnetic fields from power lines including the studies in Denver,[18] in California,[19] and the 'Swedish' study[20] were discussed in Volume III (Section 5.2.2) of the DEIS/R. (The results of the Swedish study were later published in the *American Journal of Epidemiology* in 1993).[21] These and other studies raised in comments are described herein. One comment requested information on the "NCI Study." The National Cancer Institute is collaborating with other groups to study childhood leukemia and extremely low frequency (ELF) magnetic fields, but the study is not complete, so it is not discussed herein. Before discussing the epidemiologic studies in more detail, it is helpful to consider the basic characteristics of these epidemiologic studies and the strengths and limitations of the data that are obtained from these studies.

5.4.2 Basic Characteristics of Epidemiologic Studies of EMF on Children's Health

Epidemiology studies are concerned with the disease patterns of people in their normal environment. The predominant type of epidemiologic study used to study EMF exposures and childhood cancers is the case-control study. Case-control epidemiological studies are designed to compare the exposures of groups of individuals with disease (cases) with groups of healthy individuals (controls). The results are expressed as odds [of exposure] ratios (OR). If large and consistent differences in the exposures of these groups are observed in repeated studies, then this could mean that these exposure factors affect disease development. However, other research is usually necessary to determine whether, in fact, an observed difference in exposure is a cause of the disease.

Any deviation in the odds ratio from 1.0, indicating greater or lesser exposures of cases relative to controls, is termed an association. Thus, the reporting of an association in case-control studies reflects a difference in exposure between two groups. Odds ratios that are above 1.0 suggest that cases are more likely to have been exposed than have controls. A higher odds ratio, above 5 or 10, means that the exposure is many times more frequent in cases. Odds ratios that are low (e.g., below 2 or 3) suggest a weak association, meaning that the exposure is seen in cases only slightly more often than in controls. For various reasons, odds ratios in epidemiologic studies are inexact, but low odds ratios are less convincing of an association than high odds ratios.

Because the groups being compared are very small samples of the entire population, it is easy to appreciate that the cases and controls being compared may not be truly representative of the population. Moreover, a single odds ratio value itself is only an estimate for the population in question. Therefore, odds ratios are expressed as a range of values (the confidence interval) that is likely to contain the true value that would be measured if the entire population was studied. The idea is analogous to specifying the uncertainty of a public opinion poll as being within plus/minus 5 or 10 percent error.

In epidemiologic studies, the relevant exposures generally cannot be directly measured, especially in the past or over long periods of time, and so various surrogate or substitute measures of exposures are employed. The validity and reliability of surrogate exposure measures is an important question in assessing the results of epidemiology studies. The uncertainty attendant to a surrogate measure used in previous epidemiology studies of EMF, the wiring code, prompted a search for different measures of exposure for use in the Scandinavian studies. This is discussed below.

Since epidemiological studies are observational in nature, not experimental, they are inherently more susceptible than controlled laboratory studies in experimental animals or tissues to factors or conditions that could distort, or bias, the finding. Because of these potential confounding factors, care must be taken to determine whether the identification of an association in an epidemiologic study indicates a direct causal relationship.

5.4.3 Epidemiologic Studies of EMF

Studies of EMF generally need to assess exposures that occurred several years before the study date. The relevant exposures are likely to be those incurred over a period of time. Of course, long-term exposures in the past to magnetic fields in the residence cannot be directly measured, but must be estimated by substitutes or surrogates. The methods used to estimate an individual's magnetic field exposure were:

- The configuration of power line wiring outside of the residence was assessed based on the presumed ability of the power lines to carry current and thus emit magnetic fields. Using a combination of wiring configuration and distance, several categories were created, the high current carrying category is often called "high wiring code."

- Present-day spot measurements of magnetic fields were made in the residence under normal living conditions, and with the home wiring and major appliances de-energized.

- Distance from power lines to the residence was also used as a surrogate measure of exposure to magnetic fields.

The recent Swedish study and other studies from the Nordic countries used still another surrogate: the annual average magnetic field level at the residence was calculated for residences occupied. This method of estimating exposure took into account historical records of the currents flowing through transmission lines, the physical configuration of the wires, and the distance of the transmission line from the residence.

Associations have been reported between certain childhood cancers, primarily leukemia, and certain types of power lines identified as high-current carrying lines. However, those same studies did not show statistical associations between childhood leukemia and spot measurements in several rooms, or with 24-hour average magnetic field levels in the home.[22] The Swedish study also reported the same apparent contradiction: In contrast to the association reported with calculated average annual fields from power lines, spot measured fields in the home, which reflect exposure from power lines as well as other home sources of magnetic fields, were not associated with childhood leukemia.[23]

Recent research has not supported the argument that wire codes are a better method of assessing previous magnetic field exposure than present day spot measurements. The question of which is a better measure remains unresolved. Thus, results of studies that report associations with wire code, but not with measured fields remain contradictory and are not understood.

5.4.3(a) The 'Swedish' Study[24]

Sweden and other Scandinavian countries have 50 Hz power, while the U.S. uses 60 Hz, and these countries have a different transmission and distribution network than the U.S. However, 50/60 Hz are both in the extremely low frequency range, and have no known differences in terms of implications for health. The magnetic field emissions related to the proposed NEC electrification project (60 Hz) are described in the DEIS/R, Volume III Section 5.5.

Feychting and Ahlbom examined a segment of the Swedish population that had lived within 300 meters (984 feet) of 220 kV and 440 kV high voltage transmission lines between 1960 to 1985. (As a point of reference, the catenary for the proposed NEC electrification operates at 25 kV and some of the utility tie-lines will operate at 115 kV.) From this population, all cancer cases in children from birth to age 16 who had ever lived in the area were included in a case-control study. The controls were randomly selected from the same population base and where possible matched to cases based upon age, sex, and residential district.

The exposures of case and control residences to magnetic fields were compared based upon three different surrogate methods of estimating exposures. The methods used to estimate magnetic field exposure were: the annual average magnetic field level at the residence, calculated for residences occupied near the year of diagnosis, and 1, 5, and 10 years before diagnosis; present-day spot measurements of magnetic fields made in the residence with the home wiring and appliances de-energized; and distance from transmission lines. Two of these methods -- calculated average annual fields from transmission lines and distance from transmission lines -- are designed as estimates of magnetic fields from transmission lines. The third method, spot measurements in the home, estimates magnetic field levels in the home currently, from all sources.

None of these methods as yet has been validated as estimates of an individual's magnetic field exposure in the past or over a period of time.

Any commentary on this study must necessarily be cautious and tempered because of the very small number of cases in this study population. In the 26 years covered by this study, only 38 cases of childhood leukemia occurred, and the majority (27) resided in homes where the calculated fields were less than 1 mG (considered as an unexposed group for the purposes of this study). In any scientific studies, fewer subjects leads to greater uncertainty. In this study, because so few subjects resided where fields were calculated to be over 1 mG, the estimated associations with leukemia are imprecise and less reliable. This should be kept in mind in evaluating the results of the investigators' analyses.

None of the three methods of estimating exposure, historic calculated, measured magnetic fields, or distance from transmission lines, were associated with the grouping of all childhood cancers, or with brain tumors. That is, no statistically significant differences in exposure between cases and controls were reported using any exposure surrogate. However, two surrogate measures -- distance and historic calculated magnetic fields -- were reported to distinguish the exposures of leukemia cases and controls. The researchers suggested that there was a trend for leukemia cases to live closer to transmission lines, and to have higher calculated fields at the residence than controls. The latter trend was reported to be statistically significant. Note, however, that these two exposure estimates are not independent because distance from the home is used in the calculation of magnetic fields.

The researchers reported that they observed a "dose response pattern" for historic calculated magnetic fields and leukemia. The investigators focused their analysis on calculated historical magnetic field exposures falling into categories of < 1 mG, 1 to 2 mG, and 2+ mG. However, support for this interpretation is weakened by the fact that cases and controls do not significantly differ in their exposures in the intermediate exposure (1 to 2 mG) category.

If exposure to some level of magnetic fields was indeed one of the causes of childhood leukemia, then one would expect that the association would be observed with some consistency. However, when comparisons of exposures were made for children who only lived in Stockholm, or in apartments, or whose exposures were assessed just at the birth residence, or who lived at the same address from birth to year of diagnosis, or for cases diagnosed in the period 1960-1974, there was no indication that leukemia cases had higher estimated exposures to magnetic fields based upon either calculated field levels or distance. These analyses show that the reported associations between historic calculated magnetic fields and leukemia appear to derive entirely from data on single-family homes outside of Stockholm in the period 1975 to 1985. Again, interpretation of these analyses are hampered by the small numbers of cases and controls in each exposure category.

In contrast to some of the above findings regarding calculated historic magnetic fields, the data analyses based upon the average level of magnetic field actually measured in the residence at the time of diagnosis consistently failed to be associated with leukemia. This lack of association held even when taking into account location (Stockholm, or the rest of Sweden), type of residence (apartment or single-family home), or decade of case diagnosis (1960 to 1974 or 1975 to 1985).

To help put these findings in perspective it is important to note that Feychting and Ahlbom reported in their 1993 paper that the observed incidence (frequency of occurrence of new cases) of childhood cancer in the population living near high-voltage transmission lines was similar to that expected of the entire population of children living in Sweden. Childhood leukemia is rare, even more rare than many other types of cancer disease, occurring in four per 100,000 children under the age of 15.

5.4.3(b) Other Studies from Nordic Countries

Two other studies in Nordic countries also used calculated fields and selected study participants from a clearly identified population, similar to the characteristics of the Swedish study. However, the uncertainties in the calculated magnetic field exposure of the Danish study are clearly greater than in the Swedish studies because in many cases the current flows were estimated rather than being based on historical records. The Danish researchers designed a case-control study of the entire country.[25] The Finnish study was of cohort design.[26] Using the national cancer registries in Finland and in Denmark, researchers evaluated the association between magnetic fields and leukemia as well as other types of childhood cancer.[27] These two studies did not report associations between magnetic fields and leukemia, nor between magnetic fields of 2.5 mG and childhood cancers grouped together. The Danish study reported an association for all cancers at magnetic field strength above 4 mG, but the Finnish study did not. The Danish study reported an association with lymphoma, but the Swedish study did not.

The results of three Nordic childhood cancer studies (Sweden, Denmark, Finland) do not demonstrate consistent associations between any magnetic fields levels and any type of childhood cancer. However, the small numbers limit interpretation of the results. To compensate for the limitations imposed by small numbers of cases in some of the categories, these studies were analyzed together by the principal researchers involved in each of the published studies. Pooling of the data was possible because the cancer types and exposure measures were similar, even though the study designs, exposure assessments, and transmission and distribution systems had some differences. The pooled risk estimates were based on the estimated measure of association from each of the studies, at exposure levels of 2 or 2.5 mG. The pooled estimates indicated an association between calculated magnetic field levels and leukemia, but not with nervous system cancers or lymphoma.

This combined analysis provides useful information on the three Scandinavian studies. However, it is not a comprehensive assessment of the epidemiologic data on childhood cancers. Pooling is an alternative statistical procedure for summarizing data when results of individual studies are indeterminate because of small samples. Pooling does not adjust for unmeasured factors that can bias individual studies, or for logical inconsistencies among them and, of course, it includes no information at all on the plausibility of the association as determined from laboratory research. Consequently, while the pooled analysis provides information on the three Nordic epidemiologic studies, it is not a comprehensive analysis of all the relevant data that must be considered in weighing the evidence.

5.4.3(c) Analysis of the Impact of Magnetic Field Exposure on Children's Health

The steps to assess the health impact of any specific environmental exposure consist of answering several questions. The public health question for EMF has focused on cancer, rather than on physiological or behavioral effects. The first question is whether the exposure in general has the potential to cause an adverse health effect such as cancer; the second question is, if so, at what levels and durations of exposure cancer may occur; and the third is whether the specific environmental exposures associated with a particular project will include human exposures at harmful levels. The following discussion explains the reasoning behind the conclusion that for EMF exposure, the potential to adversely affect health at levels found in ordinary environments (including next to appliances) has not been demonstrated. As for any environmental exposure, if potential adverse effects have not been demonstrated, then exposure levels cannot be identified as harmful in general, or in association with a specific project such as the proposed electrification project.

Epidemiologists have long recognized that because epidemiology studies are observational in nature, not experimental, the identification of an association may not indicate a direct causal relationship. That is why several criteria are typically used to guide interpretation of observations gleaned from epidemiology studies. These criteria include: strength of the association; the consistency of the pattern of results across different studies; biological plausibility; and logical coherence of epidemiologic and laboratory findings.

Table 5.4-1 summarizes the results reported in the recent studies. The discussion above includes the fact that associations between surrogate measures of exposure to magnetic fields and leukemia have been reported.

However, these associations are weak and have not demonstrated logical consistency within studies or across similar studies. In studies that report odds ratios above 1.0, the odds ratios are 2 to 3, many times below those reported for known carcinogens, such as cigarette smoking and asbestos at 10 to 20. The small numbers in important categories have led to ambiguous results, and the contradictory results for various exposure surrogates are not consistent with the hypothesis that exposure to magnetic fields at the levels found in homes increases the occurrence of cancer in children. Biological plausibility is assessed from controlled laboratory studies of cancer in whole animals and of cancer mechanisms in cells and tissues. Such studies have not provided evidence that magnetic fields initiate or promote cancer.

The observations from epidemiologic studies do not support a conclusion that exposure to magnetic fields at levels found in the environment, including environments in the vicinity of power lines, are or are not a cause of, or contribute to, cancer in children. The residential exposure levels associated with the proposed electrification project are not significantly different from levels found in the environment (see Table 5.4-2 from Volume III of the DEIS/R).

To be consistent with all of the EMF analyses conducted relative to this project, the number of children in the various exposure zones have been estimated. Table 5.4-3 provides a breakdown of potentially exposed children and adults along the corridor. Zone 1, in which fewer than 100 children are projected to reside, represents the highest level of potential exposure to children, yet the exposure levels are similar to levels reported as background EMF in a relatively urban area (Section 5.4.3). Section 5.3 of the DEIS/R, Volume III, explains that interim guidelines limiting exposures are based not on cancer, but on presumed mechanisms of interactions. As Table 5.4-2 shows, these limits are hundreds if not thousands of times lower than exposures related to the proposed electrification project.

5.4.3(d) Recent Scientific Reviews of EMF Research

The above assessment is supported by reviews and assessments performed by scientists for a variety of health and regulatory agencies that have considered these recent as well as previous studies. None of these groups of scientists have proposed a limitation on the levels of fields encountered in our ordinary environment.

The views of the scientific community can be assessed from reports prepared by various scientific organizations and by other groups of scientists convened to study this issue. These groups of scientists have determined that the scientific data do not currently support a limitation on the levels of ELF fields encountered in our ordinary environment, such as those from power lines. The discussion below summarizes reviews completed in 1993. The reviews originated from diverse sources including an international scientific organization and several states in the United States.

These include the National Radiological Protection Board (NRPB) of Great Britain, the Expert Advisory Group to the Danish Ministry of Health, the French Institute of Health and Medical Research (INSERM), and the Oak Ridge Associated Universities (ORAU) for the White House Committee on Interagency Radiation Research and Policy Coordination. For example, the conclusion of the Advisory Group to the Danish Ministry of Health was:

> "The expert group believed that neither the earlier nor the latest studies offers sufficient documentation to characterize 50 Hz magnetic fields in homes adjacent to high-current electricity supply plants as a cancer-inducing factor among children. The studies described do not, however, allow this assumption to be dismissed." (p. 70)

TABLE 5.4-1 Recent Epidemiologic Studies of Estimates of EMF Exposure and Childhood Cancers[1,2]

INVESTIGATOR AND DATE	LOCATION	BASE POPULATION STUDIED ------ DESIGN[3]	EXPOSURE ESTIMATE	ODDS RATIO (95% CONFIDENCE INTERVAL)			
				Total Cancer	Leukemia	Central Nervous System Cancer	Lymphoma
Feychting and Ahlbom, 1993	Sweden	Children, age ≤ 16 years 1960-1985 ------- c-c	Calculated fields ≥ 2 mG	1.1 (0.5-2.1)	2.7 (1.0 6.3)	0.7 (0.1-2.7)	1.3 (0.2-5.1)
			spot ≥ 2 mG	0.9 (0.5-1.7)	0.6 (0.2-1.8)	1.5 (0.4-4.9)	--
			distance ≤ 50 m	1.0 (0.5-2.2)	2.9 (1.0-7.3)	0.5 (0.0-2.8)	--
Olsen, et al., 1993	Denmark	Children, age ≤ 15 years 1968-1986 ------- c-c	calculated fields ≥ 2.5 mG	1.5 (0.6-4.1)	1.5 (0.3-6.7)	1.0 (0.2-5.0)	5.0 (0.3-82.0)
			calculated fields ≥ 4.0 mG	5.6 (1.6-19.0)	6.0 (0.8-44.0)	6.0 (0.7-84.0)	5.0 (0.3-82.0)
Verkasalo et al., 1993	Finland	Children, age 0-19 1970-1989 ------- co	calculated fields ≥ 2.0 mG	1.5 (0.74-2.7)	1.6 (0.32-4.5)	2.3 (0.75-5.4)	1.2 (0.26-3.6)
Ahlbom et al., 1993	Nordic Countries	Pooled data of studies in Denmark, Finland & Sweden	2.0 or 2.5 mG	1.3 (0.9-2.1)	2.1 (1.1-4.1)	1.5 (0.7-3.2)	1.0 (0.3-3.7)

Notes: [1]This table is a summary of recent studies discussed in this report in response to comments. It is not meant to be a comprehensive review.
[2]The presence or absence of statistically significant associations as summarized in this table should be interpreted in the context of other information in the study and the strengths and weaknesses of the study. See discussion of these studies in text of report.
[3]C-C: case-control study; CO: cohort study.

Source: Roy F. Weston, Inc., 1994

TABLE 5.4-2 Comparison of Estimated EMF Exposure Levels with Interim Guidelines

POPULATION TYPE	RESIDENTIAL	COMMERCIAL/ INDUSTRIAL	RECREATIONAL	AMTRAK/ConnDOT EMPLOYEES	MBTA/FREIGHT EMPLOYEES	RAIL PASSENGERS
Exposure Type	Environmental	Occupational	Occasional	Occupational	Occasional	Occasional
Relevant Interim Guideline (mG)	1,000-46,000	5,000-50,000	5,000-46,000	5,000-50,000	5,000-46,000	5,000-46,000
	Average EMF	Average EMF	Average EMF	Average EMF	Average EMF	Average EMF
Location	Exposure (mG)	Exposure (mG)	Exposure (mG)	Exposure (mG)	Exposure (mG)	Exposure (mG)
Wayside						
Zone 1	1.5-9.3	1.5-9.3	1.5-9.3	N/A	N/A	N/A
Zone 2	0.4-1.5	0.4-1.5	0.4-1.5	N/A	N/A	N/A
Zone 3	0.2-0.4	0.2-0.4	0.2-0.4	N/A	N/A	N/A
Substation						
Zone 1	2.2-13.5	2.2-13.5	N/A	N/A	N/A	N/A
Zone 2	0.5-2.2	0.5-2.2	N/A	N/A	N/A	N/A
Zone 3	0.2-0.5	0.2-0.5	N/A	N/A	N/A	N/A
Tie Line						
Zone 1	5.5-13.0	5.5-13.0	N/A	N/A	N/A	N/A
Zone 2	3.0-5.5	3.0-5.5	N/A	N/A	N/A	N/A
Zone 3	2.0-3.0	2.0-3.0	N/A	N/A	N/A	N/A

TABLE 5.4-2 Comparison of Estimated EMF Exposure Levels with Interim Guidelines (Continued)

POPULATION TYPE	RESIDENTIAL	COMMERCIAL/ INDUSTRIAL	RECREATIONAL	AMTRAK/ConnDOT EMPLOYEES	MBTA/FREIGHT EMPLOYEES	RAIL PASSENGERS
Exposure Type	**Environmental**	**Occupational**	**Occasional**	**Occupational**	**Occasional**	**Occasional**
Relevant Interim Guideline (mG)	**1,000-46,000**	**5,000-50,000**	**5,000-46,000**	**5,000-50,000**	**5,000-46,000**	**5,000-46,000**
	Average EMF	**Average EMF**	**Average EMF**	**Average EMF**	**Average EMF**	**Average EMF**
Location	**Exposure (mG)**	**Exposure (mG)**	**Exposure (mG)**	**Exposure (mG)**	**Exposure (mG)**	**Exposure (mG)**
Electrified Train						
On-Train (Coach)	N/A	N/A	N/A	2.7-26.2	N/A	2.7-26.2
On-Train (Loco.)	N/A	N/A	N/A	21.7-134	N/A	N/A
Off-Train	N/A	N/A	N/A	4.1-37.0	N/A	N/A
Station	N/A	N/A	N/A	16-209	N/A	16-209
Diesel Train						
On-Train	N/A	N/A	N/A	N/A	4.1-37.0	4.1-37.0
Off-Train	N/A	N/A	N/A	N/A	4.1-37.0	N/A

Source: DMJM/Harris, 1993

TABLE 5.4-3 Summary of Estimates of Total Potentially Exposed Persons Along ROW Categorized by Distance From EMF Source and by Population Type and Age

POPULATION TYPE	POPULATION WITHIN EACH ZONE									TOTALS		
	Exposure Zone 1[1]			Exposure Zone 2[2]			Exposure Zone 3[3]					
	Under 18[9]	Over 18	Sub-Total	Under 18[9]	Over 18	Sub-Total	Under 18[9]	Over 18	Sub-Total	Under 18[9]	Over 18	Total
Residential - Wayside												
Existing (1993)	68	232	300	1,492	5,108	6,600	294	1,006	1,300	1,854	6,346	8,200
Projected (2010)	68	232	300	1,582	5,418	7,000	317	1,083	1,400	1,967	6,733	8,700
Residential - Tie-Line Substation[8]												
Existing (1993)	23	77	100	23	77	100	23	77	100	69	231	300
Projected (2010)	25	83	108	25	83	108	25	83	108	75	249	324
Commercial/Industrial - Wayside												
Existing (1993)			2,600			18,500			18,500			39,600
Projected (2010)			2,800			20,000			20,800			43,600
Commercial/Industrial - Tie-Line/Substation[8]												
Existing (1993)			10			82			83			175
Projected (2010)			12			89			90			191
Recreational												
Existing (1993)	3,842	13,158	17,000	3,842	13,158	17,000	3,842	13,158	17,000	11,526	39,474	51,000
Projected (2010)	4,068	13,932	18,000	4,068	13,932	18,000	4,068	13,932	18,000	12,204	41,796	54,000
Amtrak, ConnDOT, and MBTA Employees[4]												
On-train			250									250
Off-train			560[5]			160[6]						720
Freight Employees												
On-train			18									18
Average NEC Rail Ridership, per day[7] (2010)	9,108	31,192	40,300							9,108	31,192	40,300.

Notes:
[1] 0 to 50 ft. from edge of rail (0 to 20 ft. from edge of ROW).
[2] 50 to 100 ft. from edge of rail (20 to 70 ft. from edge of ROW).
[3] 100 to 150 ft. from edge of rail (70 to 120 ft. from ROW).
[4] Current estimates; projected estimates not currently developed by rail agencies.
[5] Yard, rail, and maintenance workers.
[6] Station and management workers.
[7] Includes Amtrak, MBTA, RIDOT, and ConnDOT.
[8] Includes Revised Populations from FEIS/R Electrical Facility Location Changes.
[9] The 18 and under population is based on 1990 and 2000 U.S. Census Data. Population estimates indicate that 22.6% of the population in CT, RI, & MA was under 18 in 1990 and 22.5% is expected to be under 18 in the year 2000. Since this is a decline in the percentage, it has been conservatively assumed that 22.6% of the population in 2010 will be under 18.

Source: Roy F. Weston, Inc., 1994

The Panel on Health Effects of Low Frequency Electric and Magnetic Fields/ORAU reviewed and evaluated the scientific research at the request of the United States Committee on Interagency Radiation and Policy Coordination. The Panel's report, released in November 1992, states:[28]

> "This review indicates that there is no convincing evidence in the published literature to support the contention that exposures to extremely low-frequency electric and magnetic fields (ELF-EMF) generated by sources such as household appliances, video display terminals, and local power lines are demonstrable health hazards."

After the results of the Swedish studies became available, the Panel wrote, in a letter to the journal *Science*:[29]

> "In our opinion, the evidence presented in these studies [Swedish] is not sufficiently compelling to alter the conclusions of the ORAU report."

The NRPB is a British organization that carries out research and provides advice and technical services to those government agencies that have responsibilities in radiation protection. The Advisory Group reviewed all of the epidemiologic and laboratory studies relevant to a possible carcinogenic effect of electromagnetic fields and evaluated and interpreted these data.[30] The Group concluded that the epidemiological findings that have been reviewed:

> ". . . provide no firm evidence of the existence of a carcinogenic hazard from exposure of paternal gonads, the fetus, children, or adults to the extremely low frequency electromagnetic fields that might be associated with residence near major sources of electricity supply, the use of electrical appliances, or work in the electrical, electronic and telecommunication industries." (page 132)

In a brief update provided in March 1993, the Information Services of the NRPB reports that the Advisory Group reviewed the papers from Sweden and Denmark. The Group concluded that the residential studies were well-controlled and better than previous studies of childhood cancer, however, they continue, "They do not establish that exposure to EMF is a cause of cancer, although they provide weak evidence to suggest the possibility exists." The Advisory Group noted that ". . . at present, epidemiological studies do not provide an effective basis for quantitative restrictions on exposure to electromagnetic fields."

5.5 DOCUMENTATION OF EMF OCCUPATIONAL STUDIES

5.5.1 Introduction

In the past year or two, EMF occupational studies have been completed in Norway, Sweden, Denmark, the United States, and in Canada and France. Comments on the DEIS/R included questions referring to certain occupational studies, particularly the foreign studies. In response to these comments, this technical study specifically addresses the recent Swedish, Danish, and Norwegian occupational studies of EMF exposures. Because these recent studies must be considered in the context of the broad range of previous occupational studies, this section provides background information to clarify relevant characteristics of occupational studies and a framework for considering the role of these studies in an EIS.

The Nordic countries (Norway, Sweden, and Denmark) have developed nationwide comprehensive cancer registries and census data, which they have utilized to examine correlations between cancer and occupation. In some of these studies, information is also available on railway workers. Railway workers provide information relevant to this electrification project because of their occupational exposures and because railway engine drivers incur higher exposures to magnetic fields than other occupations. In most of these Nordic studies, the frequency of the power source is 16.67 Hz, which is in the extremely-low-frequency range. The proposed project operates at 60 Hz, but the New York to Washington Amtrak trackage operates at 25 Hz. Available scientific data does not provide definitive answers to the question of whether 16 Hz, 25 Hz, and 60 Hz frequencies interact in the same manner with biological tissue.

5.5.2 Background

Epidemiologists often study the health of individuals who may have been exposed to an environmental factor in the course of their work. Under some circumstances, workers' exposure to chemicals or other factors is higher or more frequent than exposures of people in ordinary environments. For this reason, any health effects that are associated with the exposure in question are more likely to be detected in workers than in the general public. However, it is often difficult to estimate the long-term exposure of individual workers.

As discussed in the DEIS/R, a wide range of occupational studies have examined occupational exposures to EMF and cancer. By the early 1990s, numerous epidemiologic studies of various designs had been completed. Several of these studies reported a weak association between various jobs grouped as 'electrical work' and certain types of cancer in adults, mainly leukemia and brain cancer. On several occasions, groups of scientists have evaluated these studies and have described limitations that interfere with interpreting the results, and had suggested that additional studies were needed.[31] One major limitation is that job titles were used as surrogate measures of exposure; results would have been more reliable if measurements had been made of electric or magnetic fields. Another limitation of the studies, as stated by most of these researchers as well as the reviewers, is that these workers have frequent contact with solvents and other chemicals that have been linked to leukemia in other studies. Exposure to cancer-causing chemicals associated with electrical work can distort, or confound, the analysis.

An important characteristic of the recent epidemiologic studies is the improved information on exposure to electric and magnetic fields. Systematic measurements obtained in the workplace or for individual workers under the guidance of a prescribed protocol provide the most reliable exposure data. Few studies have obtained workplace measurements of individual workers.

5.5.3 Studies of Norwegian Workers

Researchers in Norway used job title as a surrogate measure of exposure to electric and magnetic fields. Törnqvist et al., in a study of leukemia and brain cancer, reported an association between leukemia and some of the occupations that were presumed to include exposure to electric and magnetic fields. However, neither railway conductors nor engine drivers exhibited increases in leukemia or brain cancer. In view of the available data, Törnqvist's conclusion about the study that ". . . no homogeneous pattern of increased risk in occupations with a presumed exposure to high magnetic fields was found . . . ."[32]

Subsequently, other Norwegian researchers used the national registries to study cancer, incorporating refinements in the definition of magnetic field exposure. Tynes et al. studied male electrical workers, and classified electrical occupations into five categories of exposure based on discussions with workers and technical experts. No field measurements were made, but the attempt to distinguish levels of exposure for power frequency fields by judgement improves upon previous studies that grouped all electromagnetic field exposures together. The power frequency categories specified jobs with potential exposure to weak, intermediate, or heavy magnetic fields. Exposure was not measured at any workplace and no chemicals or other potential confounding factors were measured or accounted for.[33]

Tynes et al. reported that leukemia, but not brain cancer, was associated with work in the category 'heavy magnetic fields.[34] No association was reported for non-Hodgkin's lymphoma and Hodgkin's disease. Breast cancer was elevated in the larger grouping of electrical workers.

Railway engine drivers were categorized as potentially exposed to intermediate magnetic fields, and railway track walkers to weak magnetic fields; these fields are at 16.67 Hz. Leukemia was less frequent in the railway engine drivers than in other workers, and about the same in railway track walkers as other workers. As was the case for leukemia, brain cancer was less frequent in railway engine drivers than in other workers. Railway track walkers who were still active in the 20-year followup group had more brain cancer than other workers. The reported results did not indicate that the more highly exposed engine drivers had more of these cancers than the less exposed track walkers, that is, a dose-response effect was not observed.

A subsequent case-control study obtained more specific exposure information for individual railway line workers, electricity workers, and outdoor station workers. Railway workers studied were exposed to fields at 16.67 Hz, having a group mean 197 mG. From this more detailed study, the researchers reported that neither leukemia nor brain cancer was associated with magnetic field exposure from work on electrified railways. Neither brain cancer nor leukemia was increased in rail workers in the high or very high exposure categories.[35]

5.5.4 Studies of Swedish Workers

In Sweden, Floderus et al. utilized national cancer and census registries to study leukemia and brain cancer. Exposure was estimated by measuring the magnetic fields of EMF-related jobs during a typical workday. The evaluation was based on the measurements in the job held longest in the 10 years before diagnosis. Working in a job that had higher average magnetic fields (above 3 mG) was associated with one type of leukemia, chronic lymphocytic leukemia (CLL), but not with all leukemia together. The association with CLL was stronger for higher field levels, and remained after accounting for possible exposure to possible confounding agents -- benzene, solvents, or ionization radiation. There was not a consistent association between magnetic field levels and brain cancer, although some elevated rate ratios appeared for cases under age 40. Neither brain cancer nor leukemia was associated with employment as a railway engine driver or conductor.[36]

In a followup analysis, these researchers focused on railway workers and specific railway occupations. Daily mean and median exposures for engine drivers were higher than for conductors and other railway workers including linemen. Neither leukemia nor brain cancer was elevated in railway workers or the occupations studied. An association was reported between the job engine driver and the leukemia subtype CLL, but not for any other job category or all railway workers combined.[37]

5.5.5 Studies of Danish Workers

In a study of the Danish working population, Guénel et al. estimated, by judgement, whether workers in each occupation were likely to incur intermittent or continuous exposure to magnetic fields over 3 mG. Potential occupational exposure of the cohort of Danish workers (men and women, 1970-1987) to magnetic fields over 3 mG was not associated with an increased incidence of the overall rate of cancer or with brain cancer. In men, but not in women, leukemia was associated with assumed continuous, but not intermittent exposure to fields over 3 mG.[38]

5.5.6 Studies of Electric Utility Workers

Magnetic fields measurements for workers in an electrical utility in California formed the basis for an epidemiologic study of magnetic fields and cancer. The measurements for specific jobs were combined with each subject's work history to develop a summary measure of the worker's long-term occupational exposure. Neither leukemias, brain cancers, lymphomas, or total cancer were associated with exposures above the mean.[39]

A study of workers in Canada and in France also combined measured exposures at the workplace with job history. As in Sahl's study, exposure was estimated by an exposure score that included magnetic field values of specific jobs, weighted by the duration of time at that job. In addition, exposure to chemicals was considered in the analysis. No association was reported for all leukemia together, or for all brain cancers together, or for any of 29 other types of cancer.[40]

In one of the three utilities, cumulative exposure levels above the median were associated with one type of leukemia. This type of leukemia, acute myelocytic leukemia (AML), was not associated with cumulative exposure to magnetic fields in the other two utilities. Exposures above the 90th percentile were estimated to be strongly associated with one type of brain cancer (astrocytoma), but the margin of error was broad; that is, the estimate was quite imprecise.

5.5.7 Summary

Recent studies have improved upon the design of older studies in order to provide more reliable information. Table 5.5-1 presents a brief summary of results reported in these studies. Previous reports to the FRA provide comprehensive summaries of occupational epidemiology studies.[41] Few of the recent studies were able to estimate and control for other occupational exposures or personal factors that may affect the occurrence of cancer. Some of the studies were limited in their ability to assess an individual's lifetime occupational exposure.

None of the studies, including these recent studies using improved measures of EMF exposure, indicates an overall increase in total cancers, that is, all types considered together, in electrical workers or other exposed populations. Consistent associations have not been reported for any specific type of cancer and exposure to magnetic fields. Studies in progress are evaluating EMF exposures and brain cancer, leukemias, and breast cancer.

5.5.8 Comment Regarding Question of Swedish Occupational Requirements

A comment on the electrification project stated that there exists a Swedish requirement to limit railway workers' EMF exposure by reducing the amount of time spent on trains. No such requirement is known to exist. As of May 1994, Sweden's National Occupational Health and Safety Board has not promulgated guidelines or occupational criteria regarding reduction of hours because of EMF exposure.

Recently, four organizations in Sweden jointly published a brochure entitled *Magnetic Fields and Potential Health Risks* (May 1994). The brochure states that there are no limit values for magnetic fields. The four organizations are: Swedish Housing Department; Swedish National Electrical Safety Board; Swedish Social Welfare Board: and the Swedish Radiation Protection Institute.[42]

TABLE 5.5-1 Update: Recent Occupational Epidemiologic Studies of Estimated EMF Exposure: Leukemia and Brain Cancer[1, 2]

INVESTIGATOR AND DATE	LOCATION	BASE POPULATION STUDIED —— Design[3]	EXPOSURE ESTIMATE	ODDS RATIO (95% CONFIDENCE INTERVAL)	
				Leukemias	Brain Cancers
Floderus et al., 1994	Sweden	Railway workers ------ co	Workplace measurements, sample: Engine drivers (16.66 Hz)	1.6 (0.7-3.6) CLL 2.7 (1.0-7.4)[4] AML 2.6 (0.6-10.4)	1.1 (0.6-2.2)
Tynes et al., 1994[5]	Norway	Railway workers ------ c-c	Job description, work history, and estimated historical magnetic field (16.66 Hz), 'very high' cumulative exposure	1.07 (0.3-3.87)	0.97 (0.24-4.01)
Tynes et al., 1992	Norway	Electrical workers ------ co	Jobs with exposure to 'heavy' magnetic fields (no field measurements; 16.66 Hz)	1.79 (1.09-2.76)	1.37 (0.81-2.17)
Floderus et al., 1993	Sweden	Employed men, mid-Sweden ------ c-c	Work history, workplace measurements 1 day, mean daily magnetic fields 4th quartile	1.6 (1.1-2.4) CLL (3.0 (1.6-5.8) AML 1.0 (0.6-1.9)	1.4 (0.9-2.1)
Guénel et al., 1993	Denmark	Danish population ------ co	Jobs with estimated 50 Hz magnetic field levels above 3 mG; continuous, men; continuous, women	1.64 (1.20-2.24) 0.56 (0.07-2.03)	0.69 (0.44-1.04) 1.23 (0.56-2.34)
Thériault et al., 1994	Canada, France	Electric utility workers at 3 companies ------ c-c	Work history; workplace exposure measurements. Cumulative exposure. Above median	1.54 (0.9-2.63) AML 3.15 (1.20-8.27)[6]	1.54 (0.85-2.81)
			90% percentile (AML)	2.68 (0.5-14.5)	12.29 (1.05-143)
Sahl et al., 1994	California	Electric utility workers ------ c-c and co	Work history, workplace exposure measurements, c-c, above measurements	1.07 (0.8-1.45)	0.81 (0.48-1.36)

TABLE 5.5-1 Update: Recent Occupational Epidemiologic Studies of Estimated EMF Exposure: Leukemia and Brain Cancer[1,2] (continued)

Notes: [1]This table is a summary of recent studies discussed in this report in response to comments. It is not meant to be a comprehensive review.
[2]The presence or absence of statistically significant associations as summarized in this table should be interpreted in the context of other information in the study and the strengths and weaknesses of the study. See discussion of these studies in text of report.
[3]C-C: case-control study; CO: cohort study.
[4]Odds ratio for other job categories (conductors, railway workers, railway industry) were lower, well below 2 for the first decade of follow up; none statistically significant.
[5]The study designed to follow up Tynes et al., 1992.
[6]Because of the complexity of the data (3 utility groups, several dose categories, several cancer subtypes), it is particularly difficult to characterize the results in a summary table. The reader is directed to the text for additional information.

Source: Roy F. Weston, Inc., 1994

5.6 ANALYSIS OF EMF IMPACTS RELATED TO AMTRAK DESIGN MODIFICATIONS

5.6.1 Introduction

The planned locations of a number of electrical facilities associated with the Proposed Action have been modified since the preparation of the DEIS/R (see Table 5.6-1). Because the population assessment and EMF impact analysis define the number of people in zones corresponding to distances from EMF sources, the population assessment must be evaluated to reflect these new locations. This study has reviewed electrical facility relocations and has revised the estimated numbers of people that could be potentially exposed to EMF. The design of the electrification system and the EMF-mitigating features of that design are not discussed herein, as they remain the same as described in the DEIS/R.

5.6.2 Revised Population Estimates

Revised residential and industrial/commercial population estimates are based on a review of facility design drawings, zoning maps, "high-rail" field inspection notes, road maps, and a video recording of aerial photographs. The methods used to estimate populations are consistent with those described Appendix 5A, Section 5, Volume III of the DEIS/R.

All facility relocations, with the exception of the New London feeder line route, would result in no net change to the population estimates provided in DEIS/R. Population estimates at these facilities would not be impacted because the facilities would be moved either parallel and adjacent to the tracks into locations already accounted for in the DEIS/R, or slightly away from the tracks, but into areas more than 150 feet from population centers.

Modifications to population estimates at New London were necessary due to the significantly revised 115 kV feeder line route. The new route would result in the feeder line running along the southwesterly outskirts of a residential neighborhood before extending north through the neighborhood. The previously proposed utility feed corridor would have routed the cable directly north from the substation through an industrially zoned area before turning westerly through the northern tip of a residential neighborhood. The change would result in an overall decrease in the industrial/commercial populations potentially exposed to EMFs, while slightly increasing the potential residential population exposure.

Overall, the electrical facility relocations (i.e., New London) would result in increases to potential exposed residential population of approximately 244 (current) and 268 (projected) people within the 150-foot study area. Conversely, the current and projected employee population estimates would decrease by 174 and 190 employees, respectively. It should be noted that, as in the DEIS/R, the commercial/industrial employee population estimates are for workers in businesses within the exposure zones established. Amtrak employees, whose exposure is unaffected by these changes, are not estimated herein. The revised power supply residential and industrial/commercial population estimates resulting from the electrical facility relocations are presented in Table 5.6-2 and Table 5.6-3, respectively.

TABLE 5.6-1 Modifications in Facility Sites and Utility Feed Corridors Since DEIS/R

ACTIVITY SITE	MILEPOST	CHANGES
Branford SS	79.26	Moved approx. 80' away from main line
Westbrook SwS	103.74	Moved 150' towards New Haven
Millstone PS	117.54	Moved 100' towards New Haven
New London SS	N/A	New feeder route
Noank PS	129.52	Moved 320' towards Boston and across tracks
Richmond SwS	150.15	Moved 1,080' towards New Haven
Elmwood PS	181.49	Moved 1,090' towards New Haven
Providence PS	187.45	Moved 550' towards New Haven & 160' away from main line
Canton PS	212.38	Moved 110' towards New Haven & 100' away from main line
Readville PS	219.08	Moved 90' towards New Haven

Notes: SS - Substation PS - Paralleling Station SwS - Switching Station N/A - Not Applicable

Source: DMJM/Harris, 1994

TABLE 5.6-2 Revised Population Estimates Based on Electrical Facility Relocations Residential Population Estimates

		CURRENT (1994) RESIDENTIAL POPULATION			PROJECTED RESIDENTIAL POPULATION[1]		
TOWN/STATE	SOURCE[2]	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
New London (DEIS/R)	Power Supply	37	12	7	37	13	7
New London (FEIS/R)	Power Supply	100	100	100	108	108	108
Connecticut (DEIS/R)	Power Supply	37	12	7	37	13	7
Connecticut (FEIS/R)	Power Supply	100	100	100	108	108	108
Total Corridor (DEIS/R)	Power Supply	37	12	7	37	12	7
Total Corridor (FEIS/R)	Power Supply	100	100	100	108	108	108

Notes: [1]Projected populations are based upon statewide growth projections, and may tend to overestimate growth in highly populated areas and underestimate growth in low populated areas.
[2]Power supply includes substations and tie-lines. Potential populations exposed to EMF from track sources remain unchanged, as presented in the DEIS/R.

Source: Roy F. Weston, Inc., 1994

TABLE 5.6-3 Revised Population Estimates Based on Electrical Facility Relocations Commercial/Industrial Population Summary

		CURRENT (1994) EMPLOYEE POPULATION			PROJECTED EMPLOYEE POPULATION[1]		
TOWN/STATE	SOURCE[2]	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
New London (DEIS/R)	Power Supply	2	155	155	5	167	167
New London (FEIS/R)	Power Supply	4	67	67	5	72	72
Connecticut (DEIS/R)	Power Supply	2	155	155	5	167	167
Connecticut (FEIS/R)	Power Supply	4	67	67	5	72	72
Total Corridor (DEIS/R)	Power Supply	8	170	171	12	184	185
Total Corridor (FEIS/R)[3]	Power Supply	10	82	83	12	89	90

Notes: [1]Projected populations are based upon statewide growth projections, and may tend to overestimate growth in highly populated areas and underestimate growth in low populated areas.
[2]Power supply includes substation and tie-line. Potential populations exposed to EMF from track sources remain unchanged, as presented in the DEIS/R.
[3]Includes exposure to other power sources.

Source: Roy F. Weston, Inc., 1994

5.7 SAFETY AND NOISE ANALYSIS

5.7.1 Introduction

Potential safety and interference concerns from EMF along the NEC were analyzed for the Proposed Action.[43] The approach is based on the International Telephone and Telegraph Consultative Committee (CCITT) Directives as detailed in Volume II, Chapter 7, of "Calculating Induced Voltages and Currents in Practical Cases."[44]

The analyses have been performed in two stages. In the first stage, a screening concept has been developed to identify potentially affected objects/utilities along the catenary system for further detailed analysis. The screening evaluations are performed in terms of limiting exposure lengths for disturbed circuits as a function of distance from the catenary and earth resistivities. For the specified location and the earth resistivity, if the exposure length of the circuit is shorter than the limiting exposure length, the electromagnetic impact of the railway electrification is acceptable; otherwise, a more detailed, site-specific analysis is required. The results of the screening study provided the limiting exposure lengths for the close-by communication and signaling circuits, underground and above-ground pipes, large objects, and fences. The associated companies along the railway route were identified, and contacted to gather more detailed information for the second stage analysis. Also, a site survey was initiated to locate large objects and long fences along the railway.

In the second stage, site-specific studies have been performed to evaluate the electromagnetic impact of railway operation on the neighboring utilities. Specifically, Southern New England Telephone Company (SNET), Valley Gas Company, Boston Gas Company, Massachusetts Water Authority (MWRA), Regional Water Authority, Amtrak, and several small businesses have been analyzed. In addition, large objects and fences within 500 feet of the railway for 20 miles have been evaluated. Potential problems due to electric and magnetic field induction are identified, and recommended mitigation methods are suggested.

5.7.2 Inductive Coordination Issues and Applicable Limits

The electrified railway systems can affect the nearby circuits and/or objects due to electromagnetic induction which includes both inductive and capacitive coupling effects. They may cause malfunction or damage to equipment located close by, or represent a danger for persons. An inductive coordination study is required to assess the extent of these effects which are generally confined into a zone of influence around the railway. In most cases of inductive coupling, the zone of influence can be limited to a strip of 3 km on both sides of the electrified railway. The zone of influence for capacitive effects is generally less than 200 to 300 meters. Within the zone of influence, the following circuits and/or objects are usually evaluated in an inductive coordination study:

- communication and signal circuits
- underground and above-ground water, gas, or oil pipelines
- large objects, and fences

The inductive coordination issues related to the AC railway electrification can be broadly classified as safety related or noise related. They are evaluated by calculating the following variables on the induced circuits and/or objects:

- longitudinal voltage also called common mode voltage
- transverse voltage also called differential mode voltage
- psophometric voltage using the transverse voltage
- trapped charge

The longitudinal EMF calculations and trapped charge are related to the personnel safety whereas the psophometric EMF calculations are for the admissible noise disturbance in telecommunications systems. The technical approach to calculate longitudinal voltages for all of the circuits and/or objects listed above are the same. The noise disturbance calculations in terms of psophometric voltages apply only to the communication and signaling circuits that operate at frequencies at or below audio range. The harmonic currents that are generated by the electric trains generally fall into this range. Note that the power line carrier systems are not expected to interact with the electric railways due to much higher range of frequencies involved.

The types of cables and associated screening methods may greatly influence the noise performance of the communication circuits. The following types of communication circuits are considered in this study:

- twisted pairs in screened cable
- coaxial pairs in screened cable
- unscreened cable
- open wire line

The induced voltage calculation results are compared with the permissible values. If the calculated quantities exceed the permissible values, mitigation measures must be taken to ensure the satisfactory performance of the railway electrification project. For most of the practical cases, it is sufficient to analyze those effects only as summarized in Table 5.7-1. For safety related issues, both normal and abnormal system conditions should be considered. Table 5.7-1 also includes the permissible limits for the quantities considered per CCITT Directives.

TABLE 5.7-1 Practical Cases of Inductive Coupling from AC Traction Lines and Associated Permissible Values

INDUCING SOURCE	CONDITIONS TO BE CONSIDERED	QUANTITIES TO BE CALCULATED	PERMISSIBLE LIMITS
AC Traction Line	Normal Train Load*	Longitudinal EMF	60 Vrms
		Psophometric EMF	1 mV weighted rms
	Short-Circuit	Longitudinal EMF	430 Vrms
	Maximum Catenary Voltage	Current through human body due to trapped charge on large objects	10 mA per CCITT

Notes: *Both normal and contingency configurations for train operations must be considered
Vrms = effective voltage
mV = millivolt
mA = milliampere

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

5.7.3 Technical Approach

The longitudinal and psophometric voltages on nearby circuits due to electric railway operation are determined using the Bonneville Power Administration's (BPA) ElectroMagnetic Transients Program (EMTP), Version M39. A detailed EMTP model for the AC traction power substation and associated catenary system was already developed in a previous study. The EMTP model is extended to include parallel circuits representing the disturbed conductors using the Line Constants routine of the EMTP.

5.7.3(a) AC Traction System Modeling

The 115 kV and 2x25 kV systems are represented by a frequency dependent impedance model which includes both tracks, the catenary, the feeders, rails/static wires, autotransformers, power supply transformers, substation ground grid, shunt capacitors, incoming 115 kV feeders, and the utility system.

The Catenary System. An equivalent pi representation is used to represent the catenary system. The line parameters are calculated at 60 Hz utilizing the EMTP Line Constants program based on the conductor type and configuration of the catenary, the feeder, and the rail. A sensitivity analysis on the line parameters is performed at 3,000 Hz to ensure that using 60 Hz values are not overly conservative in noise calculations. An EMTP data file for the catenary system is described in detail in Section 5 of *Northend Railroad Electrification Impact Studies*.[45]

Rail-to-Earth Leakage Resistance. The value of the rail-to-earth resistivity was assumed to be 25 Ω-km. Since the systems were modeled in segments, the rail-to-earth resistances were modeled as lumped elements at the end of each segment. Half of the conductance -- twice the resistance -- was placed at each end of the segment to more accurately represent the distributed nature of the grounding.

Power and Auto Transformers. The EMTP transformer model is used for all of the transformers in the catenary system including the power transformers at the substations, and the autotransformers at the paralleling and switching stations.

Utility System. The utility system is represented by the positive and zero sequence equivalent impedances at the point of common coupling. The minimum equivalent impedance corresponding to the maximum fault current duties is used for worst-case conditions considering the effect of the incoming 115 kV feeders. The reactive power compensation component at the traction power substations are also modeled.

Disturbed Circuits. The disturbed circuits are modeled as a conductor at a distance **d** and at a height **h** with respect to the catenary system assuming earth resistivity **rho** for longitudinal voltage calculations in regard to safety issues. This conductor model is used to represent the communication circuits, the pipes, as well as the fences and guardrails, considering whether they are underground or above ground. The conductor is integrated into the catenary system model to account for the mutual impedances between the catenary and the conductor by means of the Line Constants routine of the EMTP. The screening effects from nearby circuits are neglected in safety-related calculations for conservative results.

For the noise disturbance calculations, different types of communication wires are considered per CCITT directives. Open wire telecommunication circuits are modeled as two additional conductors which are also integrated into the catenary system model by means of the Line Constant routine. In some of the cases, the second conductor is grounded at both ends to simulate the screening effects of the nearby circuits and/or non-ferromagnetic metallic sheaths. The characteristics of unscreened cables, twisted pairs with screens, and the coaxial cables in terms of balance and screening factors are properly modeled by considering experimentally obtained factors per CCITT Directives. The details of these experimentally obtained factors can be found in Volume II, Chapter 4, of the CCITT Directives.

In this modeling effort, the disturbed conductors are assumed to be parallel to the catenary. The procedure outlined in CCITT Directives is used to model oblique or crossing exposures of the disturbed circuits. Catenary system and disturbed conductor models consist of sections each 1 mile long to allow accurate calculation of longitudinal voltage in an autotransformer-based traction power system.

5.7.3(b) Train Load

As described in CCITT Directives, both normal train load and short circuit conditions need to be considered for safety evaluations. The train load for safety evaluations is based on the maximum (100 percent) 50/50 train traffic. The magnitudes of these loads for each traction power substation are summarized in Table 5.7-2 for normal (both East and West directions) and one transformer outage conditions. The noise disturbance calculations use the train loads based on 15-minute-average real traffic.

The "99 Percent Load" point on the load duration curve is used. This load magnitude is exceeded only 1 percent of the time in a day at the traction power substation; in other words, the train load will be less than this value 99 percent of the time. The corresponding train loads are shown in Table 5.7-3.

TABLE 5.7-2 Train Loads for Safety Calculations (MVA)[1]

CONFIGURATION	BRANFORD	NEW LONDON	WARWICK	ROXBURY
A - West	34.3	46.3	46.3	42.6
B - East	46.4	52.6	29.8	36.8
C - Emergency	47.4	65.8	46.8	62.2

Note: [1]Based on maximum (100%) load and 50/50 traffic

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-3 Apparent Power (MVA)[1]

CONFIGURATION	BRANFORD	NEW LONDON	WARWICK	ROXBURY
A - West	34.3	46.3	46.3	42.6
B - East	46.4	52.6	29.8	36.8
C - Emergency	47.4	65.8	46.8	62.2

Note: [1]99 percent 15 minute average real traffic

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

5.7.3(c) Limiting Exposure Lengths

For both safety and noise disturbance evaluations, the limiting exposure lengths were calculated. The limiting exposure length is defined as the length of the disturbed circuit for which the longitudinal or psophometric voltage is equal to the specified limit for the given separation distance and earth resistivity. A similar limiting exposure length was calculated for electrostatic coupling.

The resultant plots of limiting exposure lengths as a function of separation distance can be used to determine which circuits near the railway may be adversely affected. Using the length and average separation distance for each of the nearby circuits, individual circuits can be plotted as points on the graphs provided. The circuits that are not likely to have any problems are below the locus of the limiting curve. For the circuits with the coordinates above the curve, or below the curve with a very small margin, then a closer look is warranted. The exposure of adversely affected circuits can be analyzed in more detail using accurate representations of their paths with respect to the catenary system as described in the CCITT Directives.

5.7.4 Computer Simulation Results

Simulations were performed under various conditions considering both the safety and noise issues. The results are limiting exposure lengths. For safety issues, concerns are:

- 60 Hz induced longitudinal voltages under normal operations and fault conditions
- For noise issues, the concern is the transverse voltage across the communication circuits due to harmonics generated by trains.

5.7.4(a) Safety Issues

Train Load. The results for limiting exposure lengths due to 60 Hz induced voltages under worst-case train load are obtained through simulations and summarized in Tables 5.7-4 through 5.7-7 for each traction power substation. The maximum train loads at east and west directions are simulated separately, and are indicated in parts (a) and (b) of the tables, respectively. The total train load is assumed to be concentrated at the worst-case location along the catenary. Effects of earth resistivity and distance are also examined in these simulations.

Short Circuit. The results for limiting exposure lengths due to 60 Hz induced voltages during railway system faults are summarized in Table 5.7-8 for the Roxbury Substation. For this figure and table, part (a) is for catenary-to-rail fault, part (b) is for feeder-to-rail fault, and part (c) is for catenary-to-feeder fault.

Electrostatic. The maximum exposure lengths due to capacitive coupling with the rail electrification system for parallel circuits are given in Table 5.7-9. These lengths were determined using the 10 mA limit required to prevent bodily harm as specified in the CCITT Directives, Volume VI, Section 5.5. A total body impedance of 750 ohms was assumed in accordance with the asymptotic minimum resistance of 50 percent of the population specified in the CCITT Directives, Volume VI, Section 2.2.3.

In addition, the electric field induction on objects in close proximity of railroad systems, energized at 60 Hz power frequency, could pose a design concern if associated shock hazards are above pre-specified levels. Calculations show limiting dimensions for: (1) large buildings (e.g., factories) and (2) metallic fences in terms of 10 mA maximum induced current, as specified by the CCITT Directives.

TABLE 5.7-4. Limiting Exposure Length due to 60 Hz Induced Voltages Under Normal Conditions (miles)[1]

a) Branford West 100 percent 50/50 Rule Load = 34.3 MW

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.30	0.25	0.21	0.18
50	0.36	0.28	0.23	0.20
100	0.46	0.34	0.27	0.22
500	1.18	0.61	0.41	0.31
1,000	2.48	0.90	0.53	0.37
2,500	13.90	2.02	0.83	0.50
5,000	55.47	5.58	1.36	0.68
10,000	221.62	24.84	2.87	1.01

b) Branford East 100 percent 50/50 Rule Load = 46.4 MW

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.22	0.18	0.16	0.14
50	0.26	0.21	0.17	0.15
100	0.34	0.25	0.20	0.17
500	0.88	0.45	0.30	0.23
1,000	1.84	0.67	0.39	0.28
2,500	10.28	1.49	0.61	0.37
5,000	41.00	4.13	1.00	0.50
10,000	163.82	18.36	2.13	0.75

Notes: [1]Rails have 25 ohm-km resistivity to Earth and station grids have 5 ohms resistance

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-5 Limiting Exposure Length due to 60 Hz Induced Voltages Under Normal Conditions (miles)[1]

a) New London West 100 percent 50/50 Rule Load = 46.3 MW

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.23	0.18	0.16	0.14
50	0.27	0.21	0.17	0.15
100	0.34	0.25	0.20	0.17
500	0.88	0.45	0.30	0.23
1,000	1.84	0.67	0.39	0.28
2,500	10.30	1.50	0.61	0.37
5,000	41.09	4 14	1.01	0.50
10,000	164.18	18.40	2.13	0.75

b) New London East 100 percent 50/50 Rule Load = 52.6 MW

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.20	0.16	0.14	0.12
50	0.23	0.18	0.15	0.13
100	0 30	0.22	0.17	0.15
500	0.77	0.40	0.27	0.20
1,000	1.62	0.59	0.34	0.24
2,500	9.07	1.32	0.54	0.33
5,000	36.17	3.64	0.89	0.44
10,000	144.51	16.20	1.87	0.66

Notes: [1]Rails have 25 ohm-km resistivity to Earth and station grids have 5 ohms resistance

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-6 Limiting Exposure Length due to 60 Hz Induced Voltages Under Normal Conditions (miles)[1]

a) Warwick West 100 percent 50/50 Rule Load = 46.3 MW

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.23	0.18	0.16	0.14
50	0.27	0.21	0.17	0.15
100	0.34	0.25	0.20	0.17
500	0.88	0.45	0.30	0.23
1,000	1.84	0.67	0.39	0.28
2,500	10.30	1.50	0.61	0.37
5,000	41.09	4.14	1.01	0.50
10,000	164.18	18.40	2.13	0.75

b) Warwick East 100 percent 50/50 Rule Load = 26.8 MW

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.35	0.28	0.24	0.21
50	0.41	0.32	0.27	0.23
100	0.53	0.39	0.31	0.26
500	1.36	0.70	0.47	0.36
1,000	2.86	1.04	0.61	0.43
2,500	16.00	2.32	0.95	0.58
5,000	63.84	6.43	1.56	0.78
10,000	255.08	28.59	3.31	1.16

Notes: [1]Rails have 25 ohm-km resistivity to Earth and station grids have 5 ohms resistance

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-7 Limiting Exposure Length due to 60 Hz Induced Voltages Under Normal Conditions (miles)[1]

a) Roxbury West 100 percent 50/50 Rule Load = 42.6 MW

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.25	0.20	0.17	0.15
50	0.29	0.22	0.19	0.16
100	0.37	0.27	0.22	0.18
500	0.95	0.49	0.33	0.25
1,000	2.00	0.73	0.42	0.30
2,500	11.19	1.63	0.67	0.41
5,000	44.66	4.49	1.09	0.55
10,000	178.44	20.00	2.31	0.81

b) Roxbury East 100 percent 50/50 Rule Load = 36.75 MW

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.28	0.23	0.20	0.17
50	0.33	0.26	0.22	0.19
100	0.43	0.31	0.25	0.21
500	1.11	0.57	0.38	0.29
1,000	2.32	0.84	0.49	0.35
2,500	12.98	1.88	0.77	0.47
5,000	51.77	5.21	1.27	0.63
10,000	206.84	23.18	2.68	0.94

Notes: [1]Rails have 25 ohm-km resistivity to Earth and station grids have 5 ohms resistance

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-8 Limiting Exposure Length due to 60 Hz Induced Voltages During Fault Conditions (miles)[1]

Case A: Catenary to Rail Fault (base case)

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.84	0.73	0.66	0.62
50	0.91	0.77	0.68	0.63
100	1.16	0.92	0.78	0.70
500	2.95	1.66	1.20	0.98
1,000	6.15	2.46	1.54	1.17
2,500	33.74	5.48	2.42	1.58
5,000	134.41	15.11	3.98	2.12
10,000	536.76	66.84	8.41	3.15

Case B: Feeder to Rail Fault

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.68	0.63	0.58	0.54
50	0.84	0.75	0.68	0.62
100	1.15	0.91	0.78	0.70
500	2.92	1.64	1.19	0.97
1,000	6.09	2.44	1.53	1.16
2,500	33.38	5.43	2.40	1.57
5,000	132.98	14.97	3.94	2.11
10,000	530.99	66.19	8.34	3.13

TABLE 5.7-8 Limiting Exposure Length due to 60 Hz Induced Voltages During Fault Conditions (miles)[1,2] (continued)

Case C: Catenary to Feeder Fault

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	0.77	0.77	0.78	0.78
50	1.70	1.72	1.75	1.77
100	4.33	4.24	4.03	3.89
500	19.03	13.20	9.84	7.96
1,000	44.82	20.41	12.57	9.48
2,500	305.69	45.56	19.70	12.75
5,000	1,213.23	126.50	32.40	17.14
10,000	4,842.22	565.42	68.60	25.48

Notes: [1]Roxbury: Short circuit capacity = 10,080 MVA
Disturbed circuit at the same height
[2]Rails have 25 ohm-km resistivity to Earth and station grids have 5 ohms resistance

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-9 Limiting Exposure Length due to Capacitive Coupling (miles)[1]

DISTANCE feet	RHO=100 ohm-meters
30	1.00
50	1.10
100	1.27
500	2.41

Notes: [1]Maximum current = 10 mA
Total body resistance = 750 ohms

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

Calculations suggest that the limiting building length should be about 0.6 mile, and that the limiting fence length should be about 76 miles.

It should be noted the calculations are assumed to be for dry conditions, and there will be significant 60 Hz leakage impedance from the dampness in the fence posts, vegetation contacting the fence wire, metal fence posts to ground, and fence wires to ground, either dangling or crossed bracing. Therefore, the voltage should be expected to be so low that no sensation will be perceived when touching the fence.

In addition to the limiting exposure length due to capacitive coupling, exposure lengths were determined for magnetically induced voltages for a 3-foot-high fence located 30 and 100 feet from the center of the catenary system. For these magnetically induced voltages, an earth resistivity of 1,000 Ω-m was assumed. The limiting exposure lengths were determined for both fault conditions and normal operations. Fault condition calculations assumed a maximum short-circuit capacity of 10,080 MVA. Normal operations assumed a 100 percent 50/50 traffic load level of 52.6 MVA, which is the maximum level for all traction power loads. The results are shown below. Based on these results, it is recommended that fences be solidly grounded every 600 feet. This includes a 20 percent safety margin to help account for poor grounding and variable fence heights.

Magnetic Induction Limiting Exposure Length (ft.) for a 3-Foot-High Fence

Distance from the Middle of Catenary	Fault Conditions	Normal Operations	Captive Coupling
30'	3,952'	739'	~518,000'
100'	4,118'	898'	518,000'

O5.7.4(b) Noise

For noise issues, the concern is the transverse voltage across the communication circuits due to harmonics generated by trains. This transverse voltage depends on the balance of the communication circuit, which is different for different types of communication circuits. For typical types of communication circuits considered in this study, simulations were performed and corresponding limiting exposure lengths were obtained. Table 5.7-10 shows the results for a 60 dB unbalanced unscreened circuit, which corresponds to unscreened twisted pair cables. Table 5.7-11 corresponds to twisted pairs with sheaths, and Table 5.7-12 to the coaxial cables. Note that all the noise disturbance results are based on a train load level of 10 MW. As noted before, 10 MW corresponds to the power demand of one train driven by two AEM7s in full acceleration. For different load conditions, the corresponding results can be obtained proportionally, since the circuits involved are all linear.

5.7.4(c) Sensitivity Studies

In addition to earth resistivity and distance, traction system contingencies such as paralleling/no paralleling, and autotransformer outages were considered during fault conditions as sensitivity studies. The results are given in Table 5.7-13 for different parameters. The noise performance for open wire communication circuits was also considered, and the results are included in Table 5.7-14.

TABLE 5.7-10 Limiting Exposure Length due to Harmonic Induced Noise Voltages Under Normal Conditions[1] - 60 dB Unbalance, No Screening[2]

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm meters
30	0.09	0.08	0.07	0.07
50	0.08	0.07	0.07	0.06
100	0.10	0.08	0.07	0.07
500	0.30	0.15	0.11	0.09
1,000	0.95	0.24	0.14	0.11
2,500	26.37	0.77	0.24	0.15
5,000	111.11	5.66	0.46	0.21
10,000	449.44	82.76	1.56	0.34

Notes: [1]Fundamental Load = 10 MW
Disturbed circuit at the same height
[2]V_{max} - 1 mV, in mi

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-11 Limiting Exposure Length due to Harmonic Induced Noise Voltages Under Normal Conditions[1] - 60 dB Unbalance, with Screening[2]

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm meters
30	1.36	1.22	1.13	1.06
50	1.37	1.19	1.08	1.01
100	1.69	1.36	1.19	1.08
500	5.19	2.54	1.81	1.48
1,000	15.48	4.09	2.38	1.79
2,500	372.67	12.93	4.01	2.46
5,000	1,524.78	90.23	7.72	3.43
10,000	6,122.35	882.35	25.59	5.55

Notes: [1]Fundamental Load = 10 MW
Disturbed circuit at the same height
[2]V_{max} = 1 mV, in mi

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-12 Limiting Exposure Length due to Harmonic Induced Noise Voltages Under Normal Conditions[1] - 80 dB Unbalance, with Screening[2]

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm meters
30	13.59	12.17	11.27	10.64
50	13.68	11.86	10.78	10.08
100	16.91	13.58	11.86	10.80
500	51.90	25.44	18.09	14.83
1,000	154.84	40.91	23.75	17.88
2,500	3,726.70	129.32	40.11	24.60
5,000	15,247.78	902.27	77.18	34.28
10,000	61,223.48	8,823.48	255.87	55.45

Notes: [1]Fundamental Load = 10 MW
Disturbed Circuit at the same height
[2]V_{max} = 1 mV, in kilo-ft

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-13 Limiting Exposure Length due to 60 Hz Induced Voltages During Fault Conditions (miles)[1] - Catenary to Rail Faults

a) Disturbed Circuit Underground (h/2)

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
100	0.48	0.40	0.35	0.33

b) Disturbed Circuit at the Ground Level

DISTANCE feet	RHO=100 ohm-meters
100	0.41

c) A Parallel Grounded Level 1 Foot from Disturbed Conductor (d=100 ft.)

GROUNDING LOCATIONS	RHO=100 ohm-meters
at ends	0.41
every mile	0.82

d) A Parallel Grounded Conductor 1 Inch from Disturbed Conductor (d=100 ft.)

GROUNDING LOCATIONS	RHO=100 ohm-meters
at ends	0.41
every mile	1.13

e) Various Contingencies

#1 Disturbed circuit at half the height	0.40 miles
#2 No parallelings, with autotransformers	0.50 miles
#3 No parallelings, no autotransformers at middle	0.73 miles
#4 No parallelings, no autotransformers at end	0.48 miles
#5 No parallelings, no autotransformers	0.38 miles
#6 With parallelings, no autotransformers	0.38 miles

Notes: Short circuit capacity = 10,080 MVA

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

TABLE 5.7-14 Limiting Exposure Length due to Harmonic Induced Noise Voltages Under Normal Conditions[1]

a) 60 dB Unbalance with Screening, Disturbed Circuit Buried (h/2) (V_{max} = 1 mV, in feet)

DISTANCE feet	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
100	1,081.96	899.50	803.65	744.71

TABLE 5.7-14 Limiting Exposure Length due to Harmonic Induced Noise Voltages Under Normal Conditions[1] (continued)

b) Disturbed Circuit of Two Open Wire Conductors 1 Inch Apart (V_{max} = 1 mV, distance = 100 ft.)

DISTANCE feet	RHO=100 ohm-meters
ungrounded	6,886.96
one wire at ends	5.38

c) Disturbed Circuit of Two Open Wire Conductors 1 Foot Apart (V_{max} = 0.05 V, distance = 100 ft.)

DISTANCE feet	RHO=100 ohm-meters
ungrounded	28,285.00
one wire at ends	102.19

Notes: [1]Fundamental Load = 10 MW

Source: Morrison Knudsen/L.K. Comstock/Spie Group, 1994

5.7.4(d) General Observations

Based on the simulation results, the following observations can be made:

- In general, the larger the distance between the disturbed circuit and the railway, the longer the limiting exposure lengths
- The greater the earth resistivity, the shorter the limiting length
- The effect of the height of the disturbed circuit is relatively small.
- The normal train loads which have a 60 V safety limit create more adverse safety concerns than the fault conditions with a 430 V safety limit
- The noise voltages are very sensitive to communication circuit screening factors and rail-to-earth resistance values

5.7.4(e) Water and Gas Pipes

In this study, the types of pipes considered are:

- underground uncoated pipes
- underground coated pipes
- above-ground pipes and casings

The major concerns with pipelines for this study are:

- electromagnetic impacts in terms of safety concerns
- coating and/or pipe rupture
- corrosion and interference with cathodic protection equipment

Electromagnetic Impact. Normal transmission line analysis can be applied to above ground pipelines in determining electromagnetic induction effects. This is not true, however, for underground pipes because the surge impedance and propagation velocity are much lower for pipes than the transmission lines. These differences are due to significant shunt resistances distributed along the pipe. More realistic methods were developed in EPRI report EL-904, *Mutual Design Considerations for Overhead AC Transmission Lines and Gas Transmission Pipelines*. This report indicates that the maximum voltages will appear at electrical discontinuities. These can be due to:

- changes in pipe diameter
- changes in the incidence path of the pipeline relative to the electric transmission line
- abrupt changes in pipeline distances to the electric transmission line
- electrical isolation or grounding points
- pipe fittings such as tees and crosses

The relative magnitude of the voltages seen at these discontinuities was calculated based on the pipe segment length between discontinuities.

For the assumed values γ,ρ, and coating resistivity, the anticipated maximum voltages for long/lossy pipes at different distances from the catenary system are given in Tables 5.7-15 and 16 for Roxbury under normal load conditions and fault conditions respectively. Again, these maximum voltages are for long/lossy pipes and are independent of pipe length. The minimum distance required between the pipeline and the catenary system such that safety concerns are eliminated can be determined for a given ρ by finding the distance where the safety voltage limit is met. In general, the normal load currents (100 percent 50/50 rule) drive the safety issue limits.

For fault conditions Roxbury is the worst case since it has the highest short-circuit MVA. For normal loads that differ from those given for Roxbury, the maximum expected voltage can be determined by scaling the Roxbury voltage by the ratio of the new load to the Roxbury load.

Some comparisons can be made between the railway electrification system and the electric distribution systems near the pipelines. Gas companies have generally not experienced any major problems due to induction from single phase distribution lines. Clearly, these lines carry much less load current than the catenary system (around 1 to 10 ratio), but they are much closer to the pipelines than is the catenary system (in some cases they are directly above the pipeline). The pipelines may also be exposed to the distribution system for long distances. Furthermore, fault currents on the two systems may be comparable and faults on the railway system may pose no higher risk than the normal single-phase electrical power distribution system. Because of the screening results presented above and the lack of problems experienced, safety issues are expected to be a concern only during normal train operation.

Corrosion and Interference with Cathodic Protection Equipment. In general, corrosion due to AC currents is negligible compared to DC corrosion. The effects of AC currents superimposed on the cathodic protection (CP) DC currents can also be neglected for sacrificial anode type CP operation. Any increase in corrosion caused by the AC currents during one half-cycle will be compensated for during the next half-cycle. Therefore, the net effect over one cycle is the same as if no AC currents were impressed. It is possible that the AC may interfere with some types of impressed current cathodic protection.

TABLE 5.7-15 Maximum Pipe Voltage due to 60 Hz Induced Voltages Under Normal Conditions (miles)[1]

a) Roxbury West 100% 50/50 Rule Load = 42.6 MW

DISTANCE ft	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	612.14	753.95	886.40	1,009.44
50	520.45	666.98	804.01	931.29
100	403.00	554.14	696.14	828.10
500	157.25	305.60	454.94	596.13
1,000	74.99	205.91	353.75	497.53
2,500	13.40	92.26	225.34	369.00
5,000	3.36	33.37	137.05	274.43
10,000	0.84	7.50	64.80	184.69

b) Roxbury East 100% 50/50 Rule Load = 36.75 MW

DISTANCE ft	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	528.08	650.42	764.67	870.82
50	448.98	575.38	693.60	803.40
100	347.66	478.04	600.55	714.39
500	135.66	263.63	392.47	514.27
1,000	64.69	177.64	305.17	429.21
2,500	11.56	79.59	194.40	318.33
5,000	2.90	28.79	118.23	236.75
10,000	0.73	6.47	55.90	159.33

Note: [1]Rails have 25 ohm-km resistivity to Earth and station grids have 5 ohms resistance propagation constant = 0.4 radians/mi

Source: Morrison Knudsen/L.K. Comstock/Spie Group and DMJM/Harris, 1994

TABLE 5.7-16 Maximum Pipe Voltage due to 60 Hz Induced Voltages During Fault Conditions (miles)[1,2]

Case A: Catenary to Rail Fault (base case)

DISTANCE ft	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	1,283.86	1,472.59	1,622.77	1,741.03
50	1,187.45	1,403.15	1,575.45	1,711.68
100	926.86	1,172.48	1,370.65	1,528.52
500	364.23	647.64	896.26	1,100.68
1,000	174.67	436.78	697.01	918.66
2,500	31.86	196.07	444.15	681.38
5,000	8.00	71.14	270.23	506.79
10,000	2.00	16.08	127.85	341.10

Case B: Feeder to Rail Fault

DISTANCE ft	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	1,590.80	1,705.31	1,841.42	1,973.40
50	1,277.56	1,431.09	1,589.63	1,724.75
100	937.34	1,184.33	1,382.69	1,539.90
500	368.21	654.10	904.06	1,108.79
1,000	176.54	441.11	703.06	925.43
2,500	32.20	198.00	448.00	686.40
5,000	8.08	71.83	272.57	510.52
10,000	2.02	16.24	128.95	343.61

Case C: Catenary to Feeder Fault

DISTANCE ft	RHO=10 ohm-meters	RHO=100 ohm-meters	RHO=1,000 ohm-meters	RHO=10,000 ohm-meters
30	1,400.48	1,391.41	1,383.66	1,376.61
50	632.65	623.79	616.01	608.94
100	248.20	253.78	266.74	276.31
500	56.50	81.46	109.21	135.12
1,000	23.98	52.67	85.50	113.44
2,500	3.52	23.59	54.56	84.29
5,000	0.89	8.50	33.18	62.70
10,000	0.22	1.90	15.67	42.20

Note: [1]Roxbury: Short Circuit Capacity = 10,080 MVA
Disturbed circuit at the same height
[2]Rails have 25 ohm-km resistivity to Earth and station grids have 5 ohms resistance propagation constant = 0.4 radians/mi

Source: Morrison Knudsen/L.K. Comstock/Spie Group and DMJM/Harris, 1994

The cathodic protection on the pipelines is measured periodically to ensure that it is operating as required. The AC voltages impressed on the pipe may interfere with the measurement of the cathodic protection DC voltage. These AC voltages can be eliminated by placing bandpass filters to ground at measurement sights. These filters could be tuned to shunt 60 Hz and higher frequencies.

Coating Rupture. The typical value for the breakdown potential for pipe coating is 6.4 kV/in. Conservatively assuming that there is no earth potential rise at the coating and that the coating is as thick as 0.125 inch, a pipe potential of 800 V could cause a coating rupture. Fault conditions for Roxbury are again the worst case for this concern. As shown in Table 5.7-16, pipe potentials will not exceed 800 V for pipes farther than 750 feet from the railway for earth resistivities of 1,000 Ω-m or less. For pipes near other systems, the minimum distance is less than 750 feet due to the reduction in fault current capacity.

This problem may be extremely difficult to mitigate for existing pipelines because typical measures such as grounding or electrical isolation are ineffective for long/lossy lines. Since the maximum voltage on a long/lossy line is independent of the line length, grounding or isolation simply introduces a new discontinuity where the maximum voltage can appear. To bring the maximum voltage to a point below the rupture potential would entail forcing the pipes to approach short pipe lengths. In most instances this would be impractical.

5.7.4(f) Screening Evaluations

By examining the types of circuits and conductors that can be found along the railway, they are categorized into the following classes based on simulation results.

Communication Circuits. Telephone wires normally are shielded twisted pair wires. Shielding is usually grounded at regular intervals. The safety issues may become of concern if the induced voltage at the shield between grounding points becomes higher than the specified limits for normal train load or fault conditions. Based on the results shown in Tables 5.7-4 through 5.7-8, safety issues are determined by the normal train load operation rather than the fault conditions. For communication circuits near Roxbury west, Table 5.7-7 suggests that for an earth resistivity of 1,000 Ω-m, the shield and/or armor for the communication circuits has to be grounded at every 0.42 mile if the circuit is 1,000 feet away from the catenary and at 0.22 mile intervals, if 100 feet away from catenary.

Due to the harmonics generated by the train operation, noise disturbance may also cause undesirable performance of the communication lines. Based on the results as shown in Table 5.7-11, the minimum limiting exposure length is 5,300 feet for noise issues.

The general conclusion of the screening results is that for exposure lengths larger than the limiting exposure lengths, mitigation measure may be required. Individual telephone lines have to be investigated to determine if the interference will be of concern for either safety or noise limits. For communication circuits other than telephone, noise issues can be neglected if the transmission frequencies are above the audio range.

Water and Gas Pipes. Both water and gas company pipes can be treated similarly for electromagnetic impact evaluations. Three types of pipes, underground uncoated, underground coated, and above-ground, are considered. For this study the concerns involve safety, coating rupture, and corrosion impact. For underground uncoated pipes safety is not considered a problem because they are essentially continuously grounded. AC impact on corrosion of underground uncoated pipes is negligible.

For above-ground pipes safety becomes an issue because the pipes are exposed. These concerns can be elevated by grounding the pipes at the distances given in Tables 5.7-4 through 5.7-7. If the pipes are grounded every 0.12 mile or less, safety is not a concern.

For underground coated pipes safety is an issue where valves, measurement points, or other appurtenances become exposed. Safety concerns also arise at the service entrances to buildings. These concerns can be eliminated by grounding or electrically insulating the locations noted. Based on Table 5.7-15 and a maximum safety limit of 60 V, locations within 2 miles (in 1,000 Ω-m soil) of the railway may be a concern. The AC currents impressed on the pipes will not add to the pipe corrosion but may interfere with cathodic protection equipment or measurements. The problem must be evaluated based on the type of cathodic protection used by each utility. Coating rupture may occur if voltages across the pipe coating exceed 6.4 kV/in. This problem is extremely difficult to mitigate. Pipes within 100 feet of the railway may be of concern.

Signal Circuits. Generally, for signal circuits, noise is not a factor due to relatively larger levels of signals as compared to the noise induced by the railway electrification. Safety issues may pose a concern if shields and/or armors of the signaling circuits are not grounded at regular intervals. However, we believe that applying the industry standard practices may alleviate any such concerns.

Large Objects. Objects near the railway are expected to be much smaller than the size required for capacitive coupling to be a concern. Therefore, electromagnetic impact due to capacitive coupling is in no instance expected to be of concern for large objects near the railway.

Fences and Guardrails. Safety concerns are driven by electromagnetic inductive coupling at normal train load conditions. They can be alleviated by grounding appropriately as described in Section 5.7.4(a).

Power Lines. All power circuits can be neglected due to their relatively high voltage levels as compared to the calculated induced longitudinal voltages. The nearby transmission/distribution lines are also affected by the electric railways; but generally these effects are within tolerable limits due to relatively high levels of voltages encountered during normal operation of power systems.

Guy Wires. Guy wires can be neglected because of their short lengths. As shown in Tables 5.7-4 through 5.7-7, the minimum limiting exposure lengths for the safety consideration is 0.12 mile (634 feet), which is much longer than the guy wires.

TV Cables. TV cables can be neglected because of the high frequency of their signals. Safety is of no concern in this case.

Based on the above screening evaluations, detailed site-specific analyses are required for the following types of companies along the railway:

- communication companies
- water and gas companies
- transportation companies
- small businesses

Direct contacts to the involved companies were initiated to obtain the required information. Furthermore, a site survey at representative sections of the railway was performed to locate large structures and fences for safety evaluation.

5.7.5 Utility Impact Studies

The details of the site-specific electromagnetic impact studies are described below for each of the utilities involved.

5.7.5(a) Communications Companies

Southern New England Telephone Company. A site-specific study of the railway impact on the SNET system was performed. The aerial and underground communication lines within 0.25 mile of the railway from the New Haven Station (MP 72) eastward to the State Line Paralleling Station (MP 141) were included in the study area. Thirty-four major circuits were selected and modeled for the study. The limits of the circuits were set by one or more of the following:

- a circuit left a 0.25-mile limit and was not indicated further on the map
- a line entered the central office (switching station)
- a line reached an exchange boundary
- a circuit termination was indicated on the map

Each circuit was subdivided into smaller segments. The projection of each segment onto the catenary system to obtain equivalent exposure lengths and equivalent parallel distances was determined per CCITT standards.

The studies indicate that safety concerns during fault conditions are alleviated by SNET's policy of grounding the wire shields every 0.25 mile. This can be cross-checked with the data given for fault conditions in Section 5.7.4(e) which indicate that the minimum limiting exposure length (LEL) during fault conditions is 0.54 mile. This was based on a short-circuit capacity of 10,080 MVA versus 3,680 MVA for the Branford system and 2,060 MVA for the New London system. When scaled to the correct MVA approximate minimum LELs of 1.4 and 2.6 miles result.

Safety concerns arise under normal operating conditions using the 100 percent 50/50 rule loading criteria. They can be alleviated by grounding at the distances indicated in Table 5.7-17. For example, any communication lines west of the Branford Substation (MP 72 to MP 80) closer than 120 feet to the catenary system should be grounded every 0.15 mile or less.

Noise is a problem for all of the circuits studied. The transverse voltage of each communication circuit was calculated for different load locations along both the Branford and New London systems. A 60 dB unbalance was assumed. The maximum transverse voltages found are summarized in Table 5.7-18. Those circuits with a maximum transverse voltage greater than 24 mV exceed the 20 dBrn limit used by SNET. Note that SNET standards are significantly more stringent than corresponding CCITT standards.

Test Procedures: Measurements should be made during system tests, prior to commissioning, with and without trains in operation using SNET's standard procedures for noise measurement. Measurements when the trains are operating should be made while the trains are passing the locations where the worst noise generation is expected according to the study results. The pre- and postoperation measurements can then be compared and final mitigation requirements can be determined.

Recommended Mitigation Methods: SNET generally uses induction neutralizing transformers (INT) to abate noise problems. It is recommended that additional transformers could be installed. An INT was simulated in the middle of circuit #7 by inserting an ideal 1:1 transformer with 180-degree phase shift from the primary to the secondary. This resulted in a reduction in transverse voltage from 5.003 mV to 1.865 mV. Additional INTs could be used to reduce noise further.

Because the New York to New Haven railroad electrification measurements indicated noise disturbances well below applicable SNET limits and since noise problems have not been experienced due to the electrification project, the study results are considered conservative. Measurements are suggested per the test procedures given above prior to commissioning. If any problems are detected, SNET would require that no trains run until mitigation equipment is in place. Mitigation steps for both noise and safety issues should be taken only if the measurements indicate that they are warranted.

TABLE 5.7-17 Minimum Grounding Distances
100 Percent 50/50 Rule Load

SYSTEM	LOAD MVA	DISTANCE FROM CATENARY (ft)	MINIMUM GROUNDING DISTANCE (mi)
Branford West	34.3 MVA	Less than: 120	0.15
Branford East	46.4 MVA	500 100	0.20 0.10
New London West	46.3 MVA	500 250	0.20 0.10
New London East	52.6 MVA	750 100	0.15 0.10

Rho = 1,000 ohm-meters

Source: SNET, 1994

TABLE 5.7-18 Maximum Transverse Voltages
99 Percent Real Traffic Load

60 dB Balance

SYSTEM	99% LOAD	CIRCUIT #	VOLTAGE (mV)
Branford West	18.6 MVA	1	8.1
		2	8.8
		3	3.9
		4	4.2
		5	2.4
		6	5.7
		7	5.0

TABLE 5.7-18 Maximum Transverse Voltages (continued)

SYSTEM	99% LOAD	CIRCUIT #	VOLTAGE (mV)
Branford East	23.2 MVA	8	3.9
		9	1.8
		10	5.0
		11	4.6
		12	4.3
		13	2.4
		14	2.9
		15	2.6
		16	1.1
		17	1.1
New London West	18.6 MVA	18	1.4
		19	2.5
		20	3.6
		21	2.1
		22	1.1
		23	2.3
		24	3.2
		25	3.5
		26	2.1
		27	4.8
New London East	26.5 MVA	28	7.0
		29	7.3
		30	6.1
		31	2.7
		32	1.3
		33	2.1
		34	4.2

Rho = 1,000 ohm-meters

Source: SNET, 1994.

5.7.5(b) Water and Gas Companies

Valley Gas Company. The Valley Gas pipelines are in the general vicinity of MP 188 to MP 192. Due to the long time period in establishing the gas distribution network, many different pipe types (steel, cast, iron, PVC) have been used. The pipelines generally consist of three pressure levels: high pressure; intermediate pressure; and low pressure. The pipe diameters can vary from 8 to 12 inches for high pressure mains to 2 inches for low pressure service entrances.

Since 1972, Department of Transportation regulations have required that all underground gas pipelines be coated and cathodically protected. A considerable number of Valley Gas pipes were installed prior to 1972 and are neither coated nor cathodically protected. For those installed after 1972, Valley Gas uses sacrificial anodes (magnesium strips) for cathodic protection. These pipes are generally not grounded because grounding reduces the effectiveness of the sacrificial anode type of protection. Furthermore, Valley Gas does not ground at valve connections or measurement locations. At the service entrances to private consumers, electrical isolation is required, but there could be a significant number of installations with damaged or non-existent electrical isolation which could cause severe safety problems. Any type of pipe system can be near the railroad tracks.

Some pipelines at the bridge crossings are in casings. Because of other industry safety regulations and practices these casings are generally bonded electrically to the bridges.

The pipelines may also be exposed to the distribution system for long distances. Furthermore, fault currents on the two systems may be comparable, and faults on the railway system may pose no higher risk than the normal single-phase electrical power distribution system. Because of the screening results presented in Section 5.7.4 and the lack of problems experienced, safety issues are expected to be a concern only during normal train operation.

The safety issues involve three pipe types:

- **Uncoated Underground Pipes:** These are not expected to create safety concerns, since there is an almost continuous connection to earth. At high earth resistivity areas for very long exposure lengths, induced voltages could theoretically create a safety problem on grounded pipes, but not expected to be a practical concern.

- **Coated Underground Pipes:** For these, high voltages can be expected at electrical discontinuities as described in Section 5.7.4. These discontinuities can occur at valves, instrument test/measurement points, or service lines. Proper mitigation methods could be applied at these locations if the recommended measurements warrant it. Note that at the service entrances electrical isolation between the residences/businesses and the gas distribution system should be verified to ensure that any high voltages are not transmitted.

- **Above-Ground Pipes (or pipe casings):** Precautions should be taken to limit the maximum voltages to the 60 V safety limit on above ground pipes. To do this the pipes should be grounded or isolated at the distances indicated in Table 5.7-7 depending on the distance between the pipe and the catenary system.

Measurements with and without train loads on the catenaries are recommended for locations where valves, measurement points, or other appurtenances on coated underground pipes become exposed within 2 miles of the catenary system. Similar measurements are recommended for above-ground pipes and above-ground casings. Selected service entrances should likewise be measured. The results can be compared to determine the extent of electromagnetic influence caused by the railway electrification. Mitigation methods could be considered after the measurements.

Recommended Mitigation Methods: Safety is a concern for coated pipes and above-ground pipes. Since coated pipes are generally buried, safety of the general public becomes a concern only where pipe valves, instrument test/measurements points, or service lines are above ground. To alleviate any safety concerns two methods are available:

- Grounding the pipeline at the recommended locations. This may interfere with the effectiveness of the sacrificial anode type cathodic protection. Changing to active type of cathodic protection may allow grounding of the pipes at the indicated locations. Active type of cathodic protection may become cost prohibitive due to a large number of units or high current requirements.

- Electrical isolation of pipe segments at the recommended locations. Note that the insulating flanges have to be properly protected for possible flashover during faults.

Grounding or using electrical isolators to maintain the maximum voltage on the pipelines below the 60 V safety limit would require that the lengths between mitigation points be less than those given in Table 5.7-7. This is not a practical solution except for short above-ground pipe segments. Therefore, it must be noted that during pipe installation/repair activities, all applicable safety guidelines should be followed.

Problems relating to possible coating rupture may be extremely difficult to mitigate for existing pipelines because typical measures, such as grounding or electrical isolation, are ineffective for long/lossy lines as described in Section 5.7.4. Therefore, measurements are recommended to characterize the magnitude of the voltages that might produce coating rupture.

Regional Water Authority. The general practices of the water companies are similar to those of the gas companies except that cathodic protection is not required on the pipelines. Electrical isolation at the service entrances is also not required. However, cold water piping systems generally have very low resistance to earth and have been extensively used as grounding electrodes for residences. Therefore, high voltages which may be seen on transmission/distribution pipes will not be transmitted to the residences. Any exceptions found will be where nonmetallic, noncurrent carrying pipe or insulating joints are used. These electrically disconnect the residences from any high voltages on transmission/distribution systems. All results. test procedures, and mitigation methods not dealing with cathodic protection are the same as for Valley Gas.

5.7.5(c) Transportation Companies

Amtrak. Amtrak systems are considered immunized to both safety and noise disturbance issues.

5.7.5(d) Small Businesses

The initial contacts revealed a common concern about possible interference to computer networks. Due to relatively low frequency harmonics from the railway operation, interference is not anticipated to pose a problem to the computer network operation.

5.7.5(e) Site Survey

A site survey was performed along MP 95 + 0000 through MP 105 + 0000 and MP 179 + 0500 through MP 190 + 0000. Structures, buildings, fences, guardrails, and other miscellaneous objects were identified. The potential electromagnetic induction impact on the objects was evaluated and is reported below.

Structures and Buildings. As described in Section 5.7.4 for buildings and large objects, a very large surface area is required for capacitive coupling to become an issue. The example given there assumed a building approximately 60 feet high and 150 feet wide with an electric field equivalent to that directly under the catenary system. The result was a required length of nearly 3,000 feet before capacitive coupling becomes a concern.

The following points can be made regarding structures and buildings:

- All of the buildings in the site survey are significantly farther from the catenary and significantly smaller.
- Given the distances and small sizes of the buildings, no electromagnetic impact due to capacitive coupling is expected.
- No further surveys are necessary.

Fences and Guardrails. As described in Section 5.7.4 for fences, to mitigate the effects of electromagnetic induction on fences and guardrails, they should be solidly grounded every 600 feet. This distance includes a 20 percent margin to account for poor grounding and variable fence heights. Based on the results of the site survey, the following items are of note:

- It should be verified that guardrails of type 2 (steel on wooden posts) are grounded every 600 feet or less.
- It should be verified that the wire fences are grounded every 600 feet or less.
- Sheet metal fences should be mounted on metallic posts or solidly grounded in the center.
- No electromagnetic induction impact is expected for any other type of fence (assuming that chain link fences used metal posts) or type of guardrail included in the survey.
- Additional surveys should be made to verify that all fences and guardrails within 500 feet of the railway are grounded appropriately for their length and distance from the catenary.

Miscellaneous Objects. The following points can be made regarding the miscellaneous objects:

- The siding tracks listed are not expected to be a concern because of their nearly continuous grounding.
- As with buildings and large objects, the junk yards and storage areas are too small to be of concern.
- No electromagnetic impact due to capacitive coupling is expected to be of concern for any of the miscellaneous objects reported in the site survey.

5.7.6 Conclusions

In this study, the electromagnetic impact of the Proposed Action has been investigated at selected sections of the NEC in terms of safety and noise disturbance. The following summarizes the general conclusions of this study and extrapolates them to all potentially affected utilities, and/or objects along the railway.

Communications Companies. Site-specific studies were performed for SNET communication circuits. The study results indicate that noise disturbance may become a concern, and mitigation methods may be required for most of the circuits along the railroad. Furthermore, to alleviate safety concerns, grounding the shield at shorter lengths than the standard SNET grounding intervals may be required.

Because the study results are relatively conservative, mitigation measurements should be considered only if on-site measurements with and without the train load indicate the need. Another reason for using this measurement approach is that SNET has not yet experienced any problems due to the electrified railroad between New York and New Haven.

The other communication companies identified have fiberoptic circuits which are not prone to electromagnetic impact, and do not require any further studies and/or testing.

Water and Gas Companies. Screening studies indicated that safety is a concern for coated underground pipes and above-ground pipes. The coated underground pipes become a concern only at valves, test/measurement points, or service lines if they are not grounded or electrically isolated properly. The above-ground pipes have to be grounded or electrically isolated at the recommended intervals, if they are exposed to the general public.

Screening studies also indicated that coating rupture may become a problem for water and/or gas pipes close to the railway track during faults on the catenary system. Mitigation methods are extremely difficult for the existing pipelines, and should be considered only after detailed site measurements.

The railway operation may cause some interference to instruments measuring the effectiveness of the cathodic protection, if they are not equipped with proper AC filtering.

The above screening evaluations apply to both water and gas companies.

Gas companies generally provide electrical isolation between the residences/businesses and the gas distribution system as standard practice. Water companies are not required to provide the electrical isolation, but they generally represent very low resistance to earth at the service entrances. In both of these cases (i.e., electrical isolation or good grounding at the service entrance), high voltages which may be seen on transmission/distribution pipes will not be transmitted to the residences/businesses.

Site-specific studies for Valley Gas Company were performed. The study results indicate that the recommendations from the screening studies should be followed to ensure safe operation of the system. However, their general practice of not grounding at valves and/or measurement points due to possible interference with cathodic protection equipment may be in opposition to the recommended mitigation methods. Other more expensive mitigation methods are available. Furthermore, electrical isolation should be verified at the service entrances to buildings.

Any implementation of the mitigation methods should be delayed until after measurements at the specified locations close to the railroad tracks have been made.

Site-specific studies were also performed for the Regional Water Authority. All conclusions are the same as for Valley Gas Company except that cathodic protection may not be used by the water company.

Transportation Companies. Amtrak systems are considered immune to both safety and noise disturbance issues.

Small Businesses. No adverse reaction due to electromagnetic interference is anticipated for small businesses.

Structures and Buildings. In no instance, inside or outside the ROW, is electromagnetic impact due to capacitive coupling expected to be of concern for structures and buildings. Therefore, no further surveys or grounding actions are necessary.

Fences and Guardrails. Within the ROW and up to 500 feet from the catenary, all fences and guardrails longer than 600 feet should be grounded. Beyond 500 feet of the catenary, up to 1 mile, no grounding is required unless fences and/or guardrails are longer than 1,200 feet. Beyond 1 mile from the catenary, due to the screening effects of the ROW fences and other metallic installations within the 500-foot corridor, no requirement for grounding of metallic objects is anticipated.

Miscellaneous Objects. In no instance, inside or outside the ROW, is electromagnetic impact due to capacitive coupling expected to be of concern for miscellaneous objects. Therefore, no further surveys or grounding actions are necessary.

General Observations. Considering all of the results obtained for the various types of circuits examined in this study, the following general observations can be made:

- Most of the assumptions were made so as to reach conservative solutions. The cumulative effect of these may make the results overly conservative.

- The maximum train loads for 50/50 traffic are the driving criteria for safety issues. This allows overly conservative design criteria since fault currents were generally expected to provide the limiting results for safety concerns.

5.8 POTENTIAL EMF IMPACTS ON WILDLIFE

Most research on wildlife has focused on possible alterations in foraging and migration patterns and, although there is a limited number of studies, no effects attributable to electric and magnetic fields have been found. Relevant research includes ongoing studies of exposures to electric and magnetic fields from a 76 Hz communications system in Wisconsin and Michigan which have reported no adverse effects on wildlife. These studies analyzed the homing behavior of small animals and birds, the metabolism of small birds, and the population size of birds and deer.[46]

In addition to studies in the wild, studies of domestic livestock and studies of laboratory animals are relevant for assessing the possible effects of exposure of wildlife to electrical and magnetic fields. For example, in a 2-year study on 11 livestock farms near a transmission line, Amstutz and Miller reported that neither health, behavior, nor performance of farm animals (horses, sheep, swine, dairy and beef cattle) was affected.[47] Stormshak et al. studied sheep exposed over a year to electric and magnetic fields produced by a transmission line and concluded that these electric and magnetic fields did not interfere with weight gain, wool production, behavior, or the secretion of the hormone melatonin.[48]

A substantial amount of laboratory research has been conducted in various species of mammals to determine whether exposure to 60 Hz electric and/or magnetic fields could adversely affect the animals' ability to reproduce. Research studies have included in utero exposure and/or exposures prior to conception to study embryonic, fetal, or postnatal development. In studies repeated by different researchers and in different species, no adverse impact has been reported on reproductive fitness, fertility, or on the growth, development, or survival of the offspring.[49]

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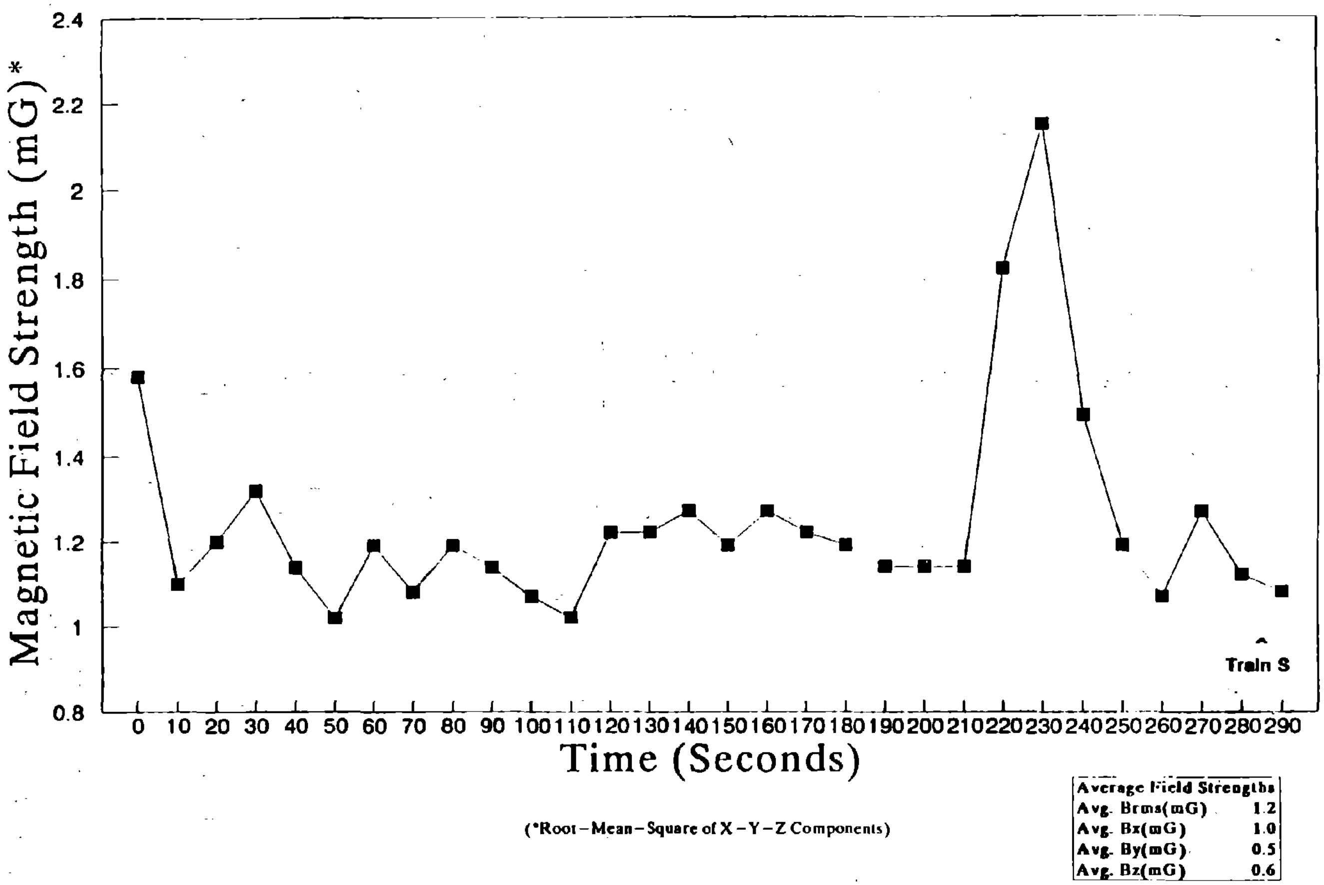
APPENDIX 5A

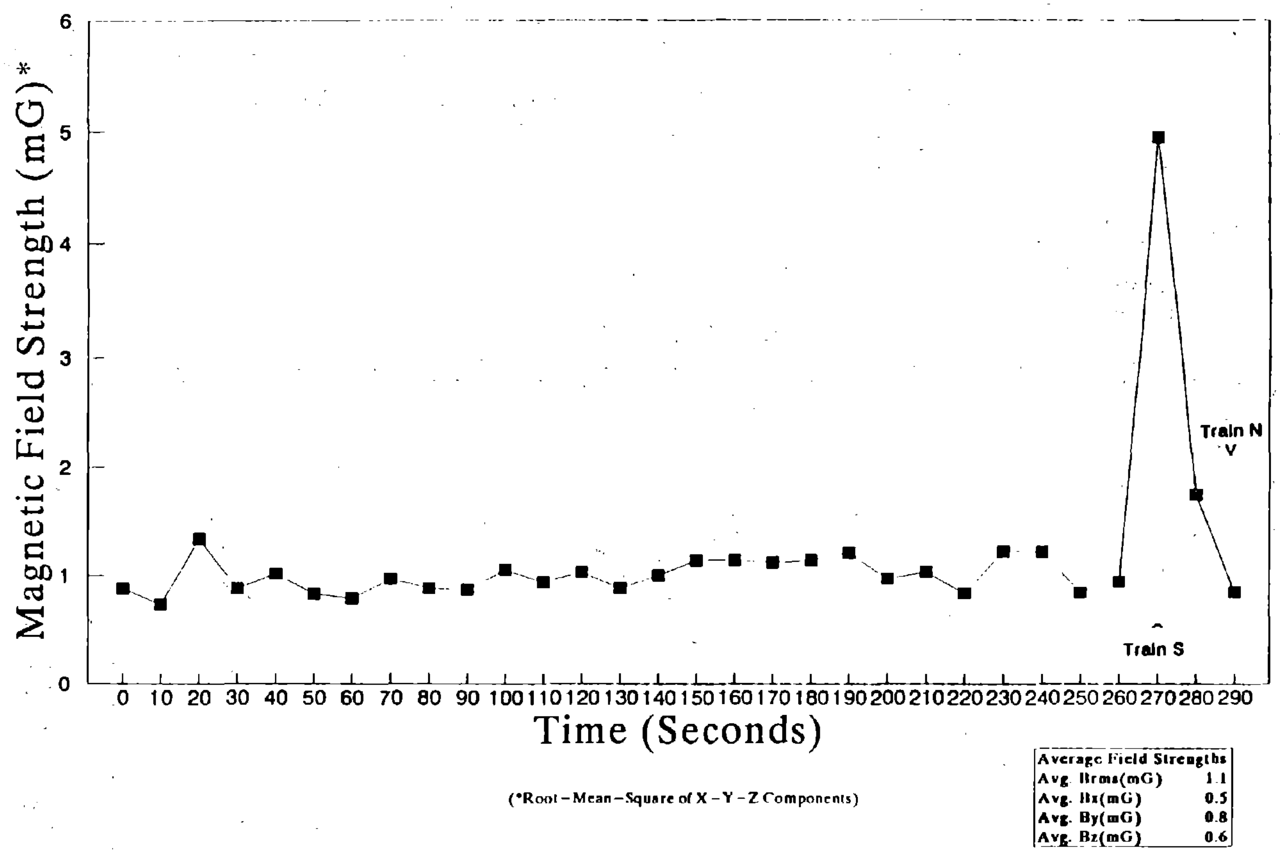


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S01

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-1

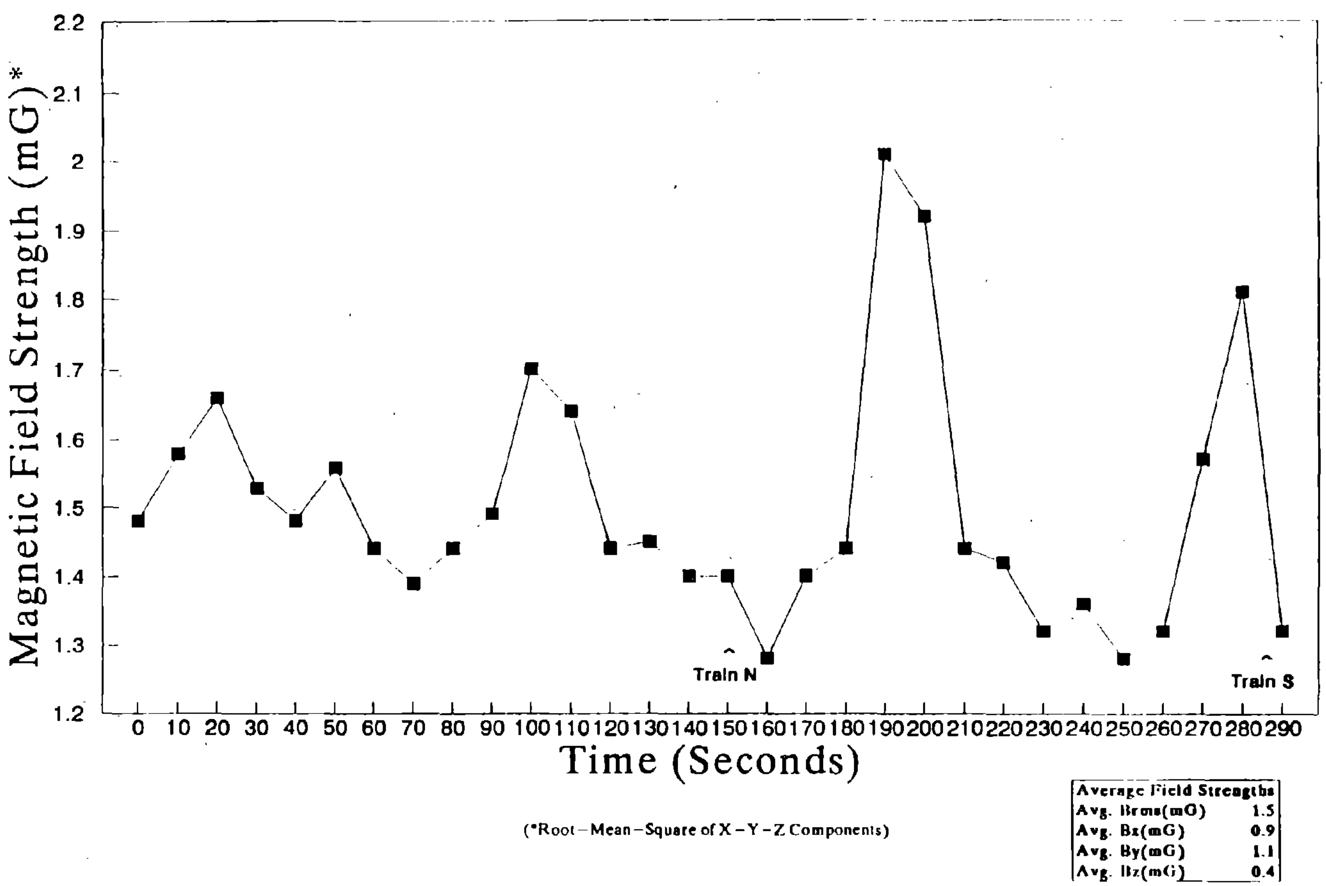


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S02

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-2

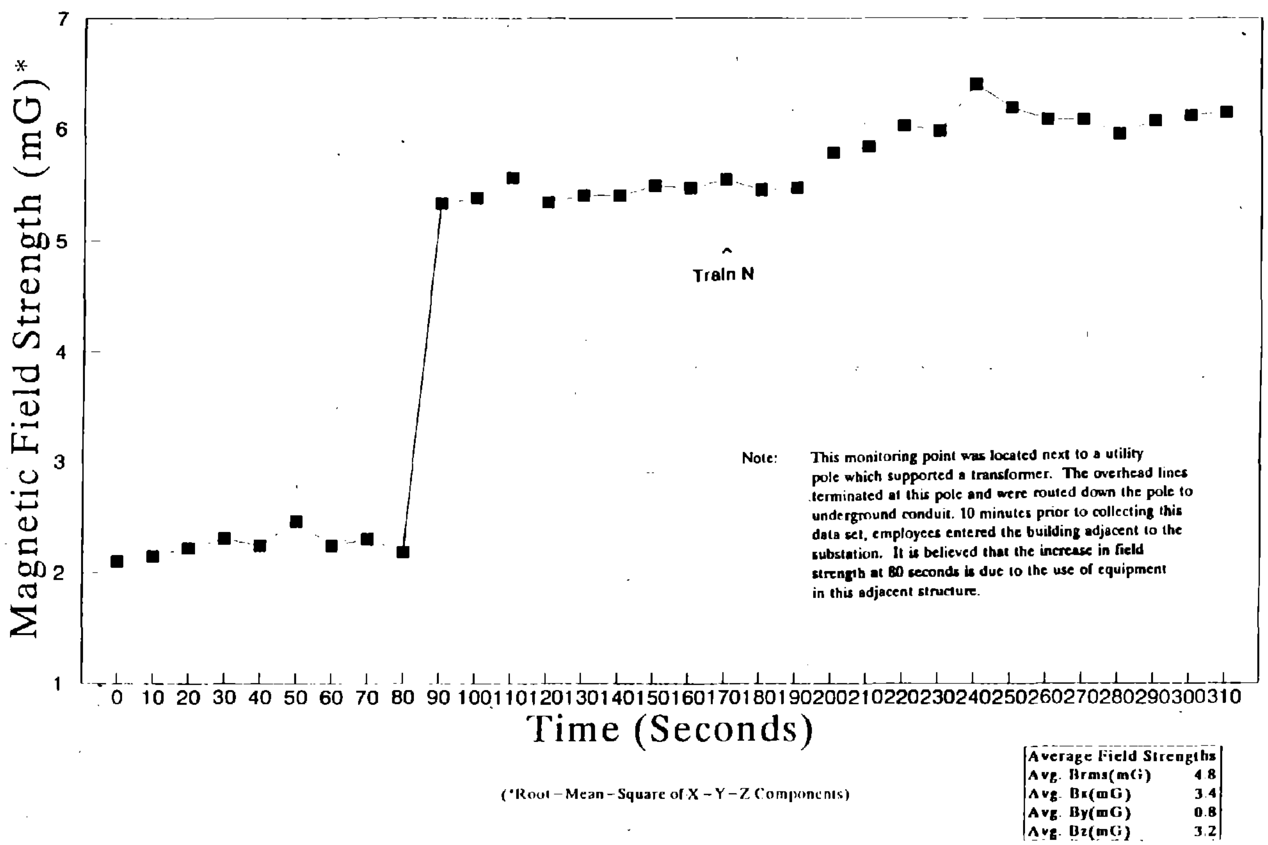


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S03

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-3

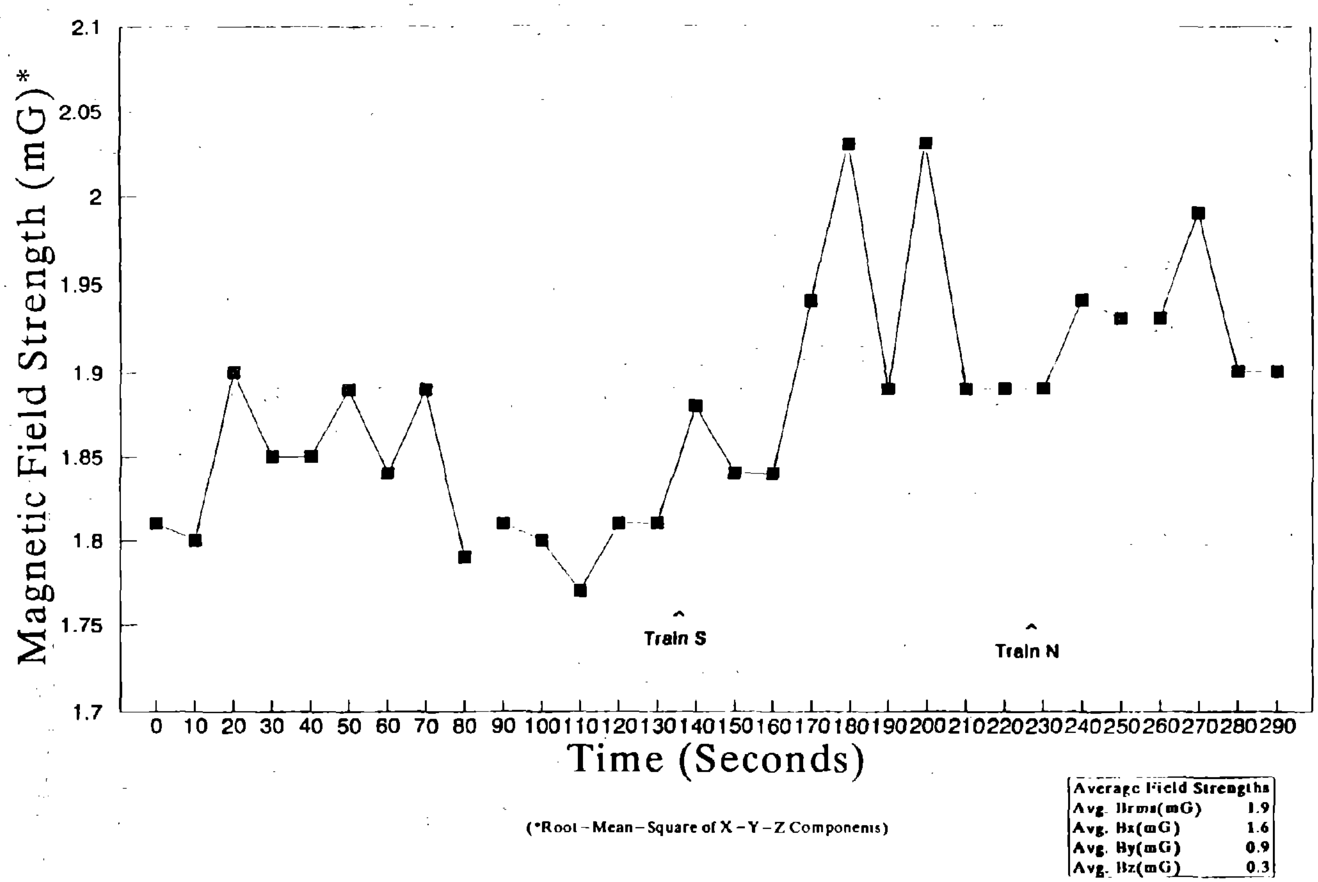


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S04

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-4

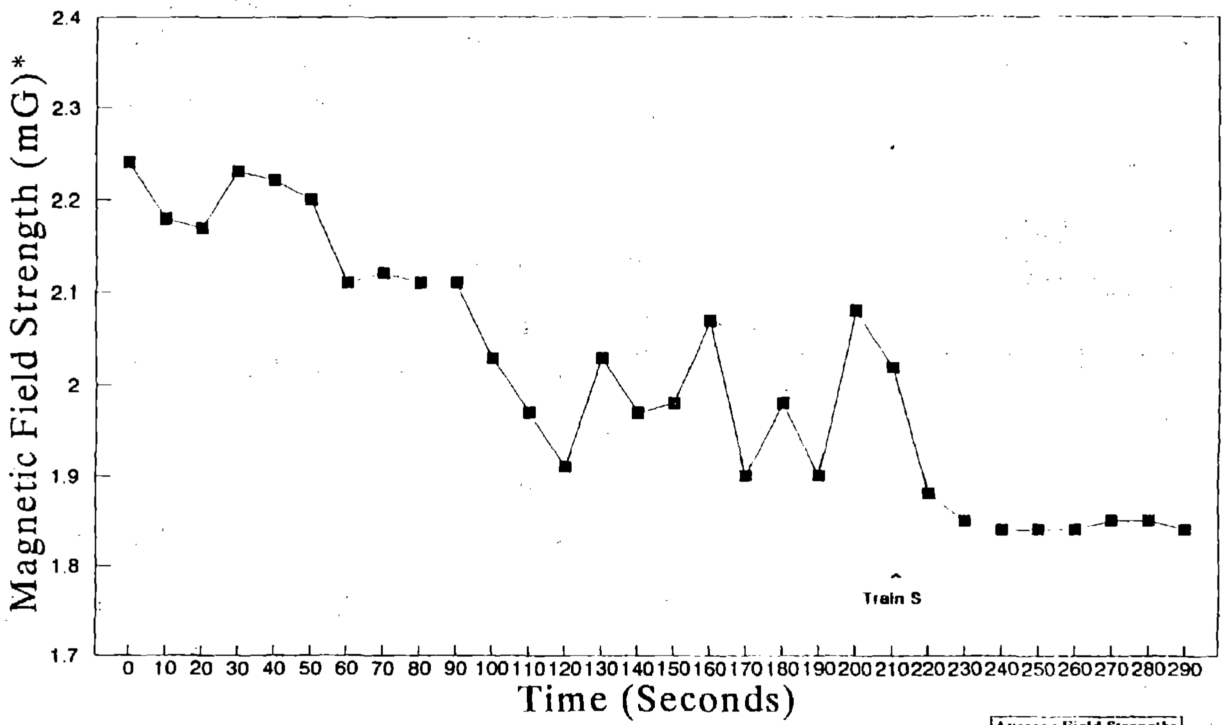


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S05

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-5



(*Root-Mean-Square of X-Y-Z Components)

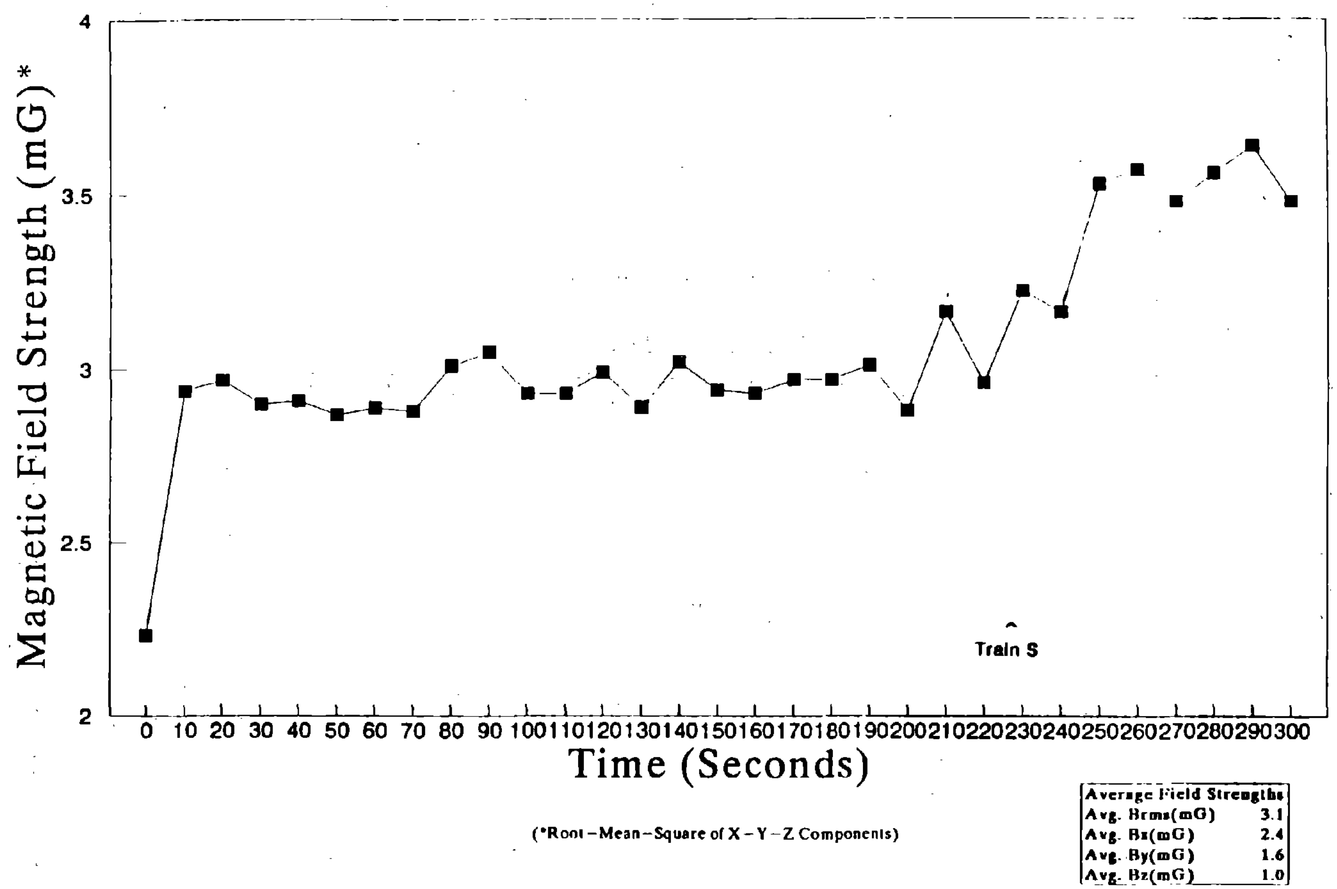
Average Field Strengths	
Avg. Brms(mG)	2.0
Avg. Bx(mG)	1.7
Avg. By(mG)	1.0
Avg. Bz(mG)	0.2

Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S06

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-6

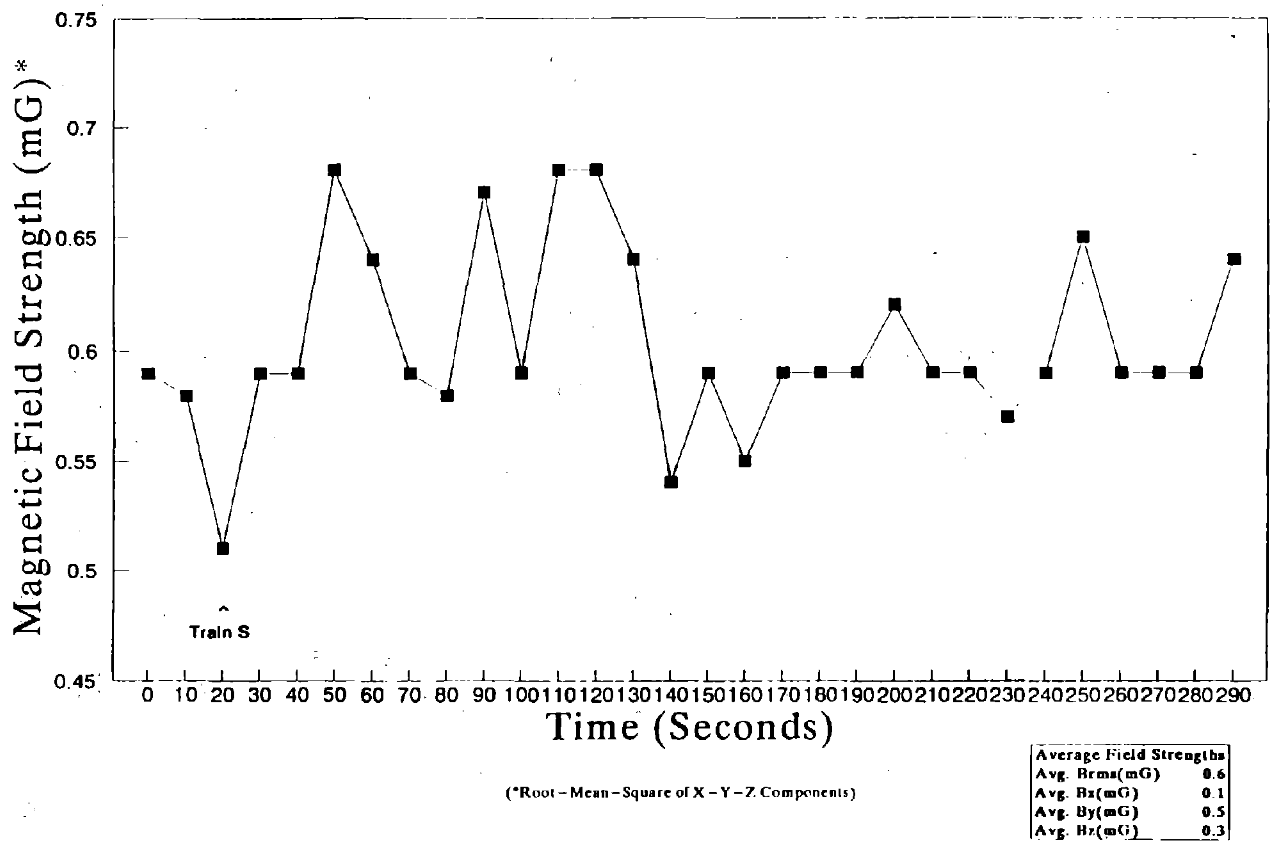


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S07

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-7

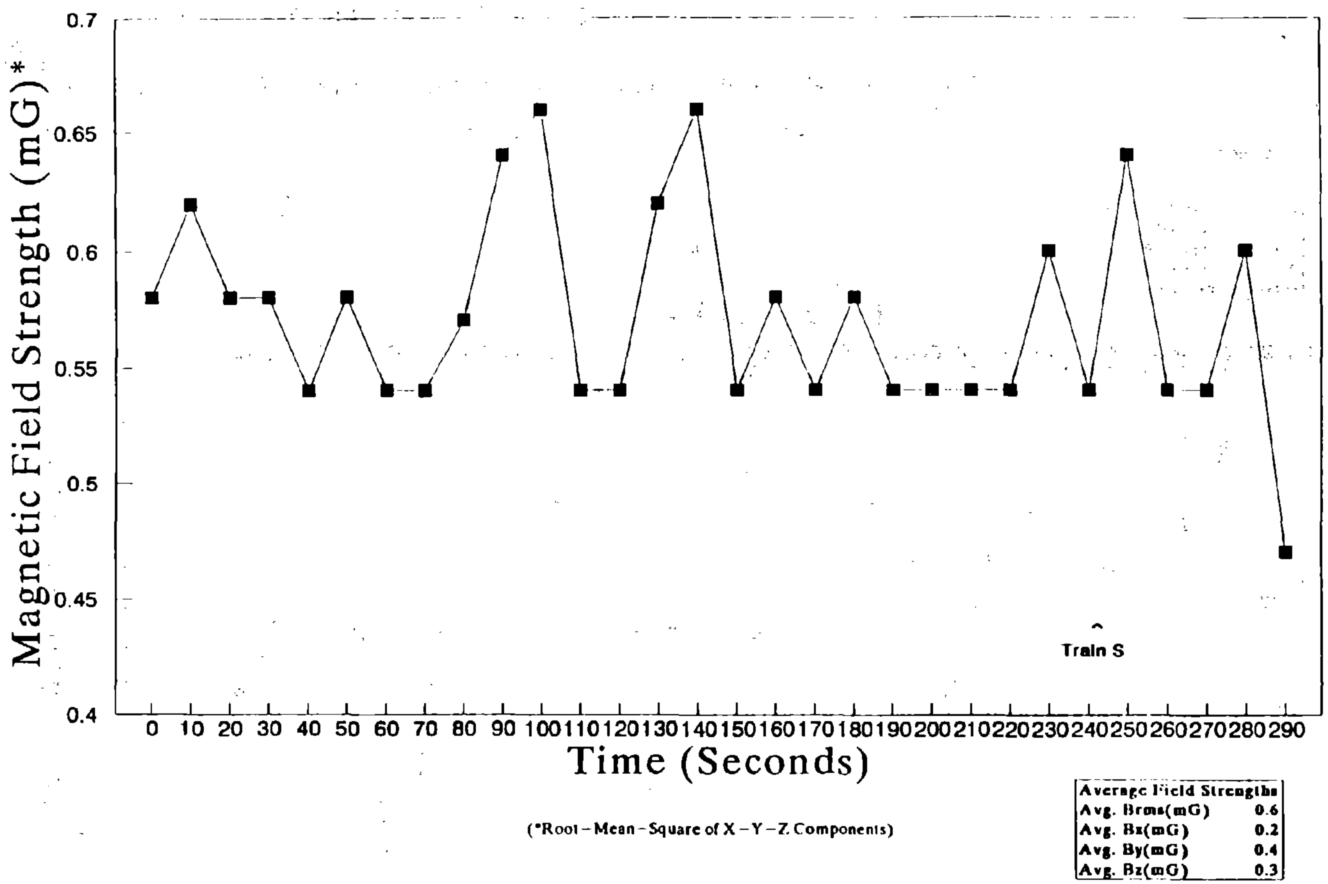


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S08

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-8

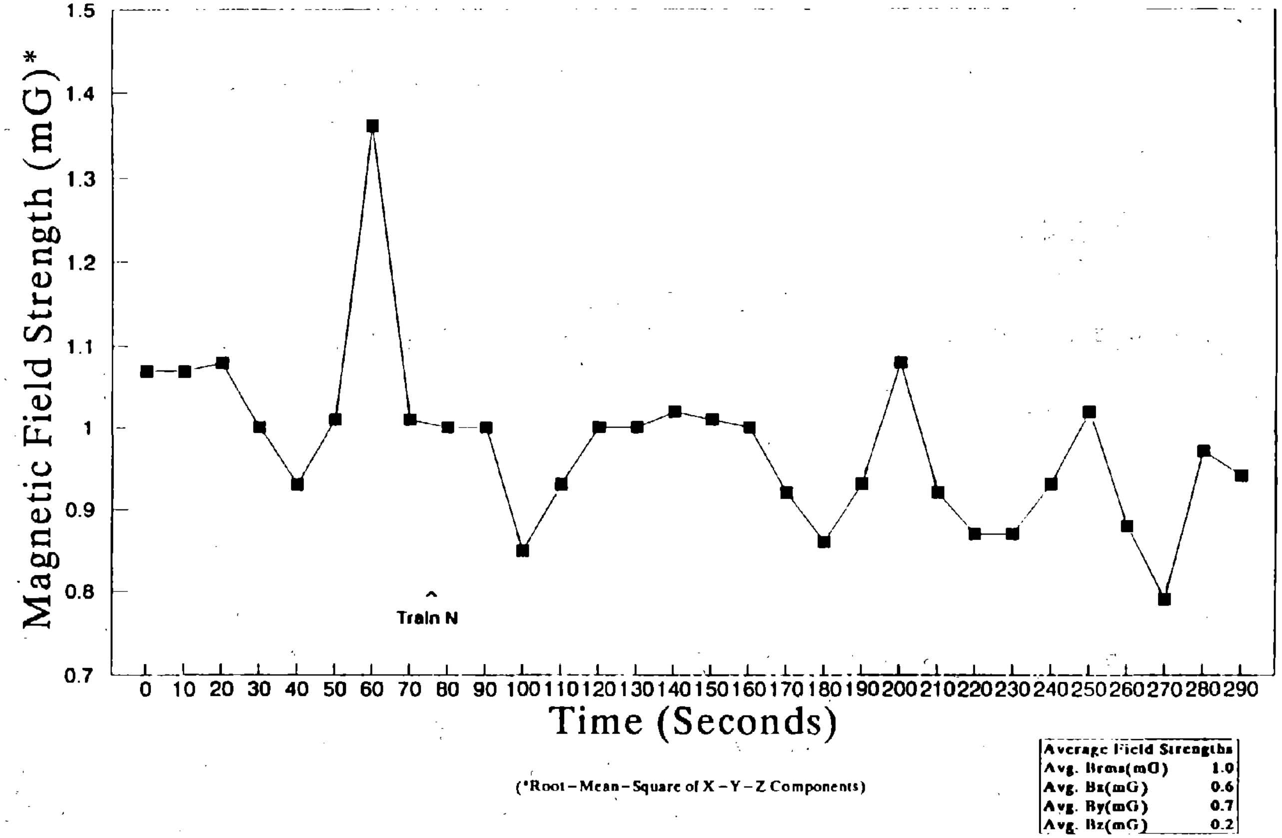


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S09

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-9

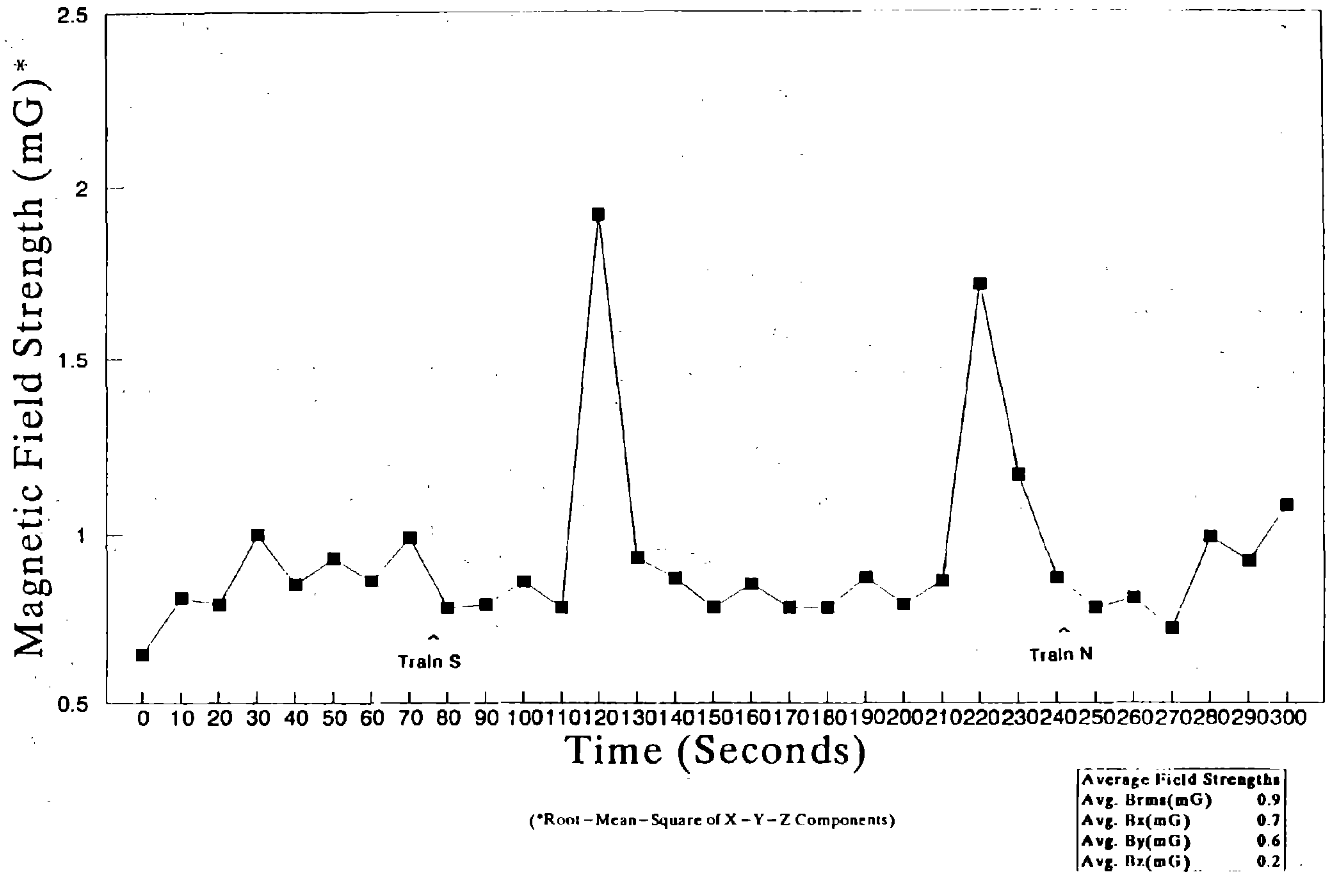


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S10

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-10

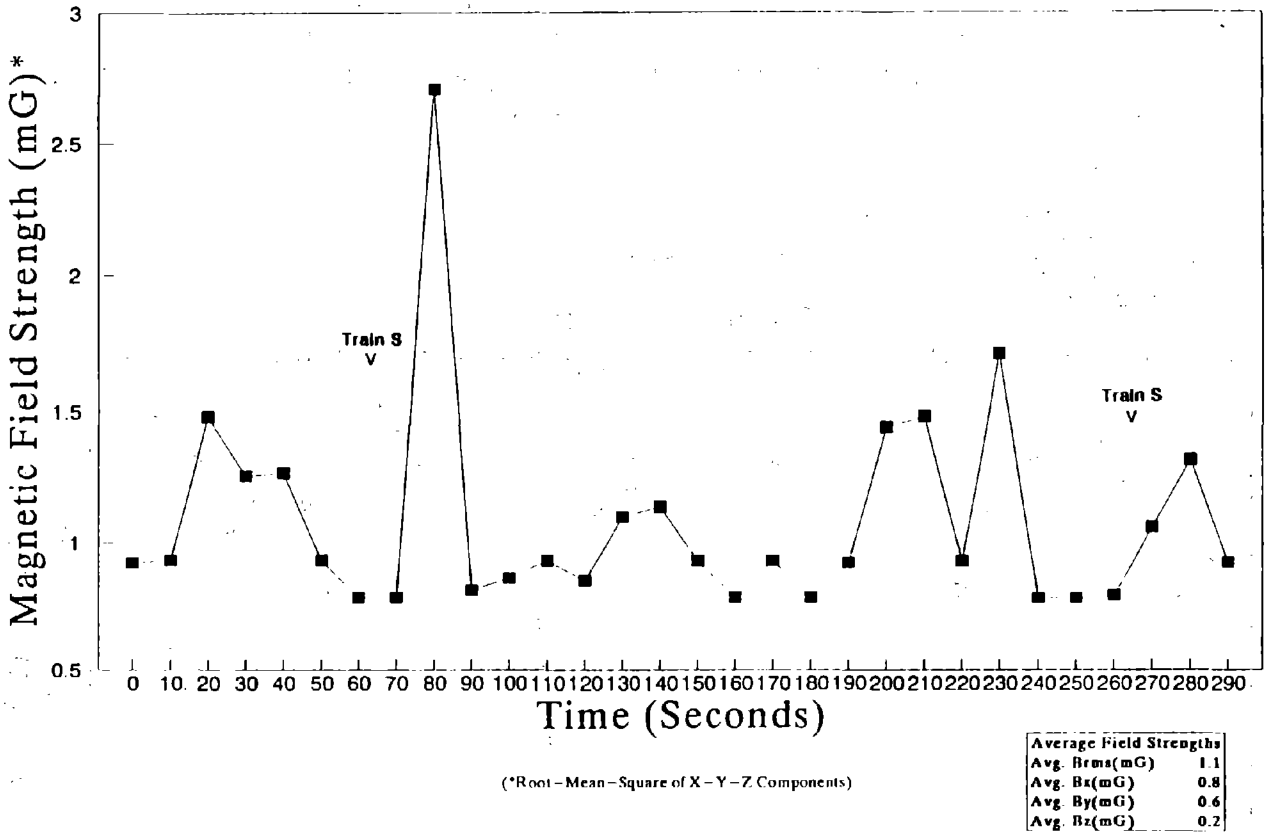


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S11

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-11

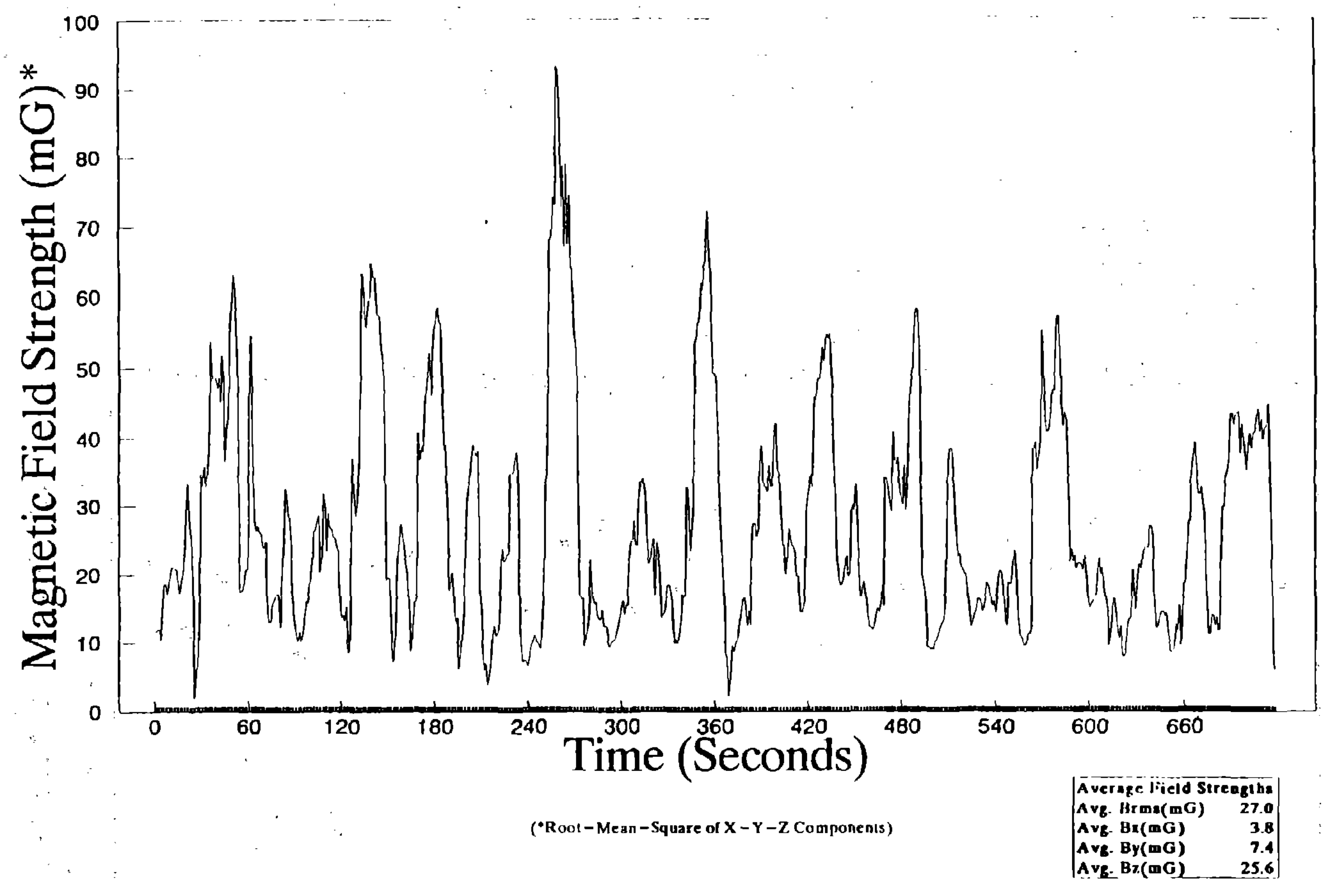


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S12

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure
5A-12

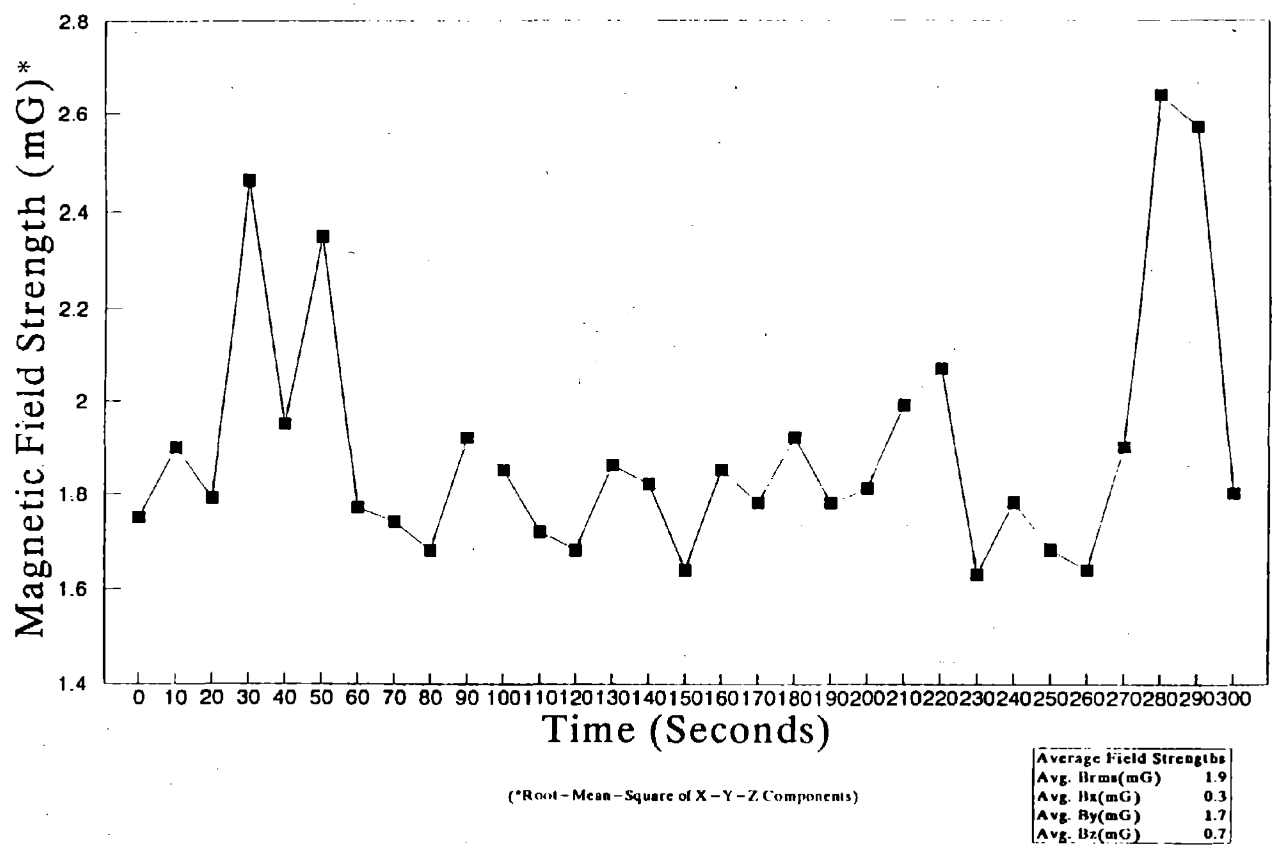


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S13

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-13

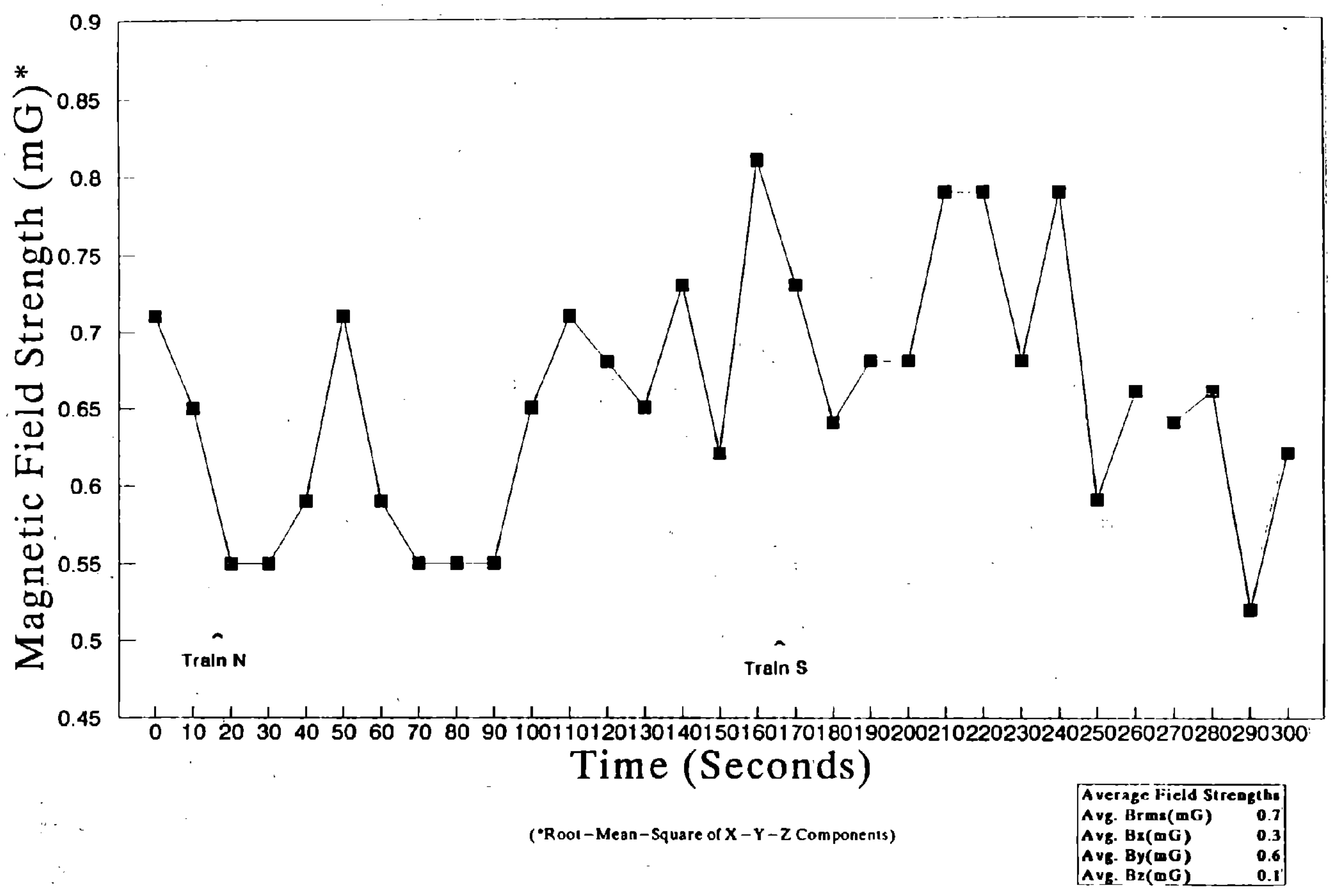


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S14

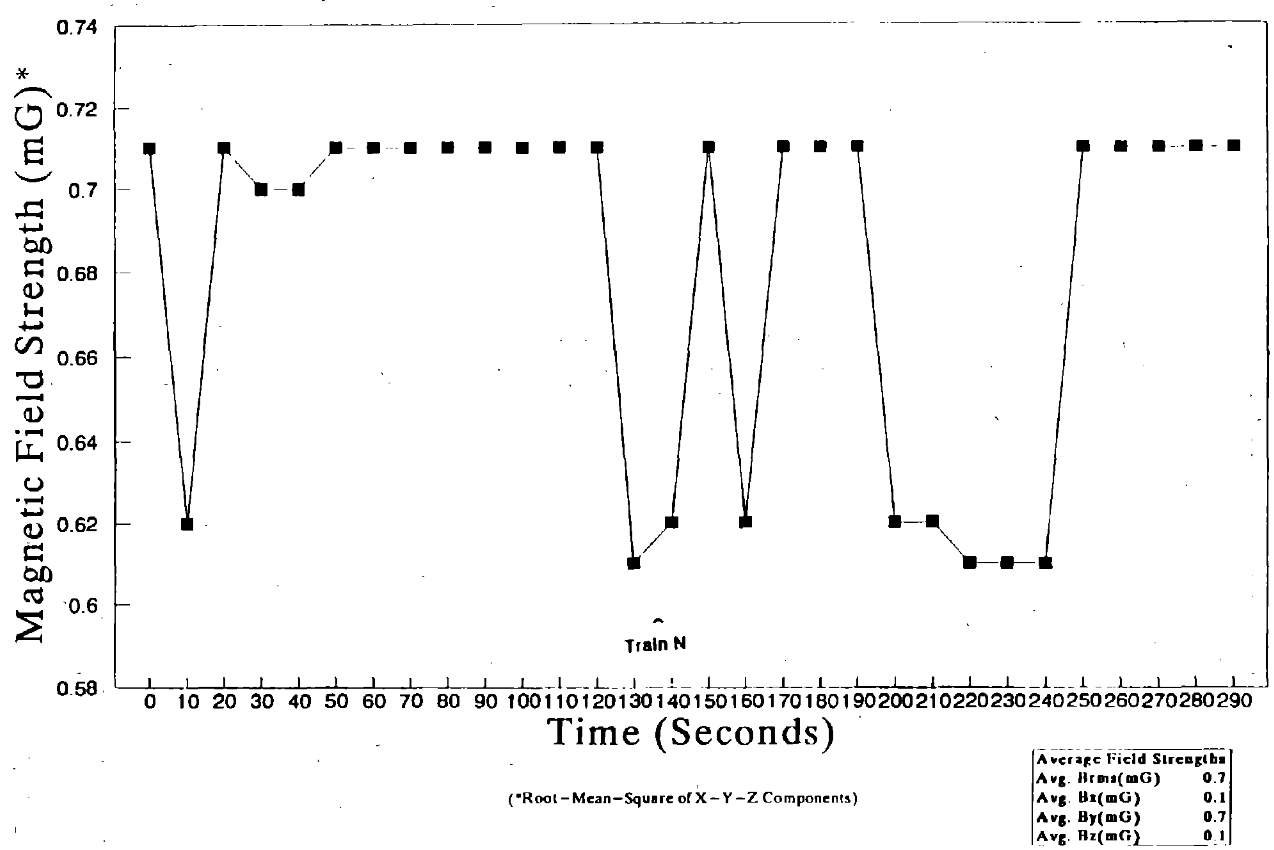
Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure
5A-14



Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S15	Figure 5A-15
Northeast Corridor Improvement Project Electrification - New Haven CT to Boston MA	

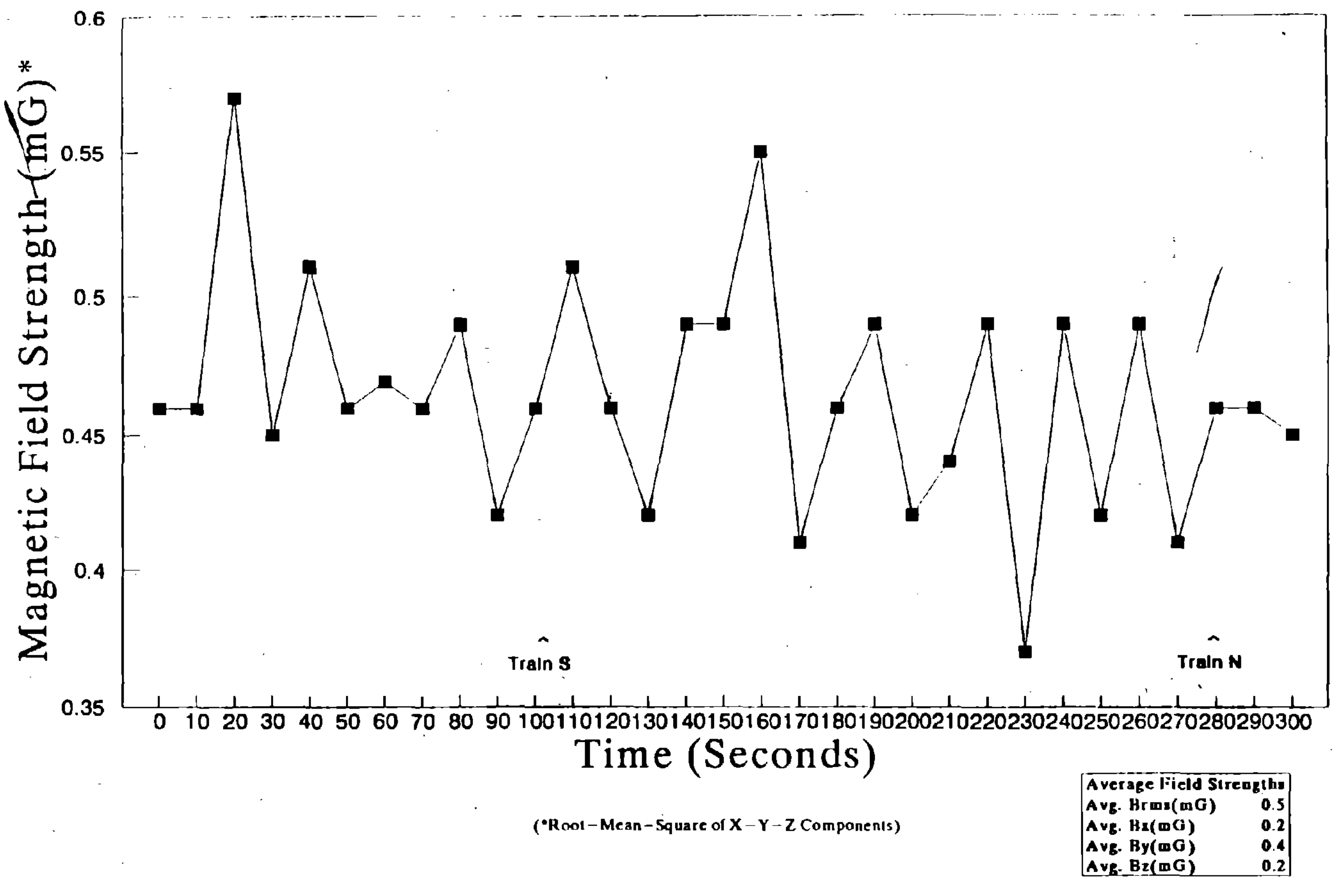


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S16

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-16

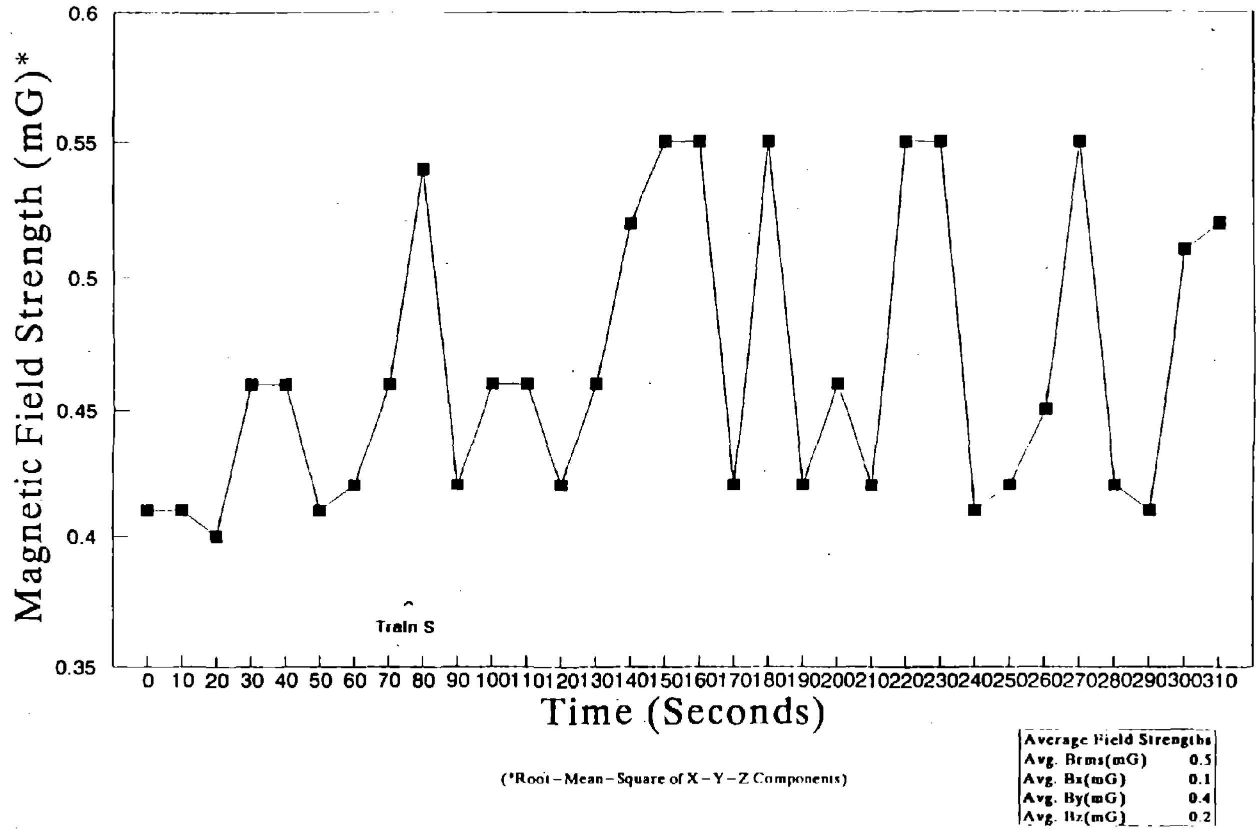


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S17

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-17

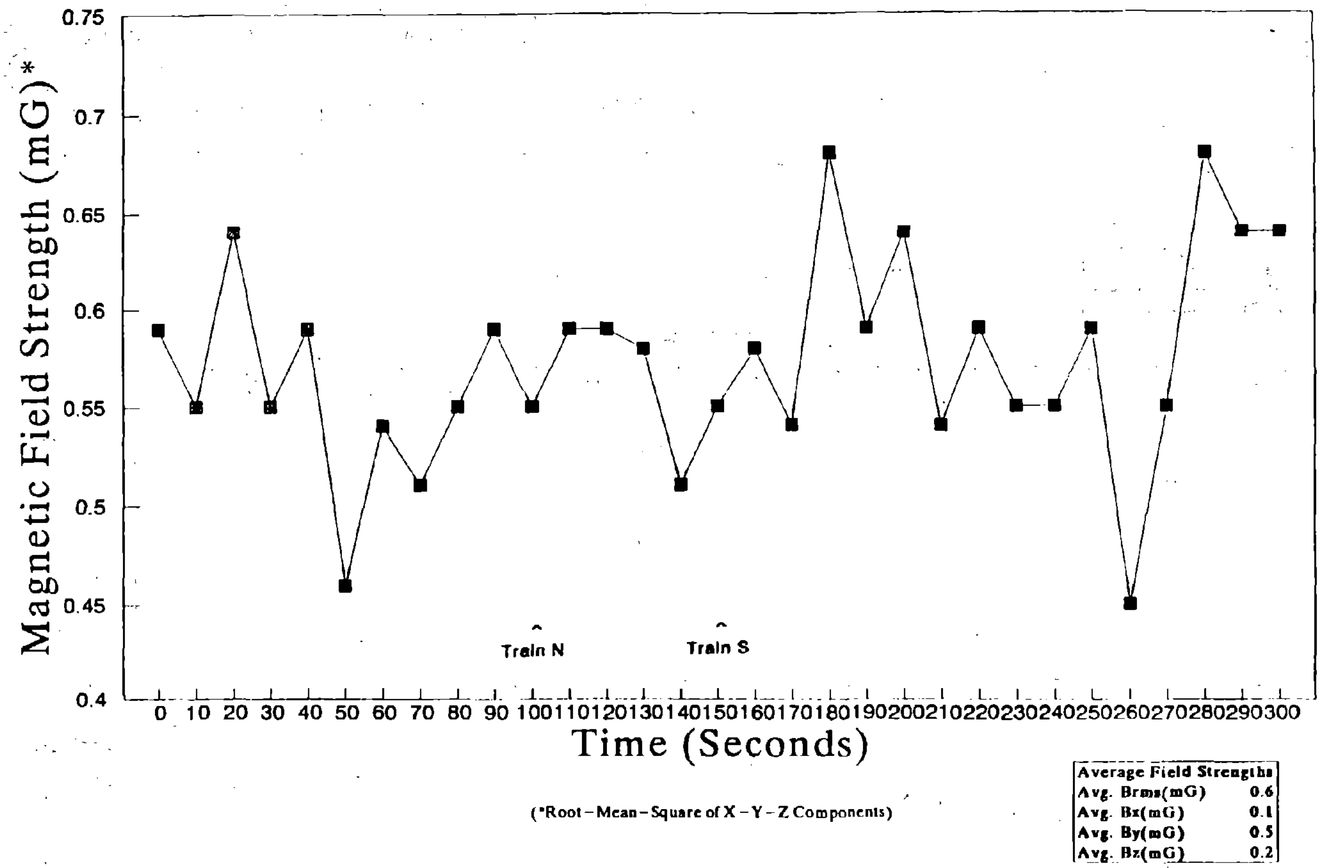


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S18

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-18

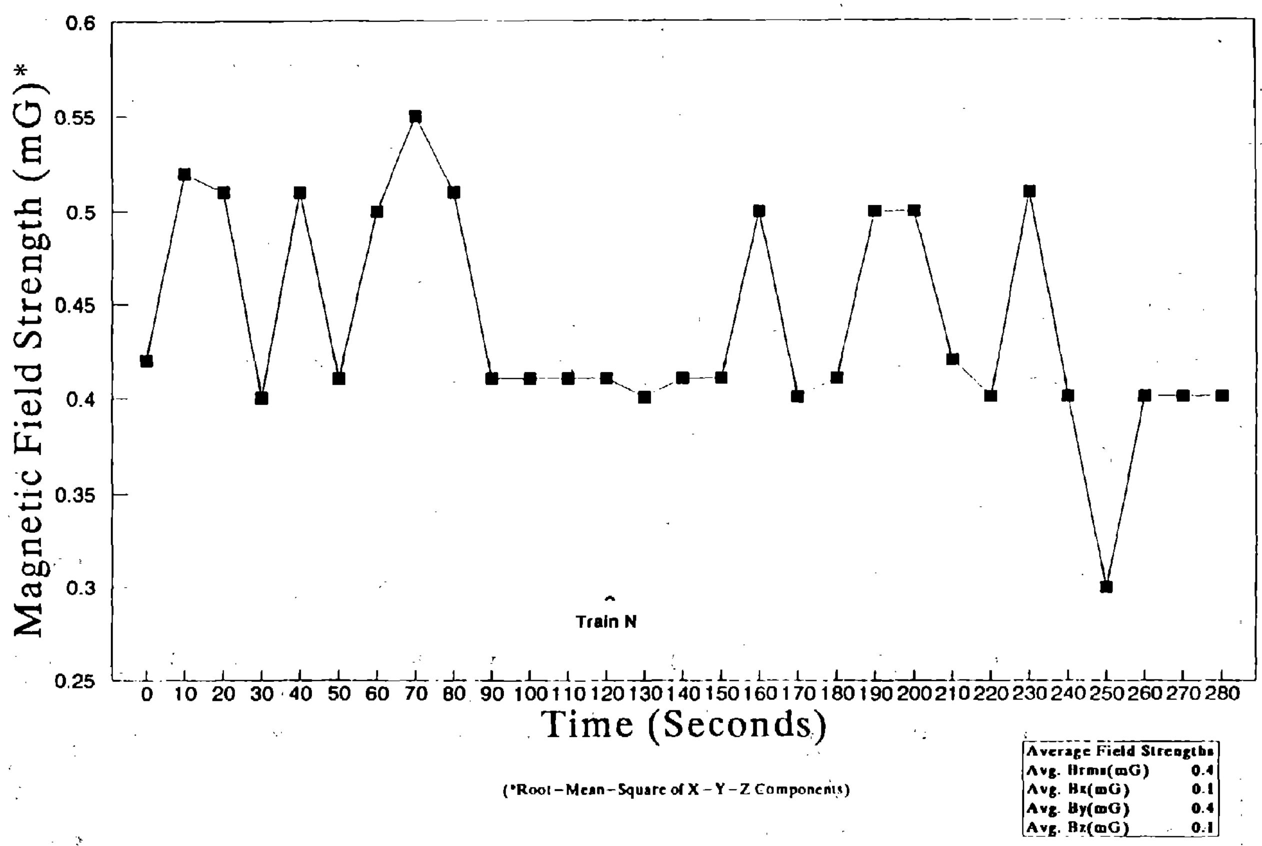


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S19

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-19

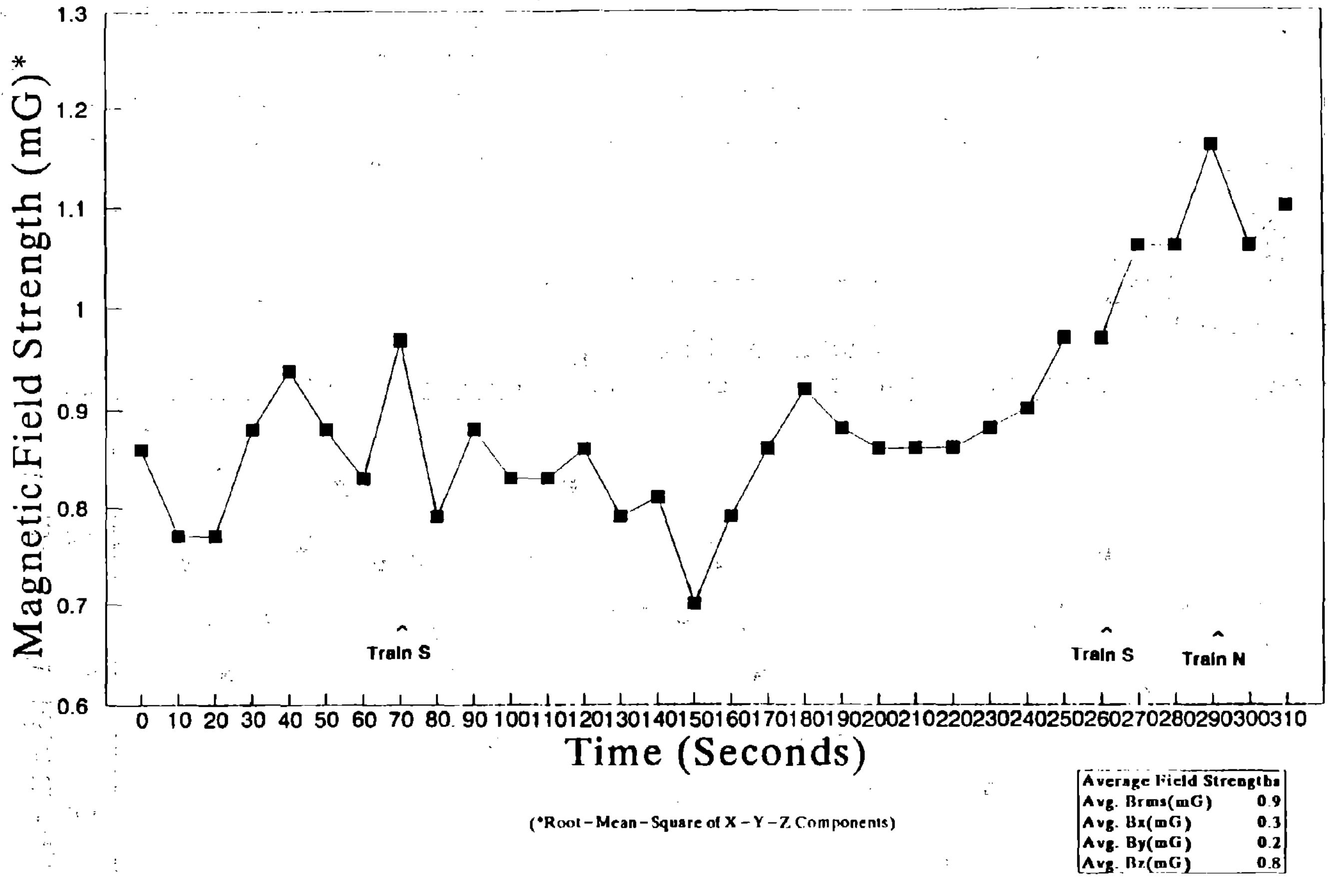


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S20

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure
5A-20

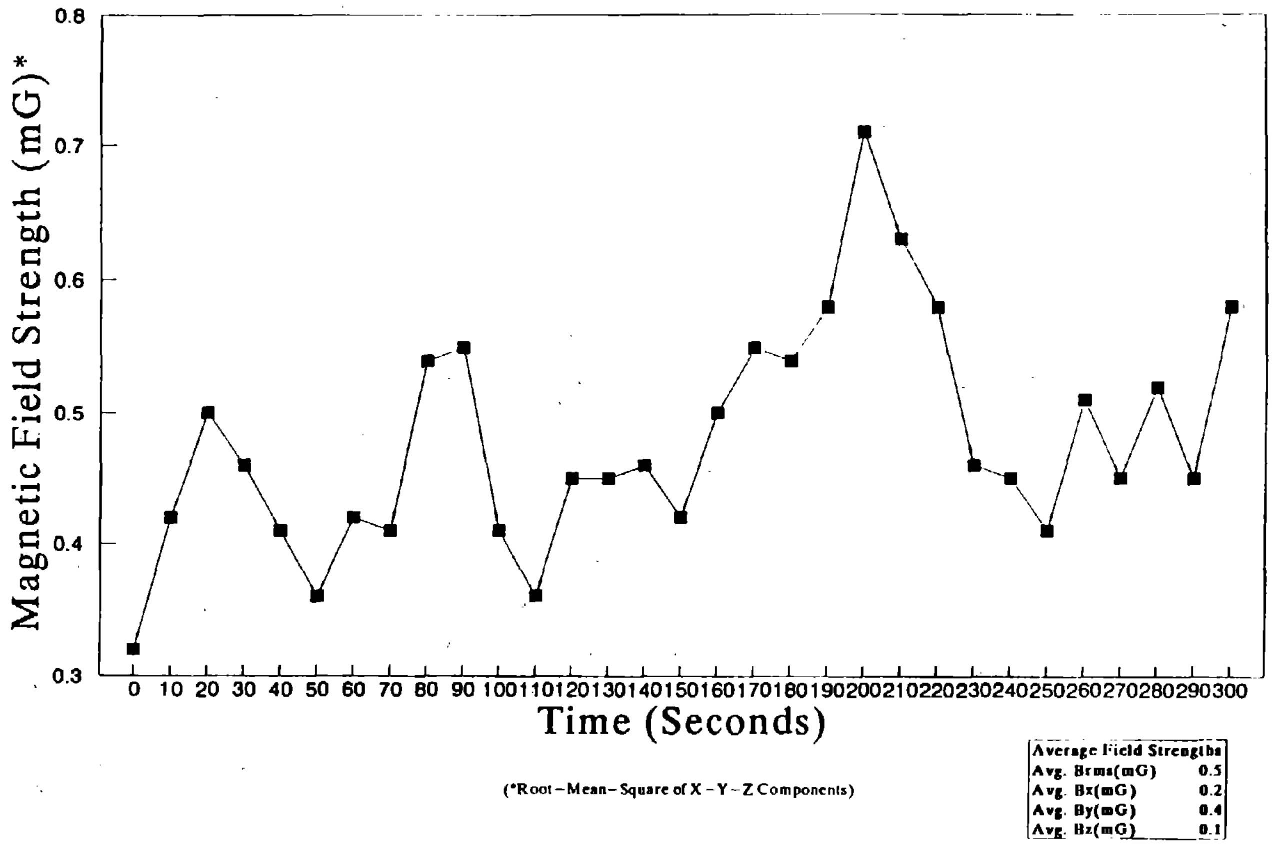


Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S21

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-21



Source: Roy F. Weston, Inc.

ROXBURY SUBSTATION MAGNETIC FIELD STRENGTH - LOCATION S22

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Figure 5A-22

CHAPTER 6
ENERGY ANALYSIS

The energy analysis presented herein represents a revised version of that contained in the DEIS/R. Although all of the evaluation criteria remain the same as in the DEIS/R, new data have become available since the DEIS/R which changes certain aspects of the energy analysis. In addition, certain comments received on the DEIS/R indicated a desire to see additional analyses performed. Therefore, this chapter of the FEIS/R presents those aspects of the energy analysis that have been revised based on newly available data, and new analyses prepared in response to comments.

6.1 AFFECTED ENVIRONMENT

The analysis in the DEIS/R of the energy consumption of the current Amtrak diesel train service is based on a schedule of 139 one-way trips between Boston and New Haven each week. The latest information available from Amtrak indicates a different schedule from that assumed in the DEIS/R.[1] Accordingly, the analysis of energy consumption associated with the current diesel train service is recalculated.

According to Amtrak, the current schedule is 20 diesel trains per day, comprised of the following:

- four one-way express trips per day with one locomotive and four cars (express service)
- ten one-way conventional trips per day with one locomotive and six cars (conventional service)
- six one-way conventional trips per day with two locomotives and ten cars (Fast Mail and Night Owl service)

Amtrak estimates energy consumption as follows:

- 263 gallons per one-way trip for express service
- 297.5 gallons per one-way trip for conventional service
- 510 gallons per one-way trip for Fast Mail or Night Owl service

Using these data, diesel consumption is estimated to be 2,586,755 gallons per year, assuming that diesel consumption will be the same every day of the year. At 141,000 Btu per gallon of diesel fuel, this represents 364.7 billion Btu per year.

The energy consumption per passenger-mile can serve as a basis of comparison with other transportation options. The estimate of passenger-miles traveled is 182,630,600 per year. Thus, 1,997 Btu per passenger-mile are consumed in the current diesel service.

Another means of comparing consumption among train alternatives is Btu per seat-mile. This eliminates any inconsistencies resulting from passenger loading assumptions. The number of seats per train is estimated as follows:

- 258 seats on an express train
- 413 seats on a conventional train with six cars
- 420 seats on a conventional train with ten cars (some of the cars do not seat passengers)

Using the distance from New Haven to Boston (approximately 156 miles), the number of seat-miles is determined to be approximately 1.2 million per day or 437.4 million per year. Based on an energy consumption of 364.7 billion Btu per year, 834 Btu are consumed per seat-mile for current operations.

6.2 ENVIRONMENTAL CONSEQUENCES

6.2.1 Environmental Impacts

6.2.1(a) Projected Energy Consumption for the Proposed Action

There are two aspects to the electricity consumption for the Proposed Action: energy use and capacity use. Capacity use is often defined in terms of demand. The analysis of electricity demand described in Volume III, Section 6.4.3 of the DEIS/R remains valid and requires no revisions. However, new data that have become available since the DEIS/R allow correction and refinement of the energy component of the energy consumption analysis.

Projected Electrical Energy Consumption. Based on data provided by Amtrak, it has been determined that the electricity consumption data utilized in the DEIS/R for analysis of the electrification alternative included a projected electricity consumption for commuter rail in 2010.[2] However, as all commuter rail systems on the NEC are expected to operate on diesel power in 2010, the projected electricity consumption for commuter rail should not be included in this analysis. The most recent data allow determination of electricity consumption without the contribution of commuter rail.

Utilizing the new data, electricity consumption is estimated to be 455,800 kilowatt-hours (kWh) per day. This is converted to an annual consumption using the assumption that electricity consumption will be the same every day of the year. This yields an estimate of 166,370 megawatt-hours (MwH) per year. This is approximately 12 percent lower than the estimate in the DEIS/R.

Fuel Required for Electricity Generation. The energy consumption identified above is the electrical energy delivered to the locomotive's transformers. This electricity is generated at power plants and transmitted to the locomotive, and this transmission involves losses from various sources such as line resistance and at transformers. To account for this loss in the analysis of energy impacts, electricity consumption was increased by a factor of 8 percent. This compensation factor is consistent with other studies conducted by utilities. Thus, 179,680 MwH of electricity must be generated to meet the energy demands of the Proposed Action.

As a base assumption the fuels used by utilities to generate the electricity required are assumed to be 50 percent oil and 50 percent natural gas. The rationale for this assumption is presented in Volume III, Section 6.4.3 of the DEIS/R. An alternative assumption regarding the mix of fuels used in electricity generation is discussed later in this section. Using the data in the DEIS/R regarding generating efficiency and heat content of fuel, the annual quantities of oil and natural gas required can be estimated. These quantities, along with all of the intermediate data used to derive them, are shown in Table 6.2-1.

It can be seen in Table 6.2-1 that a total of 1,824 billion Btu of energy input is required each year to generate the electricity required for the project. As described in Volume III, Section 6.4.3 of the DEIS/R, a total of 653,210,659 passenger-miles are projected for the electrification scenario. This results in an energy consumption of 2,792 Btu per passenger-mile. According to Amtrak, there are 1,428 seats on the conventional trains with 18 cars, and 448 seats on the express trains with 8 cars. With the schedule assumed, this results in approximately 6.7 million seat-miles per day or 2.4 billion seat-miles per year. Thus, energy consumption is projected to be 747 Btu per seat-mile.

TABLE 6.2-1 Summary of Projected Energy Consumption, Proposed Action, 2010

FUEL USE	FUEL CONSUMED
Daily express train electricity consumption	209,488 kWh
Daily conventional train electricity consumption	246,320 kWh
Daily total electricity consumption	455,808 kWh
Annual electricity consumption	166,369,920 kWh
Annual electricity generation required (w/8 percent transmission loss)	179,679,514 kWh
Annual energy input required for electricity generation (based on 10,151 Btu/net kWh)	1,824 billion Btu
Annual oil consumed (based on 50 percent of electricity generated using oil: 150,357 Btu/gallon)	6,065,231 gallons
Annual natural gas consumed (based on 50 percent of electricity generated using gas; 1,039 Btu/cubic foot)	877,718,961 cubic feet

Source: Roy F. Weston, Inc., 1994

Regenerative Braking. Modern electric high-speed rail systems in Europe incorporate regenerative braking into their design. Amtrak proposes to incorporate this concept into the electrification system between New Haven and Boston. Under this concept, as part of the train's braking system the traction motors are reversed during braking to provide resistance to turning of the drive wheels. Using this resistance, the traction motors serve as small generators that produce electricity which is then fed back into the catenary and used by other trains. This reduces the net amount of electricity required to be generated by utilities.

Calculations by Amtrak based upon the joint Amtrak/FRA demonstrations of the Swedish X-2000 and German ICE trains during 1993 indicate that regenerative braking for intercity trains would reduce the net power drawn from utilities by 17 percent.[3] If commuter rail operations on the NEC are converted to electric operation, even greater savings would be possible because commuter trains brake more often.

The energy calculations for the Proposed Action above do not incorporate the benefits from regenerative braking into the calculations owing to the relative newness of the concept and the need to address certain technical issues prior to widespread operation. Clearly, this concept has the potential to significantly improve the attractiveness of electric traction from an energy consumption standpoint.

6.2.1(b) Projected Energy Consumption for the No-Build Alternative Scenarios

No-Build Alternative - AMD-103 Scenario. A projection has been made of the changes to the current schedule of trains that would be made by 2010 if electrification were not implemented. It is projected that four one-way express (Metroliner) trips would be added per day to the current schedule with a train size of one locomotive and four cars, resulting in eight one-way Metroliner trips per day and bringing the total number of trains per day to 24. As this differs from the no-build schedule used in the DEIS/R, the energy consumption for the No-Build Alternative scenarios has been recalculated.

Since the schedule remains the same as the current schedule, except for the addition of the four one-way trips, the incremental energy consumption can be calculated and added to that for the current schedule. The four additional trips per day would consume 1,052 gallons per day, or 383,980 gallons per year, based on 263 gallons per trip. This results in total diesel consumption of 2,970,735 gallons per year, which translates to 418.9 billion Btu per year.

As reported in the DEIS/R (Volume III, Section 6.4.3.2), the No-Build Alternative - AMD-103 Scenario is projected to result in 295,598,115 passenger-miles per year. Using the energy consumption calculated above, the no-build scenario consumes 1,417 Btu per passenger-mile. The four additional express trips per day add approximately 59 million seat-miles per year, bringing the total to 496.2 million seat-miles per year. Using this data, the no-build scenario consumes 844 Btu per seat-mile.

No-Build Alternative - FF-125 Scenario. In response to comments on the DEIS/R, an alternative train technology has been considered in the impact analyses included in this FEIS/R. This alternative technology is based on a non-electric locomotive using diesel fuel, and is described in Chapter 2, Volume I of this FEIS/R as the No-Build Alternative - FF-125 Scenario. The trains used in this analysis consist of two locomotives and five cars for express trains and two locomotives and seven cars for conventional service to be comparable to the small train version of the Proposed Action. Using the small train size assumptions, the FF-125 scenario would consume 12,053,760 gallons per year of diesel fuel which represents approximately 1,700 billion Btu. This then translates into 3,324 Btu per passenger-mile and 1,634 Btu per seat-mile.

Using these data and the same assumptions regarding the schedule of trains as for the Proposed Action (16 express trains and 10 conventional trains per day in each direction), the total diesel consumption is estimated to be 56,808 gallons per day, or 20,734,920 gallons per year. This represents approximately 2,924 billion Btu per year.

The projected annual ridership for the No-Build Alternative - FF-125 Scenario is 2.84 million, which results in 511,358,950 passenger-miles per year. Using the energy consumption figure above, this scenario consumes 5,717 Btu per passenger-mile. Seat-miles calculated on the trainsets described above total 2.2 billion seat-miles per year. This scenario consumes 1,311 Btu per seat-mile.

No-Build Alternative - FRA-150 Scenario. Given the state of FRA's non-electric high-speed locomotive program, it is impossible to calculate the fuel consumption of this scenario. Maximizing fuel efficiency will be one of the criteria used in this program evaluation. On one hand, the higher speeds would tend to cause greater fuel consumption per train mile. On the other hand, several persons and firms which may participate in this program point to significant opportunities to improve upon the fuel consumption of non-electric power units presently used in rail applications in the U.S. Turbomeca, the manufacturer of the Mikila engine to be demonstrated in 1994 by FRA, Amtrak, and New York State in an upgraded RTL gas turbine trainset, estimates that this engine will improve fuel efficiency by 15 to 20 percent over the gas turbines presently used in the RTL.

Other power unit manufacturers/proponents estimate that similar or greater fuel efficiencies could be achieved as part of an advanced non-electric locomotive/trainset development program. Whether such efficiencies can be achieved in regular rail operations is unknown until the development program progresses.

6.2.1(c) Alternative Energy Analysis Assumptions

In response to comments on the DEIS/R, two alternative assumptions are utilized and their impacts on the energy analysis are estimated.

Alternative Fuel Mix Assumption. As described in the DEIS/R, the rationale for the mix of fuels assumed to be used by utilities to generate the electricity required for this project is the concept of incremental fuel use. Incremental fuel use is the fuel that would be used to satisfy an incremental increase in electricity demand. Since the total electricity demand for the NEC electrification project is a very small fraction of the total electricity demand in the region, it is not anticipated that any electricity-generating facilities would be built specifically to satisfy the demands for this project. Therefore, the electricity would be generated by some mix of facilities in the region (as well as, potentially, electricity imported into the region). The incremental fuel use may be different, however, than the overall mix of fuels used for electricity generation.

A simple example of this concept can be illustrative. Suppose there are only three facilities generating electricity in the area being considered; they are of equal size and one uses oil, one natural gas, and one coal. The mix of fuels in this study area would be one-third oil, one-third natural gas, and one-third coal. If an increase in electricity demand of 1 percent is projected to occur, in order to estimate the fuel used to supply that electricity, the change in operation of the three facilities must be projected. In this example, it can be assumed that the nature of the facilities is such that only the natural gas-fired facility will increase its output to satisfy the increased demand, and the other two facilities will not change their operation. Therefore, the incremental fuel use is 100 percent natural gas, even though the overall mix of fuels is evenly split among oil, gas, and coal.

This difference between incremental fuel use and overall mix of fuels is the reason that the projected mix of fuels for the region was not used to estimate the fuel use to generate electricity required for the project. A specific projection of incremental fuel use was not available for the region, and as a result the incremental fuel use was estimated based on the proposed new generating capacity for the region, and an understanding of the types of facilities that use different fuels.

One of the comments received on the DEIS/R from a major utility was that the incremental fuel use assumptions utilized in the DEIS/R were overly conservative in terms of showing a reliance on fossil fuels to generate the electricity required for the project. The suggestion was made that projections prepared by the New England Power Pool (NEPOOL, the regional utility organization) regarding the future mix of fuels for generating electricity in the region be utilized.

Using the data supplied by the utility company in its comments, we have determined the overall mix of fuels in the year 2008, which is the last year included in the forecast (*1993 NEPOOL Generation Emissions Analysis*, draft report dated November 30, 1993). The amount of energy generated by each of the fuel sources breaks down as follows:

- nuclear: 25.2 percent
- hydroelectric: 3.5 percent
- imported (assumed to be hydroelectric): 2.3 percent
- other fuels (bio-fuels, solid waste): 3.7 percent
- natural gas: 27.0 percent
- oil: 15.5 percent
- coal: 22.9 percent

Note: Does not equal 100 percent due to rounding.

Using this assumed mix of fuels, and the electricity generating requirements for the project, as described earlier, the amounts of coal, oil, and gas consumed are estimated. The transmission loss and generating efficiency assumptions remain the same as in the earlier analysis. The only new piece of data required is a heat content for coal, since no incremental coal burning was assumed in the earlier analysis. Using the same source of data as for the heat contents of oil and natural gas (*Electric Power Annual 1991*, Energy

Information Administration), the heat content of coal used by utilities in Connecticut and Massachusetts is 13,148 Btu per pound. Applying this and the other data described, the quantities of oil, gas, and coal consumed were projected; the results are summarized in Table 6.2-2, and compared with the base case analysis in Table 6.2-3. Note that no estimates have been made for fuel consumption for "other fuels" since the exact nature of these fuels is not known. In addition, since hydroelectric power plants do not consume fuel, and nuclear facilities do not consume fuel in the traditional sense, fuel consumption estimates for these components of the electricity generation are not included.

TABLE 6.2-2 Alternative Fuel Mix Analysis

FUEL USE	FUEL CONSUMED
Annual electricity consumption	166,369,920 kWh
Annual electricity generation required (w/8 percent transmission loss)	179,679,514 kWh
Annual energy input required for electricity generation (based on 10,151 Btu/net kWh)	1,824 billion Btu
Annual oil consumed (based on 15.5 percent of electricity generated using oil; 150,357 Btu/gallon)	1,881,435 gallons
Annual natural gas consumed (based on 27.0 percent of electricity generated using natural gas; 1,039 Btu/cubic foot)	473,090,520 cubic feet
Annual coal consumed (based on 22.9 percent of electricity generated using coal; 13,148 Btu/lb)	31,780,916 pounds (15,890 tons)

Source: Roy F. Weston, Inc., 1994

TABLE 6.2-3 Comparison of Fuel Consumed in Base Case and Alternative Analyses

FUEL CONSUMPTION	BASE CASE	ALTERNATIVE FUEL MIX	PERCENT DIFFERENCE
Oil	6,065,231 gallons	1,881,435 gallons	69 percent reduction
Gas	877,718,961 cubic feet	473,090,520 cubic feet	46 percent reduction
Coal	0	31,780,916 pounds (15,890 tons)	Increase from zero

Source: Roy F. Weston, Inc., 1994

Alternative Train Size Assumption in the Proposed Action. Amtrak has indicated that the schedule and train sizes assumed for the electrification in the analyses in the DEIS/R and above were utilized for the purposes of design of the electrification. These assumptions are overly conservative for the purposes of an energy consumption analysis. Supporting this assumption is the fact that the two-locomotive, 18-car train assumed to be utilized in the electrification scenario would not fit into existing or planned passenger platforms. Amtrak believes that much smaller trains would be utilized.

Amtrak's projected schedule is as follows:

- 16 express round-trips per day, with one locomotive and six cars
- 10 conventional round-trips per day, with one locomotive and eight cars

This schedule keeps the same frequency of trains as the electrification analysis described previously in this section, but decreases the size of the trains. Amtrak has estimated the electricity consumption associated with the smaller train sizes as follows: 10,183 kWh per round-trip for an express train and 11,084 kWh per round-trip for a conventional train. This results in a daily electricity consumption of 273,768 kWh per day or 99,925,320 kWh per year.

This electricity consumption is approximately 60 percent of that projected based on the larger train sizes. Assuming these smaller trains could hold the projected passenger-mile loading, the Btu per passenger-mile would also be 60 percent of the value calculated, based on larger train sizes, or approximately 1,675 Btu per passenger-mile. The smaller trains obviously have fewer seats than the larger ones. Based on data provided by Amtrak, the smaller trains would represent, in total, about 50 percent of the number of seats in the schedule with the larger trains. Since the energy consumption has decreased less than seat-miles traveled (40 percent reduction versus 50 percent reduction), the Btu per seat-mile show an increase of about 20 percent when compared with the larger train sizes (885 Btu per passenger-mile versus 747 Btu per passenger-mile).

Alternative Train Size Assumption in the No-Build Alternative - FF-125 Scenario. A similar analyses to that above was prepared on a smaller FF-125 consist. The key data inputs and findings are as follows:

- FF-125 express service: 2 locomotives + 5 passenger cars, 542 gallons per one-way trip
- FF-125 conventional service: 2 locomotives + 7 passenger cars, 784 gallons per one-way trip
- diesel fuel consumed: 12,053,760 gallons/year
- energy consumed: 1,700 billion Btu/year
- energy consumed per passenger-mile: 3,324 Btu/passenger-mile
- energy consumed per seat-mile: 1,634 Btu/seat-mile

While Btu/passenger-mile go down with the smaller FF-125 consist (3,324 vs. 5,717), the Btu/seat-mile actually go up (1,634 vs. 1,311). This is due to (1) the large number of seats in the original consist, and (2) the fact that in the case of the smaller consist, the reduction in energy consumed does not drop in proportion to the reduction in seating capacity. Thus, energy consumed per seat-mile goes up.

6.2.1(d) Comparison of Current Schedule, Proposed Action, and No-Build Alternative Scenarios

Table 6.2-4 provides a summary of the key aspects of energy consumption for the current schedule of trains, the Proposed Action, and the No-Build Alternative - AMD-103, FF-125, and FRA-150 scenarios. It can be seen that total energy consumption is higher than the current level for all future alternatives, as would be expected, given the increased numbers of trains. The FF-125 has the highest total energy consumption, as well as the highest consumption per passenger-mile and per seat-mile. The Proposed Action has higher energy consumption than the No-Build Alternative - AMD-103 Scenario in terms of total energy and on a passenger-mile basis. It is lower than the No-Build Alternative scenarios on a per-seat-mile basis, which is due to the high number of seats assumed in relation to number of passengers.

TABLE 6.2-4 Comparison of Energy Consumption of Train Alternatives, Base Case

	1993 CURRENT SCHEDULE	2010 NO-BUILD AMD-103	2010 NO-BUILD FF-125	2010 PROPOSED ACTION
Total energy consumption	364.7	418.9	2,924	1,824
Btu per passenger-mile	1,997	1,417	5,717	2,792
Btu per seat-mile	834	844	1,311	747
Petroleum consumption	2,586,755	2,970,735	20,734,920	6,065,231
Natural gas consumption	0	0	0	877,718,961

Source: Roy F. Weston, Inc., 1994

Comparison of the No-Build Alternative scenarios and the Proposed Action in terms of energy consumed per seat-mile and per passenger-mile can be somewhat misleading, however. The large trainsets assumed in the Proposed Action result in artificially low energy consumption per seat-mile and artificially high energy consumption per passenger-mile. The smaller train sizes planned by Amtrak and more representative of how the system would actually operate may be a more valid point of reference. The energy consumption for the Proposed Action train size is slightly higher than the No-Build Alternative - AMD-103 Scenario on both a passenger-mile (1,675 vs. 1,417 Btu per passenger-mile) and a seat-mile (885 vs. 844 Btu per seat-mile) basis. Thus, it appears that significant increases in train speed and ridership can be achieved with only a slight reduction in energy efficiency.

Another valid comparison is with the energy efficiency of other modes of transportation. Data compiled nationally[4] indicate the following energy efficiency for other modes of transportation:

- passenger car 3,558 Btu per passenger-mile
- intercity bus 997 Btu per passenger-mile
- aircraft 4,647 - 9,194 Btu per passenger-mile

Using the 1,675 Btu per passenger-mile estimated to be consumed by the Proposed Action with smaller trainsets as a point of reference, it can be seen that, excluding intercity bus, all other modes of transportation are significantly less efficient than rail. In addition, the 1,675 Btu per passenger-mile compare favorably with the 1,975 Btu per passenger-mile estimated for Amtrak operations nationally in 1991.[5]

In summary, the data suggest that:

- Significant increases in train speed and ridership can be achieved with only a slight reduction in energy efficiency.
- In comparison with the passenger car and aircraft, an intercity train between New Haven and Boston is a very efficient transport mode.

6.2.1(e) Projected Energy Impacts Associated with Shifts from Freight Rail to Truck
As a result of the increase in passenger train traffic associated with the No-Build Alternative - FF-125 and FRA-150 scenarios, and the Proposed Action, the ability to move freight rail may be impacted on certain sections, absent measures to increase the capacity of the NEC mainline. A shift of some freight shipments

from rail to trucks may occur. This shift would have impacts on energy consumption; these potential impacts are developed below.

The additional truck traffic resulting from a number of 2010 alternatives has been estimated for the year 2010 under a range of assumptions. Two different levels of modal shift have been assumed: 25 and 50 percent. This means that 25 or 50 percent of the freight rail traffic on the NEC is assumed to be shifted to trucks. In addition, two different growth rates in freight rail use have been assumed: Two percent and 8.8 percent annual growth rates have been utilized in order to project the level of demand for freight rail in the year 2010. More detail on the development of these figures is contained in Section 3.1, Volume II of this FEIS/R.

Table 6.2-5 shows the energy implications associated with the projected number of vehicle miles traveled within the states of Connecticut, Rhode Island, and Massachusetts as a result of shifts from rail. The vehicles assumed are transfer-trailer trucks. The fuel efficiency of these vehicles is based on national data for 1991, the last year for which data were compiled. Using the 5.65 miles-per-gallon figure from the national data, the number of gallons of diesel fuel consumed are calculated. It can be seen that the full range of incremental fuel consumption is between 8 and 48 million gallons per year depending on freight rail growth rate and modal shift assumptions. Based on 141,000 Btu per gallon of diesel fuel, this can be converted to the total number of Btu consumed. This ranges from 1,100 to 6,800 billion Btu per year.

TABLE 6.2-5 Energy Impacts in Connecticut, Rhode Island, and Massachusetts of Modal Shift from Freight Rail to Truck in the Year 2010

FREIGHT RAIL GROWTH RATE	25 PERCENT MODAL SHIFT	
	Low	Medium
Additional vehicle miles traveled per year	1,435,800	4,291,600
Additional fuel (diesel) consumed per year (gallons)[1]	8,112,270	24,247,540
Additional energy consumed (billions Btu/Yr)[2]	1,144	3,420
	50 PERCENT MODAL SHIFT	
	Low	Medium
Additional vehicle miles traveled per year	2,871,600	8,583,200
Additional fuel (diesel) consumed per year (gallons)	16,224,540	48,495,080
Additional energy consumed (billions Btu/Yr)	2,288	6,838

Notes: [1]Based on 5.65 miles/gallon in 1991, as reported in *National Transportation Statistics, Annual Report*, September 1993, Bureau of Transportation Statistics, Department of Transportation.
[2]Based on 141,000 Btu per gallon.

Source: Roy F. Weston, Inc., 1994

This increased energy use by trucks would be partially offset by a decrease in energy use by freight rail. As freight cars are eliminated from trains, the energy consumption of the locomotives would decrease. However, insufficient information was available regarding the energy consumption of freight rail and the manner in which freight rail operations would change as a result of the shift to trucks to be able to reasonably estimate the decrease in freight rail energy consumption. Therefore, it has conservatively been assumed that freight rail energy consumption would remain the same. Consequently, the incremental energy use projected in Table 6.2-5 reflects the total energy impacts estimated as a result of shifts from freight to truck rail.

6.2.2 Construction Period Impacts

There are no significant energy impacts anticipated during the construction of any of the alternatives.

Endnotes

1. Popoff, 1994a. Memorandum from John Popoff, Amtrak, to Cassandra Koutalidis, DMJM/Harris, dated May 17, 1994.

2. Popoff, 1994b. Memorandum from John Popoff, Amtrak, to Cassandra Koutalidis, DMJM/Harris, dated June 6, 1994.

3. Amtrak Interoffice Memorandum from E.J. Lombardi to A.L. Jones dated October 18, 1993.

4. U.S. DOT, 1994. *Transportation Statistics Annual Report 1994*, Bureau of Transportation Statistics, U.S. Department of Transportation, January 1994.

5. U.S. DOT, op. cit.

CHAPTER 7
AIR QUALITY

This chapter presents the results of four air quality analyses performed for the FEIS/R for this project. The first analysis is an evaluation of air quality impacts of the 2010 Proposed Action and the No-Build Alternatives, with the build conditions based on a revised energy analysis. The second analysis evaluates the Proposed Action using an alternative set of fuel mix assumptions. The third analysis evaluates two alternative scenarios involving the impact of freight being hauled by trucks: freight which is unable to utilize the NEC due to scheduling limitations. The fourth analysis assesses the air quality impacts associated with the No-Build Alternatives - FF-125 and FF-150 scenarios.

7.1 AIR QUALITY ANALYSIS BASED ON REVISED ENERGY ANALYSIS

This section provides the results of the evaluation of air quality impacts of the 2010 Proposed Action and the No-Build Alternative - AMD-103 Scenario, with the build conditions evaluated based on a revised energy analysis. Based on revised energy consumption data (see Chapter 6 of this volume), it was determined that the air quality emissions from energy consumption activities (power plants) presented in the DEIS/R included projected electricity consumption for commuter rail in 2010. However, as all commuter rail systems on the NEC are expected to operate diesel-powered locomotives in 2010, the air quality emissions from projected electricity consumption for commuter rail should not be included in this analysis. The most recent data allow determination of air quality emissions without the contribution of commuter rail.

An emission inventory analysis was performed to identify operational impacts. The emission inventory analysis is comprised of estimates of volatile organic compounds (VOC), oxides of nitrogen (NO_x), and carbon monoxide (CO) emission levels attributable to project-related sources. An assessment is made of the impacts of the proposed project by comparing the emission inventories under the Proposed Action to the existing and No-Build Alternative - AMD-103 Scenario, in accordance with the requirements of each State Implementation Plan (SIP). Project-related sources include the proposed Amtrak trains, other trains, automobiles, aircraft, buses, and power plants. Section 10.3.3 of Volume III of the DEIS/R describes in detail how the estimates are made. The results presented below describe this analysis for the Proposed Action and No-Build Alternative - AMD-103 Scenario and compares them to each other and to the existing 1992 condition.

7.1.1 Evaluation Criteria

The air quality impacts due to the revised energy analysis were assessed for compliance with emission limits required by the SIPs.

The SIPs require that transportation projects not result in increased VOC, NO_x, or CO emissions over a no-build scenario. Any increase in emissions generated by the proposed project over the 2010 No-Build condition is considered a significant impact and would not be in compliance with the SIP requirements.

7.1.2 Emission Inventory Analysis

The impacts of the alternatives are discussed with respect to projected VOC, NO_x, CO, and SO_2 emissions. The emission inventories are described with respect to the entire NEC and on a state-by-state basis. A description of the methods and components of this analysis is provided in Section 10.3.3 of Volume III of the DEIS/R.

In addition to the emission sources described in Section 10.3.3 of Volume III of the DEIS/R, this inventory includes electrical power necessary to run the proposed electrified Amtrak service. Electrical power necessary to run the electrified rail corridor was translated into energy needs and fuel use equivalents. Fuel use was distributed by fuel type so that appropriate emission factors could be used to estimate the anticipated emissions from the power plants along the NEC. Emission factors for these sources were taken from U.S. Environmental Protection Agency's (EPA) Compilation of Air Pollutant Emissions Factors[1] and combined with the fuel use data to obtain power plant emissions.

7.1.2(a) Volatile Organic Compounds

Corridorwide Inventory. VOC emissions in 1992 from transportation sources in the NEC were estimated at 6,432 kilograms per day (kg/day). Automobiles and aircraft are the primary source of such emissions (see Table 7.1-1).

Between 1992 and 2010, with any of the No-Build Alternatives, vehicle miles traveled (VMT) in the NEC are projected to increase. But because of the Federal Motor Vehicle Emissions Control Program (FMVCP) and the state Inspection and Maintenance (I/M) programs, automobile emissions are expected to decrease by almost 40 percent. Similarly, even though aircraft flights are not expected to change significantly between 1992 and 2010, the change in the fleet mix (the future mix is expected to have more fuel-efficient engines which emit lower VOCs) is expected to lead to an overall decrease in aircraft emissions. These two sources are responsible for a decrease in the total VOC emissions in the NEC of approximately 39 percent and 52 percent, respectively, in 2010, when compared with the 1992 emissions (see Table 7.1-1).

The electrification project is expected to reduce total VOCs in the NEC by 202 kg/day, or a savings of 5 percent from the No-Build emissions. This reduction is due in part to the elimination of the Amtrak diesel locomotives, and in part to modal shifts from aircraft and automobiles to trains. With the proposed electrification, a new source of emissions associated with power generation (to provide the electrical power for the trains) is introduced. But the estimated 7 kg/day of VOCs from this source is quite minimal when measured against the reduction of 68 kg/day expected from eliminating Amtrak's diesel operations.

State-by-State Inventories. Table 7.1-2 presents project-related VOC emissions separated by state for the 1992 existing scenario, the 2010 No-Build Alternative, and the 2010 Proposed Action. These data show that, in each state, VOC emissions for the Proposed Action are estimated to be lower than the corresponding emissions for the No-Build Alternative.

VOC emissions in Connecticut for the Proposed Action in 2010 of 2,279 kg/day are lower than the corresponding emissions for the 2010 No-Build Alternative of 2,354 kg/day. Therefore, the proposed electrification is beneficial to air quality and is consistent with the Connecticut SIP provision to achieve the ozone standard in the statewide ozone nonattainment area (see Table 7.1-2a).

In Rhode Island, VOC emissions in 2010 for the No-Build Alternative are estimated to be 629 kg/day versus 572 kg/day for the Proposed Action. Since the estimated emissions for the Proposed Action are less than the predicted emissions for the No-Build Alternative, this project is consistent with the Rhode Island SIP provision to achieve the ozone standard in the statewide ozone nonattainment area. The air quality benefits to be derived by Rhode Island from the proposed project amount to a reduction of 57 kg/day of VOC emissions (see Table 7.1-2b).

VOC emissions in Massachusetts for the Proposed Action are estimated to be lower than the corresponding emissions for the No-Build Alternative (936 kg/day versus 1,006 kg/day). Thus, this project is consistent with the Massachusetts SIP provision to achieve the ozone standard in the statewide ozone nonattainment area (see Table 7.1-2c).

TABLE 7.1-1 VOC Emissions in the Project Corridor by Transportation Mode

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	5,595	3,417	3,348	-2,178	-39	-69	-2
Aircraft	679	328	256	-351	-52	-72	-22
Amtrak	60	68	0	8	13	-68	-100
Other Trains	66	154	154	88	133	0	0
Buses	32	22	22	-10	-31	0	0
Power Generation	0	0	7	0	0	7	N/A
TOTAL	6,432	3,989	3,787	-2,443	-38	-202	-5

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.1-2 VOC Emissions in the Project Corridor by Transportation Mode by State

a) Connecticut

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	3,464	2,227	2,181	-1,237	-36	-46	-2
Aircraft	42	42	42	0	0	0	0
Amtrak	28	32	0	4	14	-32	-100
Other Trains	16	43	43	27	169	0	0
Buses	15	10	10	-5	-33	0	0
Power Generation	0	0	3	0	0	3	N/A
TOTAL	3,565	2,354	2,279	-1,211	-34	-75	-3

TABLE 7.1-2 VOC Emissions in the Project Corridor by Transportation Mode (continued)

b) Rhode Island

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	1,029	480	470	-549	-53	-10	-2
Aircraft	230	107	78	-123	-53	-29	-27
Amtrak	18	20	0	2	11	-20	-100
Other Trains	2	20	20	18	900	0	0
Buses	3	2	2	-1	-33	0	0
Power Generation	0	0	2	0	0	2	N/A
TOTAL	1,282	629	572	-653	-51	-57	-9

c) Massachusetts

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	1,102	710	697	-392	-36	-13	-2
Aircraft	407	179	136	-228	-56	-43	-24
Amtrak	14	16	0	2	14	-16	-100
Other Trains	48	91	91	43	90	0	0
Buses	14	10	10	-4	-29	0	0
Power Generation	0	0	2	0	0	2	N/A
TOTAL	1,585	1,006	936	-579	-37	-70	-7

Source: K. M. Chng Environmental Inc., 1994

7.1.2(b) Oxides of Nitrogen

Corridorwide Inventory. Vehicle-miles-travelled (VMTs) with the 2010 No-Build Alternative are projected to increase from the 1992 conditions. But, due to the effects of the FMVCP and the state I/M programs, NO_x emissions from automobile and bus sources were estimated to decrease. This decrease is offset, however, by large increases in aircraft emissions (from 821 to 1,925 kg/day), and Amtrak and other trains' emissions (from 1,954 to 2,221 kg/day and 2,153 to 5,041 kg/day, respectively). The increase in aircraft emissions is due to a change in the fleet mix. The new fleet, with its more fuel-efficient engines, is also expected to emit more NO_x. The overall impact of these changes is a projected increase of approximately 19 percent in the total NO_x emissions in the NEC for the 2010 No-Build Alternative, when compared with the 1992 existing condition (see Table 7.1-3).

As shown in Table 7.1-3, the proposed electrification project would eliminate over 2,200 kg/day of NO_x emissions in the NEC due to a switch by Amtrak from diesel-powered locomotives to the proposed electrically powered locomotives. The proposed project would further reduce emissions by another 739 kg/day by diverting automobile and aircraft travelers to trains. These savings, however, are partially offset by a new source of emissions from power generation. Overall, NO_x emissions in the NEC with the Proposed Action are approximately 1,855 kg/day or 12 percent lower than the corresponding No-Build Alternative emissions.

State-by-State Inventories. Table 7.1-4 presents the 1992 existing, the 2010 Proposed Action, and the 2010 No-Build Alternative - AMD-103 Scenario project-related NO_x emissions estimated for each state. These data show that, in each state, NO_x emissions for the Proposed Action are estimated to be lower than the corresponding emissions for the No-Build Alternative.

NO_x emissions in Connecticut for the Proposed Action are estimated to be lower than the corresponding emissions for the No-Build Alternative. Therefore, the proposed project would not cause or contribute to a violation of the state's annual NO_2 standard (see Table 7.1-4a).

NO_x emissions in Rhode Island are presented in Table 7.1-4b for the No-Build Alternative (2,350 kg/day) and for the Proposed Action (1,932 kg/day). Since the estimated emissions for the Proposed Action are less than the predicted emissions for the No-Build Alternative this project would not cause or contribute to a violation of the state's annual NO_2 standard. Overall NO_x emissions in Rhode Island would be reduced by 418 kg/day or 18 percent due to the proposed project.

NO_x emissions in Massachusetts for the Proposed Action in 2010 are estimated to be 839 kg/day or 13 percent lower than the corresponding emissions for the 2010 No-Build Alternative. The proposed project, therefore, is not expected to cause or contribute to a violation of the state's annual NO_2 standard (see Table 7.1-4c).

7.1.2(c) Carbon Monoxide

Corridorwide Inventory. Between the 1992 existing and the 2010 No-Build Alternative - AMD-103 Scenario, CO emissions in the NEC are expected to decrease by approximately 45 percent. This dramatic decrease is attributed to the benefits of the FMVCP and the state I/M programs. Savings of over 18,600 kg/day from automobile sources were estimated between 1992 and the 2010 No-Build Alternative - AMD-103 Scenario (see Table 7.1-5).

The proposed electrification is expected to reduce the total CO emissions in the NEC by 1,007 kg/day overall. This reduction is due in part to the elimination of the Amtrak diesel locomotives (a savings of 196 kg/day), and in part to the projected diversion from automobiles (a savings of 407 kg/day) and from a reduction in aircraft flights (a savings of 485 kg/day). No diversion is anticipated from intercity buses to rail. The proposed electrification would, however, introduce a new source of CO associated with power

TABLE 7.1-3 NO_x Emissions in the Project Corridor by Transportation Mode

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	7,612	6,168	6,044	-1,444	-19	-124	-2
Aircraft	821	1,925	1,310	1,104	134	-615	-32
Amtrak	1,954	2,221	0	267	14	-2,221	-100
Other Trains	2,153	5,041	5,041	2,888	134	0	0
Buses	517	196	196	-321	-62	0	0
Power Generation	0	0	1,105	0	0	1,105	N/A
TOTAL	13,057	15,551	13,696	2,494	19	-1,855	-12

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.1-4 NO_x Emissions in the Project Corridor by Transportation Mode by State

a) Connecticut

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	4,680	3,976	3,894	-704	-15	-82	-2
Aircraft	34	34	34	0	0	0	0
Amtrak	909	1,033	0	124	14	-1,033	-100
Other Trains	505	1,404	1,404	899	178	0	0
Buses	236	89	89	-147	-62	0	0
Power Generation	0	0	517	0	0	517	N/A
TOTAL	6,364	6,536	5,938	172	3	-598	-9

TABLE 7.1-4 NO_x Emissions in the Project Corridor by Transportation Mode (continued)

b) Rhode Island

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	1,444	925	906	-519	-36	-19	-2
Aircraft	87	84	45	-3	-3	-39	-46
Amtrak	576	655	0	79	14	-655	-100
Other Trains	80	665	665	585	731	0	0
Buses	52	21	21	-31	-60	0	0
Power Generation	0	0	295	0	0	295	N/A
TOTAL	2,239	2,350	1,932	111	5	-418	-18

c) Massachusetts

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	1,488	1,267	1,244	-221	-15	-23	-2
Aircraft	700	1,807	1,231	1,107	158	-576	-32
Amtrak	469	533	0	64	14	-533	-100
Other Trains	1,568	2,972	2,972	1,404	90	0	0
Buses	229	86	86	-143	-62	0	0
Power Generation	0	0	293	0	0	293	N/A
TOTAL	4,454	6,665	5,826	2,211	50	-839	-13

Source: K. M. Chng Environmental Inc., 1994

generation. The new emissions of 81 kg/day from power generation, however, represent less than 1 percent of the total NEC emissions in the 2010 Proposed Action. Compared with the corresponding No-Build emissions, CO emissions in the NEC with the Proposed Action are approximately 4 percent lower.

State-by-State Inventories. Table 7.1-6 presents project-related CO emissions separately for each state for the 1992 existing, the 2010 Proposed Action, and the 2010 No-Build Alternative. These data show that, in each state, CO emissions for the 2010 Proposed Action are estimated to be lower than the corresponding emissions for the 2010 No-Build Alternative.

CO emissions in Connecticut for the Proposed Action are 13,399 kg/day, which is approximately 2 percent lower than the corresponding emissions for the No-Build Alternative. The proposed project would be consistent with the Connecticut SIP provision to achieve and maintain the state's CO standards because it is not expected to result in a new violation or exacerbate an existing violation of the CO standards in the New Haven CO nonattainment area (see Table 7.1-6a).

In Rhode Island, CO emissions for the No-Build Alternative are estimated at 2,948 kg/day versus 2,780 kg/day for the Proposed Action, a reduction of 6 percent. Since the estimated emissions for the Proposed Action are less than the predicted emissions from the No-Build Alternative, this project would be consistent with the Rhode Island SIP provision to achieve and maintain the state's CO standards. Rhode Island would have 168 kg/day less CO emissions due to the proposed project (see Table 7.1-6b).

CO emissions in Massachusetts for the Proposed Action and No-Build Alternative are shown in Table 7.1-6c. The CO emissions for the Proposed Action are estimated to be lower than the corresponding emissions for the No-Build Alternative (5,454 kg/day versus 5,965 kg/day or 9 percent). Therefore, this project is consistent with the Massachusetts SIP provision to attain and maintain the state's CO standards because it is not expected to cause a new violation or exacerbate an existing violation of the state's CO standards in the Boston CO nonattainment area.

7.1.2(d) Sulfur Dioxide

Corridorwide Inventory. SO_2 emissions in 1992 from transportation sources in the NEC were estimated at 928 kilograms per day (kg/day). Diesel locomotives and automobiles are the primary sources of such emissions (see Table 7.1-7).

Between 1992 and 2010 with a No-Build Alternative, SO_2 emissions from all modes of travel (except buses) are expected to increase, with total corridorwide emissions increasing by over 50 percent. This is due in part to the increases in travellers (and thus additional scheduled aircraft and train trips) along the corridor, and in part to the absence of SO_2 emissions control equipment on any of the sources. Emissions from non-Amtrak diesel powered locomotives make up almost half of the total corridorwide emissions under the 2010 No-Build Alternative, with Amtrak locomotives and automobiles each making up about 22 percent of the corridorwide total of 1,403 kg/day (see Table 7.1-7). With the No-Build Alternative in 2010, vehicle-miles-traveled (VMTs) in the NEC are projected to increase, and, since there are no Federally mandated controls for decreasing SO_2 emissions from automobiles, emissions from automobiles also increase.

The Proposed Action is expected to increase total SO_2 emissions in the NEC by 849 kg/day, a 61 percent increase over the No-Build emissions. Reductions in emissions occur due to the elimination of the Amtrak diesel powered locomotives and due to passenger modal shifts from aircraft and automobiles to trains. With the proposed electrification, a new source of emissions associated with power generation (to provide the electrical power for the trains) is introduced. The estimated 1,184 kg/day of SO_2 from this source is quite significant and represents over half of the 2,252 kg/day associated with the electrification project.

TABLE 7.1-5 CO Emissions in the Project Corridor by Transportation Mode

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	38,886	20,208	19,801	-18,678	-48	-407	-2
Aircraft	1,820	1,665	1,180	-155	-9	-485	-29
Amtrak[1]	172	196	0	24	14	-196	-100
Other Trains[1]	190	442	442	252	133	0	0
Buses	151	129	129	-22	-15	0	0
Power Generation[2]	0	0	81	0	0	81	N/A
TOTAL	41,219	22,640	21,633	-18,579	-45	-1,007	-4

Notes: [1]SO_2 emissions based on 0.5 percent sulfur in the diesel fuel.
[2]SO_2 emissions based on 1.0 percent sulfur in Number 6 fuel oil.

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.1-6 CO Emissions in the Project Corridor by Transportation Mode by State

a) Connecticut

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	23,836	13,352	13,077	-10,484	-44	-275	-2
Aircraft	102	102	102	0	0	0	0
Amtrak[1]	80	91	0	11	14	-91	-100
Other Trains[1]	45	123	123	78	173	0	0
Buses	69	59	59	-10	-14	0	0
Power Generation[2]	0	0	38	0	0	38	N/A
TOTAL	24,132	13,727	13,399	-10,405	-43	-328	-2

TABLE 7.1-6 CO Emissions in the Project Corridor by Transportation Mode (continued)

b) Rhode Island

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	7,470	2,601	2,546	-4,869	-65	-55	-2
Aircraft	403	218	141	-185	-46	-77	-35
Amtrak[1]	51	58	0	7	14	-58	-100
Other Trains[1]	7	58	58	51	729	0	0
Buses	15	13	13	-2	-13	0	0
Power Generation[2]	0	0	22	0	0	22	N/A
TOTAL	7,946	2,948	2,780	-4,998	-63	-168	-6

c) Massachusetts

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	7,580	4,255	4,178	-3,325	-44	-77	-2
Aircraft	1,315	1,345	937	30	2	-408	-30
Amtrak[1]	41	47	0	6	15	-47	-100
Other Trains[1]	138	261	261	123	89	0	0
Buses	67	57	57	-10	-15	0	0
Power Generation[2]	0	0	21	0	0	21	N/A
TOTAL	9,141	5,965	5,454	-3,176	-35	-511	-9

Notes: [1]SO_2 emissions based on 0.5 percent sulfur in the diesel fuel.
[2]SO_2 emissions based on 1.0 percent sulfur in Number 6 fuel oil.

Source: K. M. Chng Environmental Inc., 1994

State-by-State Inventories. Table 7.1-8 presents project related SO_2 emissions separated by state for the 1992 Existing, the 2010 No-Build, and the 2010 Build Alternatives. This data shows that, in each state, SO_2 emissions for the Build Condition are estimated to be higher than the corresponding emissions for the No-Build Condition.

Project related SO_2 emissions in Connecticut for the Proposed Action in 2010 of 944 kg/day are higher than the corresponding emissions for the 2010 No-Build Alternative of 536 kg/day (see Table 7.1-8a). Although this represents a 76 percent increase in emissions over the No-Build Alternative, there is no requirement in the SIP for transportation project related Build emissions of SO_2 to be less than No-Build emissions.

In Rhode Island, SO_2 emissions for the Proposed Action are estimated to be higher than the corresponding emissions for the No-Build Alternative (469 kg/day versus 246 kg/day), an increase of 91 percent (see Table 7.1-8b). Although the estimated SO_2 emissions for the Proposed Action are higher than the predicted emissions for the No-Build Alternative, this project is consistent with the Rhode Island SIP, as there is no requirement in the SIP for transportation project related Build emissions of SO_2 to be less than No-Build emissions.

SO_2 emissions in Massachusetts in 2010 for the No-Build Alternative are estimated to be 621 kg/day compared with 839 kg/day for the Proposed Action (see Table 7.1-8c). Although this is an increase of 35 percent, there is no requirement in the SIP for transportation project related Build emissions of SO_2 to be less than No-Build emissions.

TABLE 7.1-7 SO_2 Emissions in the Project Corridor by Transportation Mode

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	287	307	301	20	7	-6	-2
Aircraft	51	76	52	25	49	-24	-32
Amtrak	268	305	0	37	14	-305	-100
Other Trains	296	693	693	397	134	0	0
Buses	26	22	22	-4	-15	0	0
Power Generation	0	0	1,184	0	0	1,184	N/A
TOTAL	928	1,403	2,252	475	51	849	61

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.1-8 SO_2 Emissions in the Project Corridor by Transportation Mode by State

a) Connecticut

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	178	189	185	11	6	-4	-2
Aircraft	2	2	2	0	0	0	0
Amtrak	125	142	0	17	14	-142	-100
Other Trains	69	193	193	124	180	0	0
Buses	12	10	10	-2	-17	0	0
Power Generation	0	0	554	0	0	554	N/A
TOTAL	386	536	944	150	39	408	76

TABLE 7.1-8 SO_2 Emissions in the Project Corridor by Transportation Mode (continued)

b) Rhode Island

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	52	58	57	6	12	-1	-2
Aircraft	6	5	3	-1	-17	-2	-40
Amtrak	79	90	0	11	14	-90	-100
Other Trains	11	91	91	80	727	0	0
Buses	3	2	2	-1	-33	0	0
Power Generation	0	0	316	0	0	316	N/A
TOTAL	151	246	469	95	63	223	91

c) Massachusetts

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	57	60	59	3	5	-1	-2
Aircraft	43	69	47	26	60	-22	-32
Amtrak	64	73	0	9	14	-73	-100
Other Trains	216	409	409	193	89	0	0
Buses	11	10	10	-1	-9	0	0
Power Generation	0	0	314	0	0	314	N/A
TOTAL	391	621	839	230	59	218	35

Source: K. M. Chng Environmental Inc., 1994

7.2 AIR QUALITY ANALYSIS BASED ON REVISED FUEL MIX ASSUMPTIONS

In response to comments received on the DEIS/R, this section provides the results of the evaluation of air quality impacts of the 2010 Proposed Action and the No-Build Alternative - AMD-103 Scenario, with the Proposed Action evaluated based on an alternative set of fuel mix assumptions for energy consumption. This alternative fuel mix included electricity generated from coal-fired power plants, in addition to the previous sources using oil and natural gas.

An emission inventory analysis was performed to identify operational impacts based on the revised energy consumption data (see Chapter 6 of this volume). The emission inventory analysis is comprised of estimates of VOC, NO_x, and CO emission levels attributable to project-related sources. An assessment is made of the impacts of the proposed project by comparing the emission inventories under the Proposed Action with the alternate fuel mix assumption to the No-Build Alternative - AMD-103 Scenario, in accordance with the requirements of the SIPs. Sources include the proposed Amtrak trains, other trains, automobiles, aircraft, buses, and power plants. Section 10.3.3.1 of Volume III of the DEIS/R describes in detail how the estimates are made. The results presented below describe this analysis for the Proposed Action and No-Build Alternative (AMD-103 Scenario).

7.2.1 Evaluation Criteria

The significance of air quality impacts due to the revised energy analysis (based on an alternative fuel mix) were assessed for compliance with emissions limits required by the SIPs. The SIPs require that transportation projects not result in increased VOC, NO_x, or CO emissions over the No-Build Alternative. Any increase in emissions generated by the proposed project over the 2010 No-Build condition is considered a significant impact and would not be in compliance with the SIP requirements.

7.2.2 Emission Inventory Analysis

The impacts of the alternatives are discussed with respect to projected VOC, NO_x, and CO emissions for the entire NEC. A description of the methods and components of this analysis is provided in Section 10.3.3 of Volume III of the DEIS/R.

In addition to the emissions sources described in Section 10.3.3 of Volume III of the DEIS/R, this inventory includes electrical power necessary to run the proposed electrified Amtrak service. Electrical power necessary to run the electrified rail corridor was translated into energy needs and fuel use equivalents. Fuel use was distributed by fuel type using an alternative fuel mix (including coal-fired power plants) so that appropriate emission factors could be used to estimate the anticipated emissions from the proposed power plants along the NEC. Emission factors for these sources were taken from EPA's Compilation of Air Pollutant Emissions Factors[1] and combined with the fuel use data to obtain power plant emissions.

7.2.2(a) Volatile Organic Compounds

Table 7.2-1 presents the air quality impact analysis for VOCs. The electrification project, based on the alternative fuel mix assumption, is expected to reduce total VOCs in the NEC by 200 kg/day, or a savings of 5 percent from the emissions of the No-Build Alternative. This reduction is due in part to the elimination of the Amtrak diesel locomotives, and in part to modal shifts from aircraft and automobiles to trains. With the proposed electrification, a new source of emissions associated with power generation (to provide the electrical power for the train) is introduced. But the estimated 9 kg/day of VOCs from this source (using the alternative fuel mix assumption) is quite minimal when measured against the total of 3,789 kg/day. Therefore, the proposed electrification would be beneficial to air quality and is consistent with the individual states' SIP provisions to achieve the ozone standard in the ozone nonattainment areas.

7.2.2(b) Oxides of Nitrogen

The proposed electrification project would eliminate over 2,200 kg/day of NO_x emissions in the NEC due to a switch by Amtrak from diesel-powered locomotives to the proposed electrically powered locomotives (see Table 7.2-2). The proposed project would further reduce emissions by another 739 kg/day by diverting automobile and aircraft travelers to trains. These savings, however, are partially offset by a new source of emissions from power generation. Compared with the corresponding No-Build Alternative's emissions, NO_x emissions in the NEC with the Proposed Action (using the alternative fuel mix assumption) are approximately 1,578 kg/day or 10 percent lower. Therefore, the proposed electrification is not expected to cause or contribute to a violation of any of the states' annual NO_2 standards.

7.2.2(c) Carbon Monoxide

The proposed electrification is expected to reduce the total CO emissions in the NEC by 908 kg/day overall (see Table 7.2-3). This reduction is due in part to the elimination of the Amtrak diesel locomotives (a savings of 196 kg/day), and in part to the projected diversion from automobiles to trains (a savings of 407 kg/day) and from a reduction in aircraft flights (a savings of 485 kg/day). No diversion is anticipated from intercity buses to rail. The proposed electrification would, however, introduce a new source of CO associated with power generation. The new emissions of 180 kg/day from power generation, based on the alternative fuel mix assumption, are more than offset by the savings from the use of the electrified locomotives. Compared with the corresponding No-Build Alternative's emissions, CO emissions in the NEC with the Proposed Action are approximately 4 percent lower. Therefore, the proposed electrification is not expected to cause a new violation or exacerbate an existing violation of any of the states' CO standards.

TABLE 7.2-1 VOC Emissions in the Project Corridor by Transportation Mode, Alternative Fuel Mix Analysis

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	5,595	3,417	3,348	-2,178	-39	-69	-2
Aircraft	679	328	256	-351	-52	-72	-22
Amtrak	60	68	0	8	13	-68	-100
Other Trains	66	154	154	88	133	0	0
Buses	32	22	22	-10	-31	0	0
Power Generation	0	0	9	0	0	9	N/A
TOTAL	6,432	3,989	3,789	-2,443	-38	-200	-5

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.2-2 NO_x Emissions in the Project Corridor by Transportation Mode, Alternative Fuel Mix Analysis

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	7,612	6,168	6,044	-1,444	-19	-124	-2
Aircraft	821	1,925	1,310	1,104	134	-615	-32
Amtrak	1,954	2,221	0	267	14	-2,221	-100
Other Trains	2,153	5,041	5,041	2,888	134	0	0
Buses	517	196	196	-321	-62	0	0
Power Generation	0	0	1,382	0	0	1,382	N/A
TOTAL	13,057	15,551	13,973	2,494	19	-1,578	-10

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.2-3 CO Emissions in the Project Corridor by Transportation Mode, Alternative Fuel Mix Analysis

SOURCE	1992 EXISTING kg/day	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS			
				Existing to No-Build		No-Build to Proposed Action	
				kg/day	% change	kg/day	% change
Auto	38,886	20,208	19,801	-18,678	-48	-407	-2
Aircraft	1,820	1,665	1,180	-155	-9	-485	-29
Amtrak	172	196	0	24	14	-196	-100
Other Trains	190	442	442	252	133	0	0
Buses	151	129	129	-22	-15	0	0
Power Generation	0	0	180	0	0	180	N/A
TOTAL	41,219	22,640	21,732	-18,579	-45	-908	-4

Source: K. M. Chng Environmental Inc., 1994

7.3 AIR QUALITY ANALYSIS FOR FREIGHT TRUCKS

In response to comments received on the DEIS/R, this section provides the results of the evaluation of air quality impacts for two scenarios of freight shifting from rail to truck (See Chapter 3 of this volume for a detailed description of this subject.). Two scenarios were assessed for 2010: (1) a mode shift of 25 percent of freight being hauled by trucks, and (2) a mode shift of 50 percent of freight being hauled by trucks. These comments were based upon a concern that increased use of the NEC main line by Amtrak, absent measures to increase capacity, could adversely affect the quality and cost of freight rail service provided along the NEC. As discussed in Section 3.1, increases in passenger train traffic would not be the result of the electrification project per se but rather from the NECIP program as a whole and state efforts to increase commuter service. Consequently, the potential for impacts as a result of possible diversion of rail freight to trucks exists with the No-Build Alternative - FF-125 and FRA-150 scenarios as well as with the Proposed Action.

To address the potential for impacts of the Proposed Action on other users of the NEC main line, including freight service, Section 5.1.1(i) of Volume I of the FEIS/R includes a number of measures in the preferred alternative to mitigate potential impact. A simulation conducted for FRA concludes that, with these measures, the year 2010 freight service can be adequately accommodated on the upgraded and electrified Corridor. As a consequence, such impacts are not expected to occur as a result of the Proposed Action. The following discussion is presented, however, to show the basis for FRA's decision to mitigate these potential impacts.

An emission inventory analysis was performed to identify operational impacts based on the two scenarios described above. The emission inventory analysis is comprised of estimates of VOC, NO_x, and CO emission levels attributable to project-related sources. An assessment was made of the impacts of the proposed project by comparing the emission inventories under the Proposed Action with freight borne by trucks to the No-Build Alternative - AMD-103 Scenario, in accordance with the requirements of the SIPs. Project-related sources include the proposed Amtrak trains, other trains, automobiles, aircraft, buses, power plants, and freight trucks. Section 10.3.3.1 of Volume III of the DEIS/R describes in detail how the estimates are made. Freight truck emissions are calculated using the assumptions used for intercity buses, i.e., that freight trucks are powered by heavy duty diesel engines. The results presented below describe this analysis for the Proposed Action and the No-Build Alternative - AMD-103 Scenario.

7.3.1 Evaluation Criteria

The air quality impacts due to the revised freight assumptions were assessed for compliance with emission limits required by the SIPs. The SIPs require that transportation projects not result in increased VOC, NO_x, or CO emissions over the No-Build condition. Any increase in emissions generated by the proposed project over the 2010 No-Build condition is considered a significant impact and would not be in compliance with the SIP requirements.

7.3.2 Emission Inventory Analysis for the 25 Percent Mode Shift

The impact of the 25 percent mode shift of freight is discussed with respect to projected VOC, NO_x, and CO emissions for the entire NEC assuming an 8.8 percent growth in freight traffic between 1994 and 2010. A description of the methods and components of this analysis is provided in Section 10.3.3 of Volume III of the DEIS/R.

7.3.2(a) Volatile Organic Compounds

Table 7.3.3 presents the air quality impact analysis for VOCs if increased use of the NEC main line by passenger trains (intercity and commuter) were to lead to a 25 percent diversion of rail freight to trucks. VOC emissions could increase by 17 kg/day; however, this increase would not significantly offset the total VOC reduction from the proposed electrification project. Although the benefit would be smaller, the proposed electrification would still be consistent with the individual states' SIP provisions to achieve the ozone standard in the ozone nonattainment areas.

7.3.2(b) Oxides of Nitrogen

Table 7.3.2 presents the air quality impact analysis for NO_x if increased use of the NEC main line by passenger trains (intercity and commuter) were to lead to a 25 percent diversion of rail freight to trucks. NO_x emissions could increase by 143 kg/day; however, this increase would not significantly offset the NO_x reduction from the proposed electrification project. Although the benefit would be smaller, the project would remain consistent with the individual states' SIP provisions.

7.3.2(c) Carbon Monoxide

Table 7.3.3 presents the air quality impact analysis for CO if increased use of the NEC main line by passenger trains (intercity and commuter) were to lead to a 25 percent diversion of rail freight to trucks. CO emissions could increase by 94 kg/day; however, this increase would not significantly offset the CO reduction from the proposed electrification project. Although the benefit would be smaller, the proposed electrification would still be consistent with the individual states' SIP provisions.

TABLE 7.3-1 VOC Emissions in the Project Corridor by Transportation Mode, 25 Percent Modal Shift

SOURCE	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS No-Build to Proposed Action	
			kg/day	% change
Auto	3,417	3,348	-69	-2
Freight Trucks	--	17	17	N/A
Aircraft	328	256	-72	-22
Amtrak	68	0	-68	-100
Other Trains	154	154	0	0
Buses	22	22	0	0
Power Generation	0	7	7	N/A
TOTAL			-185	

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.3-2 NO_x Emissions in the Project Corridor by Transportation Mode, 25 Percent Modal Shift

SOURCE	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS No-Build to Proposed Action	
			kg/day	% change
Auto	6,168	6,044	-124	-2
Freight Trucks	--	143	143	N/A
Aircraft	1,925	1,310	-615	-32
Amtrak	2,221	0	-2,221	-100
Other Trains	5,041	5,041	0	0
Buses	196	196	0	0
Power Generation	0	1,105	1,105	N/A
TOTAL			-1,712	

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.3-3 CO Emissions in the Project Corridor by Transportation Mode, 25 Percent Modal Shift

SOURCE	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS No-Build to Proposed Action	
			kg/day	% change
Auto	20,208	19,800	-407	-2
Freight Trucks	--	94	94	N/A
Aircraft	1,665	1,180	-485	-29
Amtrak	196	0	-196	-100
Other Trains	442	442	0	0
Buses	129	129	0	0
Power Generation	0	81	81	N/A
TOTAL			-913	

Source: K. M. Chng Environmental Inc., 1994

7.3.3 Emission Inventory Analysis for the 50 Percent Mode Shift

The impact of the 50 percent mode shift of freight is discussed with respect to projected VOC, NO_x, and CO emissions for the entire NEC assuming an 8.8 percent growth in freight traffic between 1994 and 2010. The methods and components of this analysis are the same as were used in the 25 percent mode shift alternative described above, and, as expected, the results show higher increases of emissions than were found for the 25 percent mode shift.

7.3.3(a) Volatile Organic Compounds

Table 7.3.4 presents the air quality impact analysis for VOCs if increased use of the NEC main line by passenger trains (intercity and commuter) were to lead to a 50 percent shift of rail freight to trucks. VOC emissions could increase by 33 kg/day; however this increase would not significantly offset the VOC reduction from the proposed electrification project. Although the benefit would be smaller, the proposed electrification would remain consistent with the individual states' SIP provisions to achieve the ozone standard in the ozone nonattainment areas.

TABLE 7.3-4 VOC Emissions in the Project Corridor by Transportation Mode, 50 Percent Modal Shift

SOURCE	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS No-Build to Proposed Action	
			kg/day	% change
Auto	3,417	3,348	-69	-2
Freight Trucks	--	33	33	N/A
Aircraft	328	256	-72	-22
Amtrak	68	0	-68	-100
Other Trains	154	154	0	0
Buses	22	22	0	0
Power Generation	0	7	7	N/A
TOTAL			-169	

Source: K. M. Chng Environmental Inc., 1994

7.3.3(b) Oxides of Nitrogen

Table 7.3.5 presents the air quality impact analysis for NO_x if increased use of the NEC main line by passenger trains (intercity and commuter) were to lead to a 50 percent shift of rail freight to trucks. NO_x emissions could increase by 285 kg/day; however, this increase would not significantly offset the NO_x reduction from the proposed electrification project, Although the benefit would be smaller, the project would still be consistent with the individual states' SIP provisions.

7.3.3(c) Carbon Monoxide

Table 7.3.6 presents the air quality impact analysis for CO if increased use of the NEC main line by passenger trains (intercity and commuter) were to lead to a 50 percent shift of rail freight to trucks. CO emissions could increase by 188 kg/day more than offsetting the CO reduction from the proposed electrification project. Although the benefit would be smaller, the proposed electrification would remain consistent with the individual states' SIP provisions.

TABLE 7.3-5 NO_x Emissions in the Project Corridor by Transportation Mode, 50 Percent Modal Shift

SOURCE	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS No-Build to Proposed Action	
			kg/day	% change
Auto	6,168	6,044	-124	-2
Freight Trucks	--	285	285	N/A
Aircraft	1,925	1,310	-615	-32
Amtrak	2,221	0	-2,221	-100
Other Trains	5,041	5,041	0	0
Buses	196	196	0	0
Power Generation	0	1,105	1,105	N/A
TOTAL			-1,570	

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.3-6 CO Emissions in the Project Corridor by Transportation Mode, 50 Percent Modal Shift

SOURCE	2010 NO-BUILD AMD-103 kg/day	2010 PROPOSED ACTION kg/day	CHANGE IN EMISSIONS No-Build to Proposed Action	
			kg/day	% change
Auto	20,208	19,800	-407	-2
Freight Trucks	--	188	188	N/A
Aircraft	1,665	1,180	-485	-29
Amtrak	196	0	-196	-100
Other Trains	442	442	0	0
Buses	129	129	0	0
Power Generation	0	81	81	N/A
TOTAL			-819	

Source: K. M. Chng Environmental Inc., 1994

7.4 COMPARISON OF AIR QUALITY IMPACTS FROM PROJECT ALTERNATIVES

This analysis assesses the air quality impacts of three No-Build Alternatives and the Proposed Action. The three No-Build Alternatives are:

- The No-Build Alternative - AMD-103 Scenario: Continuation of the existing operation of diesel-powered trains between Boston and New Haven.
- The No-Build Alternative - FF-125 Scenario: Gas turbine engine-powered or other fossil fuel-powered trains able to achieve speeds of 125 miles per hour.
- The No-Build Alternative - FF-150 Scenario: Gas turbine engine-powered or other fossil fuel-powered trains able to achieve speeds of 150 miles per hour.

7.4.1 Evaluation Criteria

The air quality impacts of the project alternatives were assessed for compliance with Federal and state Ambient Air Quality Standards (AAQS), and emission limits required by the individual SIPs.

The SIPs require that transportation projects not result in increased VOC, NO_x, or CO emissions over the No-Build condition and must comply with the CO AAQS. Any increase in emissions generated by the proposed project over the 2010 No-Build condition is considered a significant impact and would not be in compliance with the SIP requirements. Exacerbation of an existing violation or contributing to a future violation of the CO National AAQS is considered a significant impact and would not be in compliance with the SIP requirements.

7.4.2 Emissions Inventory Analysis

The impact of the No-Build Alternatives are discussed below with respect to projected VOC, NO_x, and CO emissions. The emission inventories are described with respect to the entire NEC. A description of the methods and components of this analysis is provided in Section 10.3.3 of Volume III of the DEIS/R. Emission factors for these sources, except for the No-Build Alternative - FF-125 Scenario, were taken from EPA's Compilation of Air Pollutant Emissions Factors[2,3] and combined with the fuel use data to obtain emissions. Emission factors for the FF-125 gas turbine trains were based on measurements taken from manufacturer's data.[4] Emissions of toxic compounds from diesel-powered locomotives have not been quantified in air quality literature; however, toxic compounds emitted from other diesel-powered vehicles include: acetaldehyde, benzene, ethyl benzine, formaldehyde, toluene, xylenes, 1,3-butadiene, and metals, such as iron, copper, selenium, and platinum.

7.4.2(a) Volatile Organic Compounds

VOC emissions from project-related sources in the NEC for the project alternatives for the 2010 Proposed Action and No-Build Alternative - AMD-103 are presented in Table 7.4-1.

Proposed Action. The electrification project is expected to reduce total VOCs in the NEC by 202 kg/day, or a savings of 5 percent over the AMD-103 No-Build emissions. This reduction is due in part to the elimination of the Amtrak diesel locomotives, and in part to modal shifts from aircraft and automobiles. With the proposed electrification, a new source of emissions associated with power generation (to provide the electrical power for the train) is introduced. But the estimated 7 kg/day of VOCs from this source is quite minimal when measured against the total of 3,787 kg/day.

No-Build Alternative - AMD-103 Scenario. VOC emissions from the No-Build Alternative - AMD-103 Scenario were estimated at 3,989 kg/day. Automobiles and aircraft are the primary sources of these emissions, representing over 93 percent of the total VOC emissions. Amtrak trains would represent about 2 percent (68 kg/day) of corridorwide VOC emissions for this scenario.

No-Build Alternative - FF-125 Scenario. VOC emissions from the No-Build Alternative - FF-125 Scenario were estimated to be 3,949 kg/day. Automobiles and aircraft are again among the primary sources of these emissions; however, the Amtrak FF-125 trains would emit about 129 kg/day (about twice the AMD-103 emissions), and would represent about 3 percent of corridorwide VOC emissions. This increase in FF-125 VOC emissions is due to the higher fuel consumption levels estimated by FRA and Amtrak for this scenario.

7.4.2(b) Oxides of Nitrogen

NO_x emissions from project-related sources in the NEC for the project alternatives for the 2010 Proposed Action and No-Build Alternative are presented in Table 7.4-2.

Proposed Action. The proposed electrification would eliminate over 2,200 kg/day of NO_x emissions in the NEC due to a switch by Amtrak from diesel-powered locomotives to the proposed electrically powered locomotives. The proposed project would further reduce emissions by another 739 kg/day by diverting automobile and aircraft travelers to the train. These savings, however, are partially offset by a new source of emissions from power generation. Compared with the AMD-103 emissions, corridorwide NO_x emissions with the Proposed Action would be reduced by approximately 1,855 kg/day or 12 percent.

TABLE 7.4-1 Comparison of Estimated Daily VOC Emissions by Source Type

SOURCE	2010 NO-BUILD AMD-103 kg/day	2010 NO-BUILD FF-125 kg/day	2010 PROPOSED ACTION kg/day
Auto	3,417	3,382	3,348
Aircraft	328	262	256
Amtrak	68	129	0
Other Trains	154	154	154
Buses	22	22	22
Power Generation	0	0	7
TOTAL	3,989	3,949	3,787

Source: K. M. Chng Environmental Inc., 1994

TABLE 7.4-2 Comparison of Estimated Daily NO_x Emissions by Source Type

SOURCE	2010 NO-BUILD AMD-103 kg/day	2010 NO-BUILD FF-125 kg/day	2010 PROPOSED ACTION kg/day
Auto	6,168	6,105	6,044
Aircraft	1,925	1,427	1,310
Amtrak	2,221	1,276	0
Other Trains	5,041	5,041	5,041
Buses	196	196	196
Power Generation	0	0	1,105
TOTAL	15,551	14,045	13,696

Source: K. M. Chng Environmental Inc., 1994

No-Build Alternative - AMD-103 Scenario. NO_x emissions from the No-Build Alternative - AMD-103 Scenario were estimated at 15,551 kg/day. Diesel-powered trains are the primary sources of these emissions, contributing about 7,262 kg/day (47 percent) of the total NO_x emissions. Amtrak trains alone represent about 14 percent (2,221 kg/day) of corridorwide NO_x emissions for this scenario.

No-Build Alternative - FF-125 Scenario. NO_x emissions from the No-Build Alternative - FF-125 Scenario were estimated to be 14,045 kg/day. The Amtrak FF-125 trains emit about 1,276 kg/day (about one-half of the NO_x emissions from the AMD-103), and would represent about 9 percent of corridorwide NO_x emissions. This noticeable reduction in FF-125 NO_x emissions, when compared to NO_x emissions from the AMD-103, is due to the very low NO_x emission rate achievable with this technology.

7.4.2(c) Carbon Monoxide

CO emissions from project-related sources in the NEC for the 2010 Proposed Action and the No-Build Alternative are presented in Table 7.4-3.

Proposed Action. The proposed electrification is expected to reduce the total CO emissions in the NEC by 1,007 kg/day compared with the CO emissions from the No-Build Alternative - AMD-103 Scenario. This reduction is due in part to the elimination of the Amtrak diesel locomotives (a savings of 196 kg/day), and in part to the projected diversion from automobiles (a savings of 407 kg/day) and from aircraft (a savings of 485 kg/day). The new emissions of 81 kg/day from power generation, however, will represent less than 1 percent of the total NEC emissions for the Proposed Action. Compared with the AMD-103 No-Build emissions, CO emissions in the NEC with the Proposed Action are approximately 4 percent lower.

No-Build Alternative - AMD-103 Scenario. CO emissions from the No-Build Alternative - AMD-103 Scenario were estimated at 22,640 kg/day. Automobiles are the primary source of these emissions, contributing 20,208 kg/day or almost 90 percent to the total CO emissions. Amtrak trains would represent less than 1 percent (196 kg/day) of corridorwide CO emissions for this scenario.

No-Build Alternative - FF-125 Scenario. CO emissions from the No-Build Alternative - FF-125 Scenario were estimated to be 22,240 kg/day. Automobiles are again the primary source of these emissions, with almost 90 percent (19,998 kg/day) of the total corridorwide CO emissions. The Amtrak FF-125 trains would emit about 423 kg/day, which represents about 2 percent of corridorwide CO emissions. This increase in FF-125 CO emissions is due to the higher fuel consumption levels estimated by FRA and Amtrak for this scenario. The 423 kg/day of CO emissions from the FF-125 are about twice the CO emissions compared with the AMD-103 CO emissions.

TABLE 7.4-3 Comparison of Estimated Daily CO Emissions by Source Type

Source	2010 NO-BUILD AMD-103 kg/day	2010 NO-BUILD FF-125 kg/day	2010 PROPOSED ACTION kg/day
Auto	20,208	19,998	19,801
Aircraft	1,665	1,248	1,180
Amtrak	196	423	0
Other Trains	442	442	442
Buses	129	129	129
Power Generation	0	0	81
TOTAL	22,640	22,240	21,633

Source: K. M. Chng Environmental Inc., 1994

7.4.2(d) Sulfur Dioxide

SO_2 emissions from project-related sources in the NEC for the project alternatives for the 2010 Proposed Action and the No-Build Alternatives are presented in Table 7.4-4.

Proposed Action. The electrification project is expected to increase total SO_2 emissions in the NEC by 849 kg/day, an increase of 61 percent over the AMD-103 No-Build emissions. This increase is due to the SO_2 emissions from utility power plants providing power to the project more than offsetting the decreases in emissions from passenger modal shifts from aircraft and automobiles (which total 30 kg/day). Power plant emissions represent over 52 percent (1,184 kg/day) of the total corridorwide SO_2 emissions of 2,252 kg/day.

No-Build Alternative - AMD-103 Scenario. SO_2 emissions from the AMD-103 No-Build Alternative were estimated to be 1,403 kg/day. Non-Amtrak trains are the primary source of SO_2 emissions and represent about 49 percent (693 kg/day) of corridorwide SO_2 emissions; while Amtrak trains and automobiles each represent 22 percent of the total SO_2 emissions of 1,403 kg/day.

No-Build Alternative - FF-125 Scenario. SO_2 emissions from the FF-125 No-Build Alternative are also presented in Table 7.4-4 and were estimated to be 2,930 kg/day. The Amtrak FF-125 trains are the single largest source of SO_2 emissions and would emit about 1,855 kg/day (about six times the emissions from the AMD-103 Alternative). This would represent about 63 percent of corridorwide SO_2 emissions. This increase in FF-125 SO_2 emissions is due to the higher fuel consumption levels estimated by FRA and Amtrak for this alternative. Non-Amtrak trains represent about 24 percent (693 kg/day) and automobiles represent about 10 percent (304 kg/day) of the total SO_2 emissions.

TABLE 7.4-4 Comparison of Estimated Daily SO_2 Emissions by Source Type

Source	2010 NO-BUILD AMD-103 kg/day	2010 NO-BUILD FF-125 kg/day	2010 PROPOSED ACTION kg/day
Auto	307	304	301
Aircraft	76	56	52
Amtrak[1]	305	1,855	0
Other Trains[1]	693	693	693
Buses	22	22	22
Power Generation[2]	0	0	1,184
TOTAL	1,403	2,930	2,252

Notes: [1]SO_2 emissions based on 0.5 percent sulfur in the diesel fuel.
[2]SO_2 emissions based on 1.0 percent sulfur in Number 6 fuel oil.

Source: K. M. Chng Environmental Inc., 1994

No-Build Alternative - FF-150 Scenario. Given the projected 150 mph speeds for this alternative, it would be expected, barring significant advances in fuel efficiency, that this alternative would consume even more fuel than the FF-125 Alternative. Therefore, it is likely, assuming that SO_2 emissions levels would be about the same as for the FF-125 Alternative, that the FF-150 Alternative would have higher SO_2 emissions than the FF-125 Alternative.

7.4.3 Air Quality Impacts of Locomotive Passbys

The purpose of this information is to demonstrate the effect of diesel-powered locomotive passbys on air quality for each of the project alternatives. The impacts of the No-Build Alternatives are discussed below with respect to 1-hour concentrations of CO and NO_2. A description of the methods and components of this analysis is provided in Section 10.3.3 of Volume III of the DEIS/R.

Three prototypical sections of track along the NEC, one in each state through which the project passes, were identified and selected for the modeling analysis. The selection was based on evaluating combinations of train operating characteristics (for example, power settings and train speeds) and the density of nearby sensitive receptors.

The effects of individual locomotive passbys were evaluated to determine what the peak, transitory pollution levels could be under the worst meteorology conditions. The analysis was accomplished by using EPA's INPUFF model[5] and exhaust characteristics for each alternative locomotive

7.4.3(a) Diesel Locomotive Passbys in Sharon, MA

The track section selected for analysis is located between Mileposts 209 and 211 in Sharon, MA. This track section was selected because there are six sensitive receptors in the 2-mile section (one hospital, one funeral home, and four recreation areas). Figure 7.4-1 shows this track section and the sensitive receptors which were modeled. The locomotives maintain an average speed of 95 mph through this section, and there are six locomotives which pass by in the peak hour.

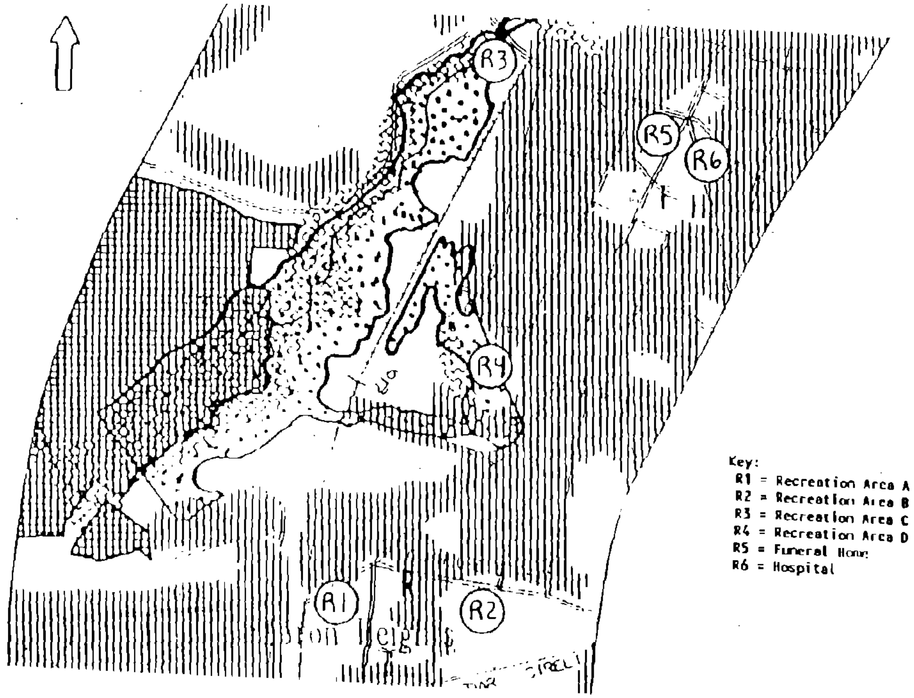
Proposed Action. As all Amtrak locomotives would be electrically powered with the Proposed Action, no CO or NO_2 emissions would occur from these locomotives.

No-Build Alternative - AMD-103 Scenario. The time variation of CO concentrations from an AMD-103 locomotive for a representative location (receptor SR6, a hospital, located at approximately 56 meters from the track) is illustrated in Figure 7.4-2. With the locomotive passby, the CO quickly increases from the background level to a peak level of $3x10^{-3}$ (or 0.003) parts per million (ppm); and just as quickly, the level drops back to background level again. The whole event was estimated to last approximately 120 seconds. No violations of any standards are expected at this exposure. The impacts of individual locomotive passbys in 1 hour were aggregated and the 1-hour average CO concentrations were then estimated. For the same SR6 receptor, the maximum 1-hour CO concentration was estimated to be less than 0.001 ppm above the background.

The time variation of NO_2 associated with a single AMD-103 locomotive passby is illustrated in Figure 7.4-2. The pattern for NO_2 is very similar to the CO pattern. Maximum NO_2 concentration encountered with this passby was estimated at a little over 100 $\mu g/m^3$. No exceedance of any NO_2 standard or health criteria is anticipated. The contributions from individual locomotive passbys were similarly aggregated to estimate the average 1-hour NO_2 concentrations. For the same SR6 location, the maximum 1-hour NO_2 concentration from these passbys was estimated at 8 $\mu g/m^3$. There are no short-term NO_2 standards that mandate compliance. There is, however, a Massachusetts 1-hour policy level of 320 $\mu g/m^3$. This policy level is a health criterion which is used to assess project impacts. The existing 1-hour concentration of 8 $\mu g/m^3$ is far lower than this criterion.

No-Build Alternative - FF-125 Scenario. The time variation of CO concentrations from an FF-125 locomotive for the hospital located at approximately 56 meters from the track is illustrated in Figure 7.4-3. With the locomotive passby, the CO increases from the background level to a peak level of $2.7x10^{-2}$ (or 0.027) ppm; and the level quickly drops back to background level again. The whole event was estimated to last approximately 150 seconds. The impacts of individual locomotive passbys in 1 hour were aggregated and the 1-hour average CO concentrations were then estimated. For the same SR6 receptor, the maximum 1-hour CO concentration was estimated to be less than 1.0 ppm above the background. No violations of any standards are expected at this exposure, even though both the instantaneous and 1-hour CO concentrations are more than a factor of 10 times larger than the impacts from the AMD-103.

The time variation of NO_2 associated with a single FF-125 locomotive passby is also illustrated in Figure 7.4-3. The pattern for NO_2 is very similar to that of CO. Maximum NO_2 concentration encountered with this passby was estimated at a little over 2.4 $\mu g/m^3$. The contributions from individual locomotive passbys were similarly aggregated to estimate the average 1-hour NO_2 concentrations. For the same SR6 location, the maximum 1-hour NO_2 concentration from these passbys was estimated at 0.8 $\mu g/m^3$. There are no short-term NO_2 standards that mandate compliance. There is, however, a Massachusetts 1-hour policy level of 320 $\mu g/m^3$. This policy level is a health criterion which is used to assess project impacts. The existing 1-hour concentration of 8 $\mu g/m^3$ is far lower than this criterion. No exceedance of any NO_2 standard or health criteria is anticipated, since NO_2 levels are less than 10 percent of those from the AMD-103.

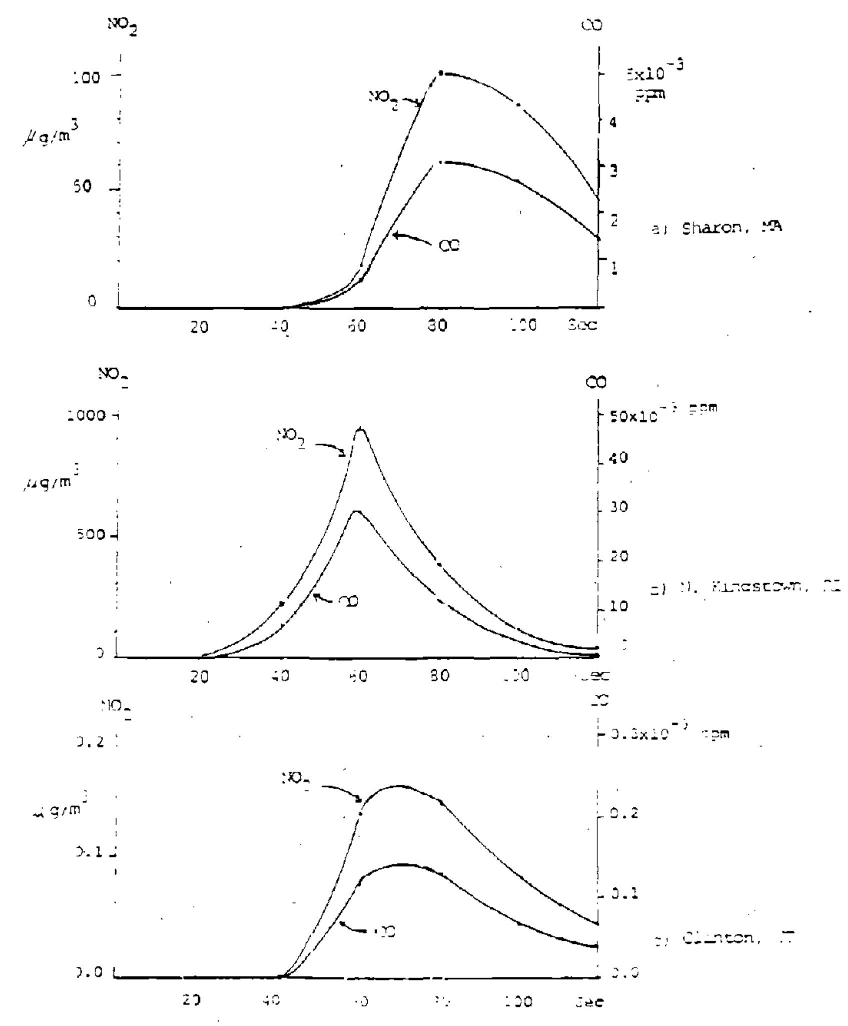


SENSITIVE RECEPTORS AT THE MODELED TRACK SECTION
IN SHARON, MA

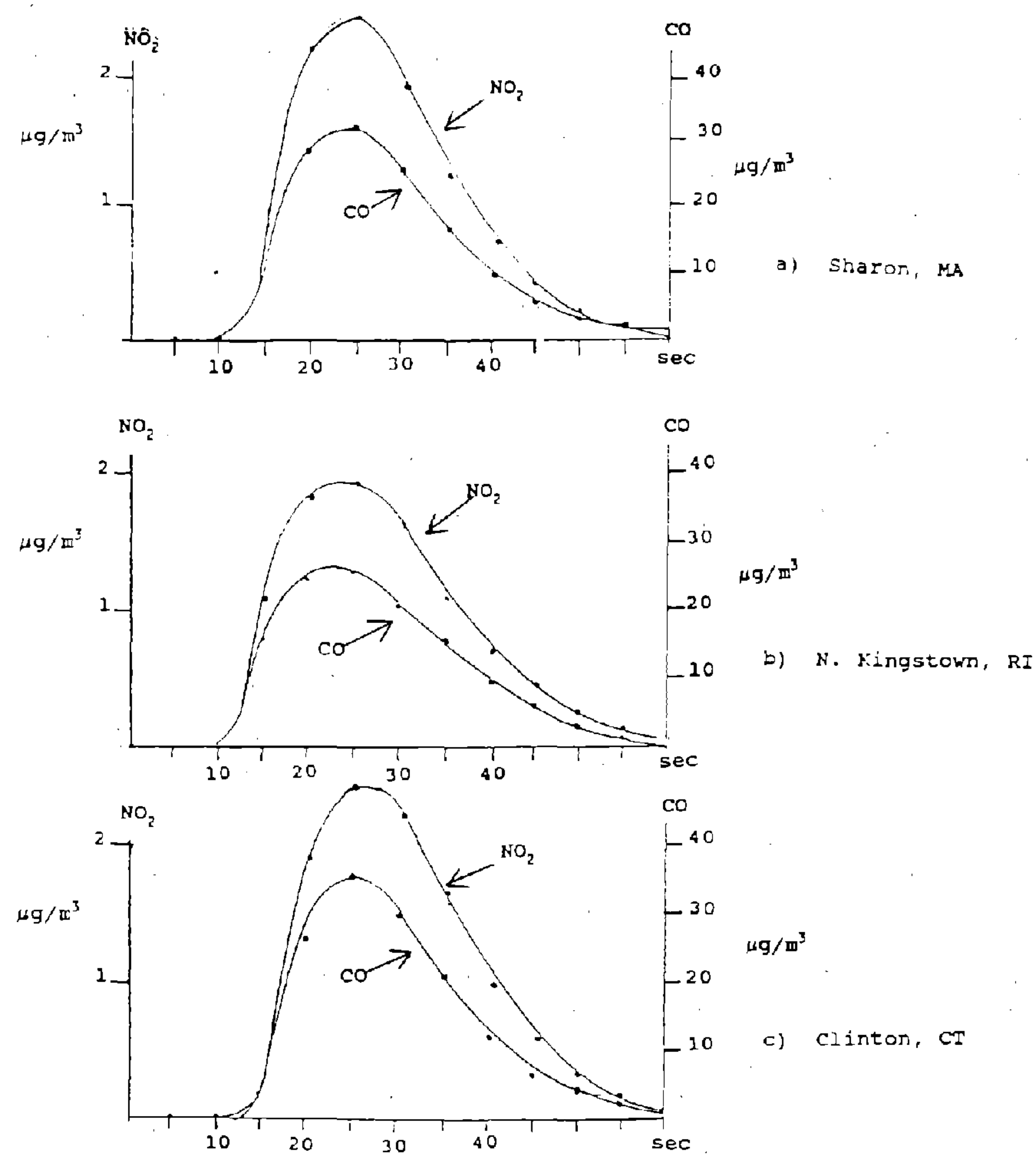
Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

FIGURE
7.4-1

Time Variations of NO_2 and CO at Selected Receptor Locations at Three Track Sections



	TIME VARIATIONS OF NO_2 AND CO AT SELECTED RECEPTOR LOCATIONS AT THREE TRACK SECTIONS, DUE TO AMD - 103 LOCOMOTIVE PASSBYS	FIGURE 7.4-2
	Northeast Corridor Improvement Project Electrification - New Haven CT to Boston MA	



TIME VARIATIONS OF NO_2 AND CO AT SELECTED RECEPTOR LOCATIONS AT THREE TRACK SECTIONS, DUE TO FF - 125 LOCOMOTIVE PASSBYS

FIGURE 7.4-3

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

No-Build Alternative - FRA-150 Scenario. Given the projected 150-mph speeds for this scenario, it would be expected, barring significant advances in fuel efficiency, that it would consume even more fuel than the FF-125. Therefore, it is likely, assuming that CO and NO_2 emissions levels would be about the same as for the FF-125, that the FRA-150 would have higher CO emissions and lower NO_2 emissions; and, therefore, create higher CO and lower NO_2 concentrations than the FF-125. However, these impacts do not appear to be significant enough to violate any CO or NO_2 standards.

7.4.3(b) Diesel Locomotive Passbys in North Kingstown, RI

The track section selected for analysis is located between Milepost 165 and 167 in North Kingstown, RI. This track section was selected because there are 11 sensitive receptors in this 2-mile section (two schools, four churches, two nursing homes, and three recreation areas). Figure 7.4-4 shows this track section and the locations of the sensitive receptors which were modeled. The express locomotives maintain an average speed of approximately 100 mph through this section, and there are four existing locomotives which pass by in the peak hour.

No-Build Alternative - AMD-103 Scenario. The peak, instantaneous CO concentration associated with a single AMD-103 diesel locomotive passby was estimated at approximately 0.03 ppm. As illustrated in Figure 7.4-2, this peak event is not expected to last more than 100 seconds. The maximum 1-hour CO concentration that would result from multiple locomotive passbys in a peak hour was estimated at less the 0.01 ppm above the background, much lower than the 1-hour standard of 35 ppm.

The peak, instantaneous NO_2 concentration due to a single AMD-103 locomotive passby was estimated at a little over 1,000 $\mu g/m^3$. As illustrated in Figure 7.4-2, this event typically lasts no more the 100 seconds. The maximum 1-hour NO_2 concentrations from locomotive passbys were estimated at 41 $\mu g/m^3$.

There are no short-term NO_2 standards or criteria in Rhode Island. However, when compared with other health criteria (such as the Massachusetts' policy level of 320 $\mu g/m^3$), these estimated concentrations are well within the guideline.

No-Build Alternative - FF-125 Scenario. The peak, instantaneous CO concentration associated with a single FF-125 diesel locomotive passby was estimated at approximately 0.2 ppm. As illustrated in Figure 7.4-3, this peak event is not expected to last more than 60 seconds. The maximum 1-hour CO concentration that would result from multiple locomotive passbys in a peak hour was estimated at less the 0.2 ppm above the background. Even though this CO level is much higher than the CO impact from the AMD-103 Alternative, it is still much lower than the 1-hour standard of 35 ppm.

The peak, instantaneous NO_2 concentration due to a single FF-125 locomotive passby was estimated at about 2 $\mu g/m^3$. As illustrated in Figure 7.4-3, this event typically lasts no more the 50 seconds. The maximum 1-hour NO_2 concentrations from locomotive passbys were estimated at 0.02 $\mu g/m^3$. This level is also much lower than the impact from the AMD-130.

There are no short-term NO_2 standards or criteria in Rhode Island. However, when compared with other health criteria (such as the Massachusetts' policy level of 320 $\mu g/m^3$), these estimated concentrations are well within the guideline.

7.4.3(c) Diesel Locomotive Passbys in Clinton, CT

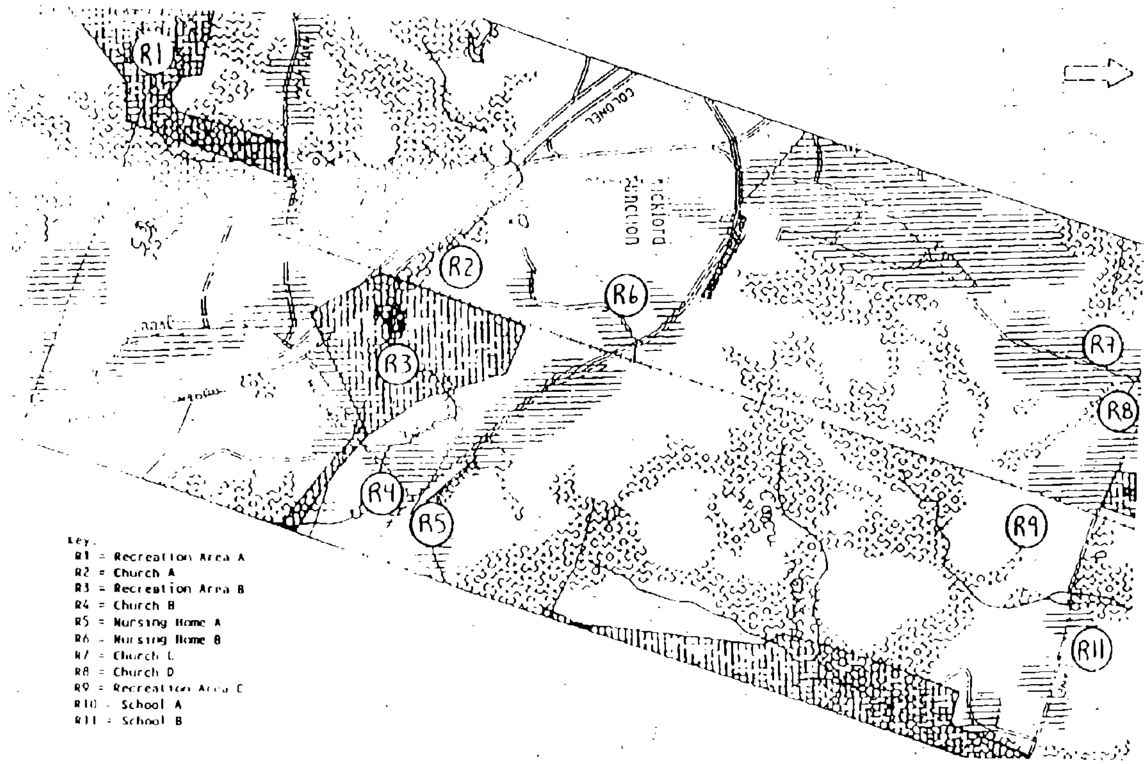
The track section selected for analysis in Connecticut is located between Milepost 96 and 98 in Clinton, CT. This track section was selected because there are 10 sensitive receptors in this 2-mile section (one school, one library, five churches, one funeral home, and two cemeteries). Figure 7.4-5 shows this track section and the locations of the sensitive receptors which were modeled. The express locomotives maintain an average speed of 85 mph through this section, and there are six locomotives which pass by in the peak hour.

No-Build Alternative - AMD-103 Scenario. The peak, instantaneous CO concentration associated with a single AMD-103 locomotive passby was estimated at $3.0x10^{-5}$ ppm. This is a very low concentration and the impact of the passby is negligible. The variation of CO with time for such a passby is illustrated in Figure 7.4-3. The maximum 1-hour CO concentration that results from multiple locomotive passbys was estimated to be less that 0.001 ppm above the background. Relative to the 35-ppm standard, therefore, the impact of these passbys is quite minimal.

The peak, instantaneous NO_2 levels due to a single AMD-103 locomotive passby are shown in Figure 7.4-4. This event typically lasts no more than 120 seconds. The maximum 1-hour NO_2 concentration due to locomotive passbys was estimated at less than 0.1 $\mu g/m^3$. There are no short-term NO_2 standards in Connecticut at this time. When compared with other health criteria (such as the Massachusetts' policy level), these 1-hour NO_2 levels are well within the guidelines.

No-Build Alternative - FF-125 Scenario. The peak, instantaneous CO concentration associated with a single FF-125 locomotive passby was estimated at 0.3 ppm. This is also a low concentration, and the impact of the passby is negligible. The variation of CO with time for such a passby is illustrated in Figure 7.4-4. The maximum 1-hour CO concentration that results from multiple locomotive passbys was estimated to be less that 1.1 ppm above the background. Relative to the 35-ppm standard, therefore, the impact of these passbys is quite minimal, even though both the instantaneous and 1-hour CO concentrations are more than a factor of 10 times larger than the impacts from the AMD-103.

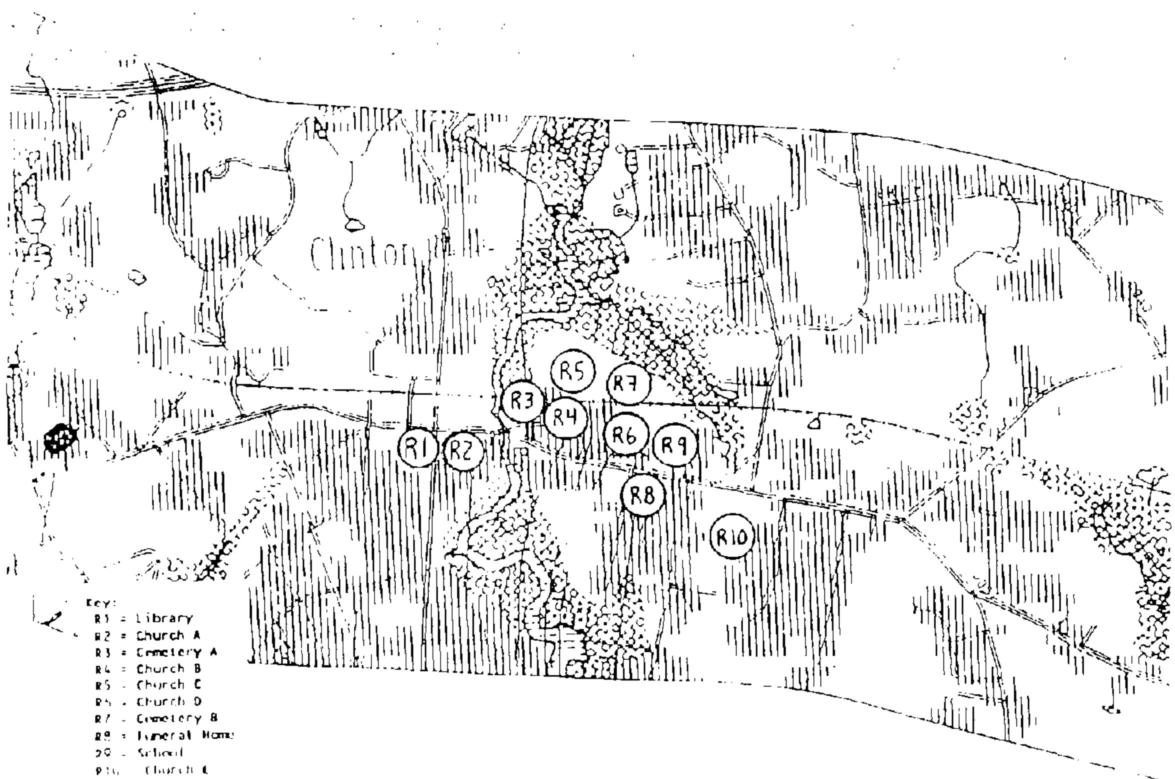
The peak, instantaneous NO_2 levels due to a single FF-125 locomotive passby are also shown in Figure 7.4-3. This event typically lasts no more than 60 seconds and was estimated to be about 3 $\mu g/m^3$. The maximum 1-hour NO_2 concentration due to locomotive passbys was estimated at less than 0.08 $\mu g/m^3$ and only slightly smaller than the impacts from the AMD-103. There are no short-term NO_2 standards in Connecticut at this time. When compared with other health criteria (such as the Massachusetts policy level), these 1-hour NO_2 levels are well within the guidelines.



SENSITIVE RECEPTORS AT THE MODELED TRACK SECTION IN
NORTH KINGSTOWN, RI

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

FIGURE
7.4-4



SENSITIVE RECEPTORS AT THE MODELED TRACK SECTION IN CLINTON, CT

FIGURE 7.4-5

Northeast Corridor Improvement Project
Electrification - New Haven CT to Boston MA

Endnotes

1. *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985.

2. Ibid.

3. *MOBILE4.1 - User's Guide (Mobile Source Emissions Factor Model)*, U.S. Environmental Protection Agency, Ann Arbor, MI, 1991. Revised March 26, 1993 as MOBILE5A.

4. Personal Communication from Pier and Associates (J. R. Pier) to KM Chng Environmental Inc., July 13, 1994.

5. *INPUFF 2.0 - A Multiple Source Gaussian Puff Dispersion Algorithm. User's Guide*, U.S. EPA, Research Triangle Park, NC EPA/600/8-86/024, August 1986. Revised March 28, 1990 as INPUFF 2.3.

CHAPTER 8
NATURAL RESOURCES

This chapter summarizes the anticipated effects of the Proposed Action upon the natural environment within the NEC. The No-Build Alternative scenarios do not involve construction of electrification facilities, modification of bridges, or installation of catenary, and thus are expected to have no impact on the natural resources in the NEC. The focus of this analysis was the construction and operation of the proposed 25 electrification facilities, the construction activities associated with seven bridge modifications, and installation of the catenary at the five moveable bridges. Operations at the bridges would have no long-term impacts on natural resources. This chapter includes an assessment of the projected stormwater runoff from the project and its potential effects on surface water resources, as well as a discussion of the existing drainage situation in the portion of the NEC in Boston between the Arlington/Tremont Streets overhead bridge and South Station. The criteria used to evaluate the project impacts on natural resources are summarized in Table 8.1-1.

8.1 METHODS OF ANALYSIS

8.1.1 Wetlands

Two types of wetlands impacts were considered in this analysis. Direct impacts on wetlands are identified by the encroachment into an area identified as wetlands according to Federal and state regulations, as described in Section 3.12, Volume I. All wetlands noted within 200 feet of a proposed location were identified and delineated according to the standards outlined by the appropriate Federal and state wetland regulations. These regulations include the delineation criteria outlined in the U.S. Army Corps of Engineers 1987 Wetlands Delineation Manual; the Connecticut Tidal Wetlands Act, Section 22a-29; and Section 22a-38 of the Inland Wetlands and Water Courses Act. In Rhode Island, the Department of Environmental Management has sole authority to determine wetland areas; however, for planning purposes, wetland limits were determined by criteria outlined in the Freshwater Wetlands Act. The Massachusetts Wetlands Regulations (310 CMR 10.00) define wetland criteria as well.

Any activity, including dredging, filling, or any alteration of a wetland would be considered to have a direct impact. Potential indirect impacts on wetlands include siltation and sedimentation, as well as runoff of contaminants or changes to salinity levels in tidal wetlands. Potential indirect impacts on wetlands are identified by the location of an activity in the state-regulated setback area from a designated wetland. The setback distance in Massachusetts is 100 feet; in Rhode Island the distance is 50 feet. In Connecticut, local jurisdictions regulate inland wetlands and designate the setback distance, which varies with locality, while Connecticut Department of Environmental Protection (ConnDEP) regulates coastal wetlands and does not identify a setback distance. For the purpose of this analysis, a 100-foot setback distance is utilized to identify potential indirect impact to wetlands in Connecticut.

8.1.2 Critical Wildlife Habitat

For the purpose of this evaluation, any activity, including the construction of facilities, that would result in degradation to wildlife habitat considered to be of high value, will be considered a potential impact on critical habitat. Significant alterations can include impacts to essential wildlife, finfish or shellfish habitats, or population characteristics.

TABLE 8.1-1 Evaluation Criteria for Impacts to Natural Resources

RESOURCE	IMPACT CRITERIA	MEASURE	SIGNIFICANCE THRESHOLD
Wetlands	Alteration[1] or destruction of wetland or resource area[2] including dredge or fill.	Volume or area of wetland or resource area altered or destroyed by the project; change in flow of water into or from a wetland, quantification of any changes in salinity levels of water in the wetland.	Violation of Federal or state limitations.
	Effect of project on functional value[1] of wetlands or resource area.[2]	Potential for altering character of wetland; project-generated change in functional value of wetland.	Any alteration or adverse impact on functions or areas subject to protection.
Critical Wildlife Habitat	Effect of project on wildlife habitat (including wetlands), resources, migration, and critical life stages (breeding, nesting, spawning, and migration).	Amount, functional value, and regional scarcity of wildlife habitat; project-generated change of carrying capacity of wildlife habitat; project activity during critical life stages.	Predicted long-term displacement of wildlife or blockage of migratory routes. Predicted long-term change in habitat incompatible with the existence of wildlife.
	Effect of project on habitat or local population of threatened or endangered species and species of general concern.	Project-generated change in carrying capacity of habitat; project activity during critical life stages.	Any predicted change in habitat or blockage of migratory routes. Any action that jeopardizes threatened and endangered species or species of special concern.
Floodplains	Effect on human health and safety and property downstream.	Project-generated change in flood storage volume.	Net reduction in flood-storage capacity.
	Effect on natural beneficial values of floodplain.	Same as above.	Same as above.
Coastal Resources	Effect of project on natural resources, as well as visual and recreational opportunities in coastal areas, including but not limited to wetlands, coastal features, floodplains, and fish and wildlife.	Consistency with applicable state Coastal Zone Management Acts, under Federal Consistency Programs.	Violation of Federal or State Limitations.
Water Resources	Stormwater runoff effects during and after construction.	Amount, duration and extent of project-generated increase in runoff and contaminant or sediment transport.	Potential for violation of Federal or state water quality criteria and standards; sedimentation of wetlands or surface water; dilution of coastal waters.
Special Protected Areas	Effect of project on Special Protected Areas.	Change in qualities or characteristics that make area eligible for special protection.	None

Notes: [1,2]As defined in Federal and state regulations.

Source: Smart Assoc., 1994.

8.1.3 Endangered Species

Any activity located in the habitat of a Federal or state-listed threatened or endangered species may affect the species. Project components proposed for such locations are identified as having a potential impact on the species. Additional consultations with appropriate agencies have been undertaken.

8.1.4 Floodplains/Coastal Flood Hazard Area

Any construction of new facilities proposed within the boundary of the 100-year floodplain will be considered a potential impact to the flood storage capacity. Adverse impacts include significant alteration of shoreline configuration, particularly in high velocity flood zones.

8.1.5 Water Resources

Two types of sensitive water resources may be affected by the Proposed Action: groundwater and surface water. Groundwater includes sole source aquifers, locally protected water resource or recharge protection areas, and water supply wells. Groundwater is susceptible to contamination, particularly from accidental spills or releases of contaminants, normal leakage from construction equipment or trucks, and stormwater runoff.

Surface waters, which include rivers, streams, lakes, ponds, bays, and oceans, are susceptible to contamination, as described above, as well as to siltation and sedimentation, particularly during construction. To address long-term impacts to surface water resources, a drainage analysis was performed at all electrification facility sites. Stormwater runoff rates were calculated for the 10-, 25-, and 100-year storm events using storm intensity curves provided by the National Weather Bureau. Sites adjacent to wetlands or surface water resources were examined for potential impacts.

For the purpose of the study, any construction (including bridge modifications) over or within the immediate vicinity of locally protected groundwater supplies or recharge areas, sole source aquifers (designated by EPA), or water supply wells will be considered to have the potential for affecting such resources. Any facilities sited within the setback zones (as described in Section 8.1.1 for wetlands) of surface water supplies will be considered to have the potential for affecting such resources.

8.2 NATURAL RESOURCES IMPACTS

8.2.1 Wetlands

There would be no direct impacts on wetlands as a result of this project except at the Leetes Island Paralleling Station, where the access road could cross a portion of a wetland. The Old Lyme and State Line paralleling stations are located in areas identified on state and local soil maps as hydric soils, which would be classified as wetlands. Field inspections of these sites, however, indicate that these particular locations are not wetlands (see Appendix A).[1] Potential indirect impacts on wetlands include siltation and sedimentation, as well as runoff of contaminants and changes in salinity levels. Potential operational impacts include stormwater runoff from the adjacent facility sites.

The Proposed Action may result in indirect impacts to wetlands (siltation, sedimentation, contamination, or changes in salinity levels) at nine of the 25 electrification facility sites and four of the seven bridges to be modified:

- Branford Substation
- Leetes Island Paralleling Station
- Madison Paralleling Station
- Grove Beach Paralleling Station
- Old Lyme Paralleling Station
- Noank Paralleling Station
- Bradford Paralleling Station
- Norton Switching Station
- Canton Paralleling Station
- Burdickville Road Bridge
- Maskwonicut Street Bridge
- Millstone Road (West) Bridge
- Kenyon School Road Bridge

The Branford Substation, Noank and Canton paralleling stations, and Richmond Switching Station have been relocated from the sites identified in the DEIS/R.

All sites would require the utilization of Best Management Practices to control erosion on-site and limit sedimentation off-site. The term Best Management Practices refers to currently accepted methods utilized to control erosion and sedimentation as well as other off-site impacts. Measures to control these impacts would include the development of site-specific erosion control plans. Steps which would be taken include, but are not limited to the establishment of temporary and permanent vegetative cover, mulching, and sediment barriers including haybales and silt fences. Other measures could include grassed swales, diversion ditches, and riprap.

8.2.1(a) Connecticut

The Connecticut Coastal Management Act, Section 22a-91(10)b(1)D, requires that structures in tidal wetlands or coastal waters be designed, constructed, and maintained to minimize adverse impacts on coastal resources, circulation and sedimentation patterns, water quality, and flooding and erosion, to reduce the use of fill to the maximum extent practicable. Adverse impacts are considered to include degrading tidal wetlands, through significant alteration of their functions, degradation of water quality, and other factors.

Of the 11 facilities located in Connecticut, none is proposed to fill, alter, or degrade tidal or freshwater wetlands except the Leetes Island Paralleling Station. Six of the electrification facility sites and one bridge modification have potential to cause indirect impacts to wetlands.

Branford Substation. This facility has recently been relocated to a new upland location. The proposed fill line for the access road would approach within 5 feet of a small, isolated freshwater wetland.

Construction Impacts: No filling of wetlands would occur as a result of the facility or access road. Access road slopes are located close enough to the adjacent wetland that shifting the road to the east would be appropriate. If the proposed location is required due to siting constraints, sedimentation and erosion control measures would be necessary, including but not limited to mulching, seeding, haybales, and geotextile barriers.

Long-Term Impacts: Steep slopes adjacent to the wetland could create long-term impacts to water quality and erosion potential. Measures such as permanent diversion ditches and vegetative swales would be utilized to control stormwater. No other adverse impacts to resources outlined in the Coastal Management Act are expected at this site.

Leetes Island Paralleling Station. This facility would be adjacent to tidal wetlands with a small pocket of freshwater wetland in proximity to the site. A portion of the site encroaches on a 100-year floodplain, and the access road would require the taking of a portion of the wetland. Retaining walls have been designed to minimize any filling of the wetland.

Construction Impacts: No filling would occur as a result of the facility. No disruption or interference with adjacent tidal flows are expected. Steep slopes between the facility and Stony Creek Road would create the potential for erosion and sedimentation. The north side of the facility would utilize a retaining wall which limits exposed slopes. Other portions of the site would require erosion and sedimentation control measures, including riprap, mulching, seeding, haybales, and geotextile fencing.

Long-Term Impacts: This site is at least partially located within the coastal flood hazard boundary. Lost flood storage volume would total 600 cubic yards. The site is not in a high velocity flood zone. Floodplain impacts are noted in Section 8.2.4, Floodplains/Coastal Flood Hazard Area. Potential off-site impacts to the adjacent tidal marsh could occur due to stormwater runoff. Best Management Practices would be incorporated including diversion channels and vegetated swales. No other adverse impacts to resources outlined in the Coastal Management Act are expected at this site.

Madison Paralleling Station. This paralleling station would be located approximately 45 feet from an adjacent freshwater wetland. The location would require the upgrading of an old road bed to allow access to the site. This road crosses a wetland to the north and is an abandoned portion of Old Copse Road.

Construction Impacts: No filling would be required for the facility. Impacts which may occur as a result of the access road would be quantified during the permitting process. Facility and access road construction would require the utilization of proper erosion and sedimentation control measures.

Long-Term Impacts: Management of stormwater runoff and any increased runoff associated with the upgrade access road would incorporate measures such as vegetative swales or diversion channels. No other adverse impacts to resources outlined in the Coastal Management Act are expected.

Grove Beach Paralleling Station. This facility would be located in an old fill location associated with a trailer court. Freshwater wetlands are located within 40 feet of the paralleling station on the south side.

Construction Impacts: No filling of adjacent freshwater wetlands would occur. Facility construction would require the utilization of proper erosion and sedimentation control measures.

Long-Term Impacts: Stormwater runoff could create water quality impacts in the adjacent wetlands. Any runoff would be diverted from directly entering the wetland through the use of vegetative swales and diversions. No other adverse impacts to resources outlined in the Coastal Management Act are expected.

Old Lyme Paralleling Station. This facility location is one of three that are considered to be located in wetlands according to the county soil survey and coastal soils maps. A field review indicated that this site is located in an area of old highway fill and appears to be the location of the road before the adjacent bridge was installed.[2] Construction of the facility could potentially impact freshwater wetlands located within 50 feet of the access road.

Construction Impacts: No filling would be required for the facility or access road. Facility and access road construction would require the utilization of proper erosion and sedimentation control measures.

Long-Term Impacts: Stormwater runoff may create water quality impacts in the adjacent wetlands. Any runoff from the site would be diverted through vegetative swales or other mitigation structures. No other adverse impacts to resources outlined in the Coastal Management Act are expected.

Noank Paralleling Station. This facility was originally to be located in a parking lot adjacent to an important tidal stream. The site now proposed would be located approximately 300 feet to the northeast at the intersection of Groton Long Point Road and Elm Street. This location is adjacent to a scrub-shrub wetland which eventually flows into the same tidal stream; however, no crossings of the stream are required and the potential for impacts is limited to water quality impacts.

Construction Impacts: No filling of wetlands would occur as a result of the facility or access road. The access road and facility are both expected to occur close to the wetland edge. Potential for erosion and sedimentation into the adjacent wetland would require the incorporation of Best Management Practices, and include steps such as mulching, seeding, haybales, and geotextile barriers. Any steep slopes would incorporate other measures such as diversion channels and riprap.

Long-Term Impacts: Stormwater runoff would potentially impact the adjacent wetland as well as the tidal restoration project downstream. Any anticipated runoff would incorporate measures such as permanent diversion and vegetated swales. This site is not expected to impact the floodplain. No other adverse impacts to resources outlined in the Coastal Management Act are expected.

Millstone Road (West) Bridge. The Millstone Road (West) Bridge is located at a small cul-de-sac crossing to a residence on the south side of the tracks. Wetlands associated with the site include two trackside, emergent wetlands on the east side of the bridge, plus a large forested wetland on the north side of the approach road.

Construction Impacts: No filling of adjacent wetlands would occur as a result of the bridge raising. Final design plans would avoid impacts to and maximize the distance to the forested wetland to the north. Construction activity along the approach road and adjacent bridge would require the utilization of proper erosion and sedimentation control measures and stormwater management measures.

Long-Term Impacts: No increase in bridge surface area is expected; any redirected surface runoff would incorporate measures such as permanent diversions and swales. No other adverse impacts to resources outlined in the Coastal Management Act are expected at this site.

8.2.1(b) Rhode Island

The Rhode Island Freshwater Wetlands Act requires permits for activities occurring in a wetland such as filling, draining, excavation, running a ditch or drain into and otherwise altering the flow of water into or from a wetland. Buffer Zones are referred to as "perimeter wetlands" or "riverbank" and are regulated as a resource area. The Freshwater Wetlands Act (R.G.L. Sec. 2-1-18 through 2-1-24) also considers impacts to functional values such as wildlife habitat and floodplains.

Of the eight sites that would be located in Rhode Island, two electrical facilities and two bridges are expected to be close to and may potentially impact on wetlands. No filling of wetlands is proposed in Rhode Island.

Bradford Paralleling Station. This facility would be located adjacent to a large wetland community; however, the site itself is on an upland area which appears to be a local refuse dumping location. Grading for the facility would occur within 10 feet of the adjacent wetland edge.

Construction Impacts: No filling of adjacent wetlands would occur. The proximity of wetlands would indicate that erosion and sedimentation are a potential problem. Control measures would be incorporated such as mulching, seeding, haybales, geotextile fencing, and diversion channels.

Long-Term Impacts: Any stormwater runoff which may occur would be directed away from the wetlands and would incorporate the use of vegetated swales and other water quality measures. No other resources outlined in the Freshwater Wetlands Act would be impacted by facility at this location.

Burdickville Road Bridge. The bridge, which would be raised, is located on an upland ridge. Road improvements would extend along the west side approach road within 10 feet of a forested wetland community, on both the north and south side of the road.

Construction Impacts: No filling of adjacent wetlands would occur as a result of the bridge raising. Final design plans should examine alternative approach designs to maximize the distance to any wetlands. Erosion and sedimentation could occur at the north end of the project. Steps would be taken to maximize the distance to the wetlands and to incorporate proper erosion and sedimentation control measures.

Long-Term Impacts: The bridge site is not located in any floodplains and would not be expected to impact floodplains, wildlife habitat, or other wetland functions. Drainage outfall pipes proposed for the location would have to be redesigned to maximize the distance to wetlands and incorporate stormwater management measures such as vegetated swales or diversion ditches. No other resources outlined in the Freshwater Wetlands Act would be impacted.

Kenyon School Road Bridge. This is a narrow wooden bridge in an industrial/residential district. The bridge appears to be located over 200 feet from the Pawcatuck River and Pasquiset Brook. The potential for impact to the 200-foot buffer or perimeter wetland would depend on the extent of work associated with the approach road on the south side of the bridge.

Construction Impacts: No filling of adjacent wetlands would occur. Impacts to perimeter wetlands or the 200-foot buffer zone of Pawcatuck River are dependent on final design. Alternative designs would be examined to maximize the distance to any wetlands. Erosion and sedimentation may occur at the north end of the site. Steps would be taken to maximize the distance to the wetlands and incorporate proper erosion and sedimentation control measures.

Long-Term Impacts: The site is not located in any floodplains and would not be expected to impact floodplains, wildlife habitat, or other wetland functions. No other resources outlined in the Freshwater Wetlands Act would be impacted.

8.2.1 (c) Massachusetts

The Massachusetts Wetlands Regulations identify "Areas Subject to Protection Under the Act," and locally issued permits are required for any activity that involves filling, dredging, removing, or altering these areas. Areas subject to protection include any bank, marsh, meadow, swamp, bog, creek, river, stream, pond, lake, land under these waterways, or land subject to flooding. Of the four sites located in Massachusetts, two electrical facilities and one bridge are expected to occur close to and may potentially impact on wetlands.

Norton Switching Station. This facility occurs within the 100-foot buffer zone regulated by the state. Development of the site would not be expected to impact the wetland's ability to perform the functions or interests identified in the Massachusetts Wetland Protection Act (M.G.L. c131, s. 40) including public or private water supplies, groundwater supplies, flood control, storm damage protection, prevention of pollution, protection of land containing shellfish, protection of fisheries, and protection of wildlife habitat.

Construction Impacts: No filling or disturbance is proposed in the adjacent wetland. The location of the facility within the buffer zone of the wetland would require the utilization of proper erosion and sedimentation control measures including mulching, seeding, haybales, and geotextile silt fencing.

Long-Term Impacts: The site lies within the Bungay River Water Resource Protection District. The associated regulations prohibit outdoor storage of hazardous materials. No municipal wells are located in the vicinity. Any stormwater runoff which may occur would be treated with water quality protection measures such as vegetative swales. No other resources outlined in the Wetlands Protection Act would be impacted.

Canton Paralleling Station. This site was relocated and is now situated at the edge of the power line easement, occurring within 100 feet of a state-regulated wetland. Development of the site would not be expected to impact the wetland's ability to perform the functions or interests of the Wetlands Protection Act, including public or private water supplies, groundwater supplies, flood control, storm damage prevention, prevention of pollution, protection of land containing shellfish, protection of fisheries, and protection of wildlife habitat.

Construction Impacts: No filling or disturbance is proposed in the adjacent wetland. The location of the facility within the buffer zone of the wetland would require the utilization of proper erosion and sedimentation control measures including mulching, seeding, haybales, and geotextile silt fencing.

Long-Term Impacts: Any stormwater runoff which may occur would be expected to incorporate water quality measures such as vegetative swales. No other resources outlined in the Wetlands Protection Act would be impacted.

Maskwonicut Street Bridge. The Maskwonicut Street bridge crosses over Beaver Brook close to the rail line. The raising of the bridge is not expected to alter the adjacent wetland's ability to perform the following functions identified in the Massachusetts Wetland Protection Act: groundwater supplies, public water supplies, and protection of fisheries habitat due to the adjacent town groundwater protection district and potential impacts to Beaver Brook. The State of Massachusetts Fish and Game Department stocks the brook with trout.

Construction Impacts: The construction work would occur within the wetland buffer zone. Potential impacts to wetlands and land under a waterway are dependent on the final bridge design. Town of Sharon water wells are located 1,000 feet and 3,000 feet to the south. The site is in a groundwater protection district.

Long-Term Impacts: The bridge site is located in a 100-year floodplain. The quantity of lost flood storage would not be available until the final design is completed. Fisheries in Beaver Brook make impacts to water quality critical. Work in the brook crossing area would have to minimize erosion and sedimentation, as well as control stormwater inputs to the brook. Impacts are not anticipated to be significant.

8.2.1(d) Mitigation Measures

The wetland mitigation process involves the three-step process of avoiding impacts, minimizing unavoidable impacts, and if necessary compensating for the unavoidable loss of wetlands and impacts to functions such as flood storage.

The avoidance of direct impacts to wetlands has been accomplished through the planning and siting process. Minimal filling of wetlands would occur as a result of the proposed work. Further minimization of impacts would include proposals to shift access roads as far from wetland edges as is possible and practicable.

Potential impacts to the wetlands around these sites include erosion and sedimentation, stormwater impacts to water quality, and flood storage volume losses in the floodplain. Steps to mitigate these impacts were outlined above and include erosion and sedimentation control and stormwater runoff Best Management Practices. Design changes to reduce slopes and exposed soils would continue to be explored. Steps which would be taken can include but are not limited to vegetative cover, mulching, sediment barriers, silt curtains, grassed waterways, diversion channels, riprap, and concrete retaining walls.

The mitigation of stormwater runoff impacts would be quantified when more complete plans are available. Site-specific erosion and sedimentation control plans and long-term stormwater management plans would then be developed. The electrical facilities are expected to have only limited impervious surface areas associated with transformer pads. The remainder of the sites would be a pervious layer of pea-gravel or similar material. In areas where runoff may occur, and especially in sites adjacent to tidal wetlands (such as Leetes Island), some method of retaining flow will be required. Other steps to be taken include diversion channels and vegetated swales.

Floodplain impacts are generally limited within the corridor; however, three of the facilities in Connecticut occur in coastal flood hazard areas. The limited availability of sites restricts the potential for moving the facilities to areas outside the floodplain. Compensation for flood storage volumes is not proposed due to the limited amount of volume lost and the location of the three facilities in the lower reaches of the watersheds.

8.2.2 Critical Wildlife Habitat

8.2.2(a) Great Swamp Wildlife Management Area

The Kingston Paralleling Station is proposed to be located at a site within the Great Swamp Wildlife Management Area (GSWMA), which has high wildlife value. Siting of this facility could have an impact to wildlife values in the area surrounding the station. Located at the edge of a forested habitat, the value of the site is due primarily to its association with the Great Swamp. As noted in the DEIS/R, the large white oak located in the vicinity of the facility would be avoided during the final siting of the facility.

The GSWMA continues to the south for approximately 2.75 miles and would also be considered to have high wildlife value. Impacts in the Great Swamp include potential disturbance to nesting osprey (*Pandion haliaetus*), since the Reservation has been identified as critical habitat for osprey.

Osprey. Critical osprey nesting habitat has been identified by RIDEM Fish and Wildlife Division as occurring in the GSWMA and in scattered areas of the Connecticut coastal region. Nesting osprey occur along the rail corridor in Rhode Island and Connecticut. Impacts to nesting birds would be expected to occur during construction of the electrical facilities if they are nesting adjacent to construction activities and if these activities occur during the critical nesting period for osprey. A temporary disturbance would be associated with catenary pole installation as well.

Osprey would be susceptible to disturbance during the nesting stage and the rearing of young birds. In the project area this period would be expected to occur from April 1 through August 15.

Long-Term Impacts: Long-term impacts associated with the Proposed Action would be expected to be limited in nature. In the past osprey have been known to nest on utility towers, and it is possible osprey would nest on catenary towers. However, the long-term increase in train traffic would be expected to deter nesting activities.

Mitigation Measures: The presence of nesting osprey adjacent to the Amtrak right-of-way necessitates the identification of critical nesting areas and the avoidance of construction activities at electrical facilities and other localities, such as catenary towers, when deemed necessary by state wildlife personnel.

Locations of osprey nests in Connecticut are mapped by ConnDEP Wildlife Division personnel. Amtrak would consult with the agency to identify sensitive localities. Where nest locations are identified, work would be avoided during the period of April 1 through August 15.

8.2.2(b) Fisheries Habitat

The Connecticut River and the four other moveable bridge sites are also located within critical finfish habitats, and the effects of burying electrical cable under the moveable portion of the bridges could affect important characteristics of the habitat. A preliminary assessment of impacts indicates that there could be temporary impacts, including turbidity and disturbance of marine sediments, that may temporarily affect marine estuarine and anadromous fish (those fish that swim from the sea to fresh water for breeding purposes), especially during migration and spawning seasons.

Potential impacts to fisheries, as noted in the ConnDEP Staff Review Comments to the DEIS/R, include water quality impacts arising during burial of the cable and long-term impacts to fish movement due to electromagnetic fields. The Proposed Action calls for burial of power cables at each of the five moveable bridges in Connecticut: the Connecticut River, Shaw's Cove, the Thames River, the Niantic River, and the Mystic River. Cables would be submersible insulated power cables designed to operate at a nominal voltage of 25 kV, single phase, and a frequency of 60 Hz. Power return cables rated for 2 kV would also be laid at this time.

Installation of Continuity Cable. The method proposed for burying the cable is trenching; however, the most suitable technique for laying the cables would be developed considering local conditions. The sediments noted at these sites are believed to be sand, silt, and clay, based on site data collected when signal cables were installed approximately 10 years ago. No blasting is expected based on this data. Dredged materials would be used for backfilling trenches. The work at each site is expected to take 10 days.

Amtrak has no knowledge of artificial obstructions which may occur at these sites. Any existing submarine cable in the work area would be located in the field.

Construction Data:

- Connecticut River
  - Length of buried cable — 216 feet
  - Total volume of disturbance — 510 cubic yards
- Niantic River
  - Length of buried cable — 103 feet
  - Total volume of disturbance — 160 cubic yards
- Shaw's Cove
  - Length of buried cable — 232 feet
  - Total volume of disturbance — 250 cubic yards
- Thames River
  - Length of buried cable — 213 feet
  - Total volume of disturbance — 410 cubic yards
- Mystic River
  - Length of buried cable — 301 feet
  - Total volume of disturbance — 500 cubic yards

Duration of disturbance:	10 days at each site
Depth of burial:	7 feet in Federal channel
Power cables:	submersible, insulated 25 kV, single phase, 60 Hz

Alternatives Analysis. Three possible methods of installing continuity conductors were considered for this project: (1) aerial, (2) horizontal drilling, and (3) submarine cable.

Aerial Method: In order to cross the moveable span of the bridge, the cable would have to be suspended from towers or poles approximately 100 to 150 feet above the bridge deck in order to allow 140 feet clearance from mean high tide to the lowest point of suspended cable. Installation of poles of this size would require major structural modification to the bridge. Poles or towers would require the installation of guy wire and aircraft navigation lights. Overall, the addition of towers, guy wires, lights, and structural alterations would drastically change the appearance of the bridge and its visual impact to the landscape.

Horizontal Drilling Method: Drilling of the cable would occur on either side of the Federal channel. Horizontal drilling requires erection of a drilling rig, which would require a foundation with significantly more environmental impact than the submarine cable.

Submarine Cable Method: As with the horizontal drilling method, the continuity conductors essentially cross only the Federal channel. This type of installation is widely used and has the advantage of requiring a short period of time for installation (estimated to be 10 days). In addition, interference with boat and shipping traffic is minimal.

The trenching would take place mostly in areas previously disturbed; installation of signal and communication cables has already taken place in the area, so new disturbance would be limited, and much less than with horizontal drilling.

Based on the above information it has been determined that the submarine cable alternative would provide a proven method for cable installation with less disturbance to the surrounding resources.

Alternative Cable Arrangements. Specifics on alternative cable arrangements are still in the design stage.

Species of Concern. In each of the five river crossings a variety of species occur which could be adversely impacted by the project. To focus the discussion of impacts and mitigation measures, Linda Gunn Alexander of ConnDEP Fisheries Division provided a list of Species of Concern at each of the crossings.

- Connecticut River
  - Anadromous fish runs
  - Shortnose sturgeon, a Federally listed endangered species
- Niantic River
  - Anadromous fish runs
  - A very good winter flounder population
- Shaw's Cove
  - No anadromous fish runs
  - Would expect larvae of estuarine species throughout area
- Thames River
  - Anadromous fish runs
  - Winter flounder

- Mystic River
    - Anadromous fish runs
    - Winter flounder

Seasonal Restrictions: ConnDEP applies the following restrictions:

Winter flounder	February 1 - May 30
Anadromous fish runs	April 1 - June 30
Shortnose sturgeon (Federal)	April 1 - August 15
Shellfish	June 1 - September 30

Construction Impacts to Fisheries: The Candidate Environmental Impact Statement (CEIS) for Dredging Portsmouth Naval Shipyard, Portsmouth, NH,[3] was consulted for information on the impacts to fisheries associated with dredging. This report notes that impacts to finfish include: (1) the effect of high suspended sediment levels, including direct effects to free-swimming fishes and the silting over of demersal eggs, (2) direct mortality to fishes caused by dredging, (3) effects of dissolved oxygen reduction caused by the release of oxygen-demanding materials into the water column, and (4) the release of any dissolved toxicants to the water column. Most of these impacts are short-term in nature and occur only during the actual dredging activity.

Of these effects, the cable burial operation could impact primarily the benthic community through direct mortality and creation of suspended sediment loads. The short duration of the work effort, as well as the minimal depth and width of the disturbance, limit long-term impacts. The release of dissolved toxicants has been cited as a potential problem in the Thames River.

Sediment load impacts noted in the Portsmouth CEIS include impacts in the immediate vicinity of the dredging such as respiratory problems among any fish not displaying avoidance behavior. Planktonic life stages of fish are described as being particularly vulnerable to suspended sediments due to their inability to avoid potentially lethal conditions.

Striped bass apparently are particularly sensitive to sediment loads, as are most plankton feeders, a category that would include mackerel, menhaden, smelt, silversides, and Atlantic herring. Bottom-dwelling fish tend to be affected to a lesser extent, although filter feeding species would tend to alter feeding patterns.

Mollusks were shown to increase filtering and pumping rates due to increased levels of fine sediments; however, the Portsmouth study noted a resumption of normal feeding patterns when suspended solids were reduced to normal. Crustaceans and other epibenthic organisms reportedly are able to tolerate high levels of suspended solids for short periods of time.

Filter feeding organisms including bivalves, polychaetes, and zooplankton apparently have varied responses to suspended solids. Bivalves may exhibit reduced feeding efficiencies while some polychaetes and zooplankton may selectively sort sediments from food particles. These species reportedly return to normal behavior when the perturbation is removed. Phytoplankton populations would also be impacted by reduced light levels; this is a temporary impact.

Overall, the temporarily high levels of suspended solids would be expected to have direct impacts to some fish species and demersal eggs. Most species of fish display effects which are temporary in nature, and recolonization of the site is expected. Studies noted in the Portsmouth CEIS indicate that although the impact of dredging may be important, repopulation of much larger dredging operations than proposed here occurred within 1.5 years.

Long-Term Impacts of Electromagnetic Fields to Finfish Movements: An analysis of EMF impacts on fish migration was conducted by Roy F. Weston, Inc.[4] This report outlined the expected magnetic fields based on maximum amperage as well as the expected current flow which is much lower, 599 amperes (amps) versus 166 amps. Current flow varies depending on whether the bridge is open or closed, or if a train is on the bridge. When the bridge is closed, the current will essentially be the same through the overhead catenary wires and the submarine cable, except when a train is on the bridge causing current to flow primarily through the catenary. Impacts were examined at the Niantic River since it is the shallowest of the rivers and impacts would be expected to be the greatest. The anticipated magnetic field levels and impacts include:

- When the bridge is open, expected EMF would be on the order of 4 milligauss (mG) at the surface, 6 mG at mid-depth, and 23 mG at the bottom. These figures would be halved when the bridge is closed.
- Expected EMF at the water surface from the overhead catenary is considered to be the same as being 33 feet from the side of the rail, or less than 4 mG at the water surface. At mid-depth this figure is estimated to be 2.5 mG. These figures are associated with a train being on the bridge, when maximum current would be flowing through the catenary wires. The amounts would be negligible when the bridge is open, and halved when the bridge is closed.
- There is evidence that some species of fish are able to orient themselves using geomagnetic cues, while others are able to detect weak electric fields. Information does not indicate sensitivity to 60 Hz fields such as those associated with overhead alternating current (ac) transmission lines or submarine cables. It has been suggested that sensitivity is limited to direct current (dc) not 60 Hz (ac) fields.
- Research associated with embryo development and EMF showed mixed results, with some species negatively impacted and others positively impacted. Available information relating to mammalian species does not indicate that 60 Hz fields adversely affect reproduction and development processes.
- Studies by the U.S. Navy indicate no differences in daily movement rates or the number of days between tagging and recapture. No other response was noted to predict an adverse impact.
- Another study suggests that field strengths of over 50 mG would be required for detection by mechanisms based on magnetite; however, these levels of field strengths would not be encountered at distances greater than 10 feet from the cable or 3 feet above the bottom. The expected EMF intensity at 3 feet above the bottom is on the order of 12 mG while the bridge is open and 0.6 mG while it is closed.

Due to the observed lack of sensitivity by fish to 60 Hz (ac) fields and the lack of fields greater than 12 mG more than 3 feet above the bottom, no adverse impacts to finfish in the river crossing areas are expected from EMF. (See Section 5.3 for a detailed discussion of EMF impacts on fish.)

In a personal communication unrelated to the above, Boyd Kynard of the U.S. Fish and Wildlife Service commented that he had not noticed any delays in tagged sturgeon movement as they traveled between locations which were crossed by existing power lines.[5]

Mitigation Measures: Installation of the submarine cable is not expected to impair biological productivity, or the maintenance of healthy marine populations and the maintenance of essential patterns of circulation and drainage.

Due to the location of anadromous fish runs at most of these crossings plus the presence of the Federally endangered shortnose sturgeon in the Connecticut River, it is anticipated that permits would require a restriction on any unconfined work in the water during the months of February through August. Combined with the blanket restriction (June 1 to September 30) on work in waters containing shellfish resources, no work is anticipated at these locations from February 1 through September 30. Since no winter flounder restrictions are anticipated in the Connecticut River, the seasonal restriction at that location would be April 1 through September 30.

Shellfish Resources at the Moveable Bridges. The five moveable bridge sites occur at water bodies which are considered to be shellfish habitat. An assessment of potential impacts associated with the installation of submarine cables was undertaken through review of the ConnDEP, Coastal Management Program, Shellfish Concentration Area maps for New London, Old Lyme, Niantic, and Mystic, CT.

John Volk of the ConnDEP, Department of Aquaculture, indicated that the shellfish concentration maps are a fair representation of existing or historical shellfish use areas, with the exception of private grounds. He stated, however, that private grounds would not be associated with the moveable bridge sites. Generally, the species found at the five sites are hard clams (*Mercenaria mercenaria*), which Volk indicated are found in a wide variety of sediments. Volk also indicated that the Niantic River crossing is the most critical of the five moveable bridge sites. Bay scallops (*Aequipectin irradians*) are associated with the Niantic River, north of the moveable bridge. Scallops prefer a hard-based sediment for habitat, with eelgrass beds utilized by juveniles.[6] The local shellfish commission had been raising seed scallops in the Niantic River; however, that project was abandoned. A representative of the commission indicated that the Federal channel is too deep and the current too swift at that site for shellfish to occur.[7]

Construction Impacts to Shellfish: The proposed installation of submarine cables at the five moveable bridges could impact shellfish species through direct impacts such as burial during construction, and indirect construction impacts such as increased sediment loads and water quality impacts, as well as disruption of spawning activities.

ConnDEP has a blanket restriction on work in these areas between June and September to protect shellfish and critical larval stages. Water quality impacts from dredging activities, as noted in the Portsmouth Naval Shipyard Dredging CEIS, are typically limited to mollusks. With increased sediment loads, several species of mollusks have been shown to increase filtering and pumping rates and decrease their utilization of suitable food materials. The organisms resumed normal feeding patterns when the suspended solid levels were reduced to normal.[8]

The short duration of the work in the rivers (10 days), the restricted length within the Federal channels, and the narrow width of the work area would indicate impacts would be minimal and short-term.

Some concern for water quality impacts associated with the disruption of contaminated sediments during the dredging effort has been raised, especially at the Thames River crossing. The disruption of heavy metals and chlorinated hydrocarbons currently existing in the sediments, would be expected to result in reduced water quality during dredging activities. Disruption of these sediments may have some undesirable long-term impacts on the biota of the waters. Primary producers (phytoplankton) and consumers (zooplankton) have been shown to significantly accumulate both heavy metals and PCBs often found in waterways associated with heavy industry.[9] Based on the anticipated dilution of these materials, levels of contamination in the water column should be minimal.

Long-Term Environmental Impacts: Long-term impacts would appear to be minimal.[10]

Mitigation Effort: Installation of the cables would be carried out in strict adherence to the seasonal restrictions (June through September) required by the state. Other mitigation efforts requested by the local shellfish commission at the Niantic River location included construction activities taking place on the outgoing tide to avoid upstream impacts to shellfish. The commission also requested that Amtrak certify that EMF would be restricted to the trench area.

Other Fisheries Impacts. No other fisheries habitats are expected to be altered or disturbed during the construction process. Any construction activity associated with catenary pole installation or electrical facilities would utilize Best Management Practices to control erosion and sedimentation off-site, thereby reducing potential water quality degradation.

8.2.3 Endangered Species

8.2.3(a) Federally Listed Species

One Federally listed endangered species, the shortnose sturgeon (*Acipenser brevirostrum*), migrates into the Connecticut River in the area of the moveable bridge. There may be temporary impacts to this species, including a temporary increase in turbidity and disturbance of marine sediments, especially during migration and spawning seasons. These impacts were evaluated in consultation with the USFWS, the National Marine Fisheries Service (NMFS), and ConnDEP, and reported in a Biological Assessment as required under Section 7 of the Endangered Species Act.[11]

Based upon review of available literature and interviews of recognized authorities on Shortnose Sturgeon in the Connecticut River, no impact to the population is expected to occur as a result of constructing the submarine cable. The following is a summary of the information provided in the biological assessment:

- The shortnose sturgeon is listed as endangered by the USFWS. There are two populations of shortnose sturgeon in the Connecticut River: one is landlocked in Massachusetts above the Holyoke Dam to the Turner's Falls Dam; the second population occurs below the Holyoke Dam to Long Island Sound.[12] The second population, below Holyoke Dam, would be the one most likely to be impacted by this project.

- Telemetry studies have been undertaken in the segment of the river above tidal influence, while Tom Savoy of ConnDEP is conducting research utilizing ultrasonic tagging in the lower reaches of the river.[13]

- The best available information would indicate that the site of the moveable bridge across the Connecticut River is primarily used by shortnose sturgeon as a feeding ground during the low salinity period occurring between April and mid-June.

- The NMFS restricts work in the Connecticut River during the months of April through mid-August. The State of Connecticut also restricts work in the river between April 1 and September 30.

- The short duration of work in the Federal channel (10 days) as well as the limited extent of excavation would not be expected to have adverse impacts on the Shortnose Sturgeon, if seasonal restrictions are followed, since the fish generally are not found in the river at that season.

Long-Term Impacts to the Shortnose Sturgeon: Long-term impacts to spawning or feeding grounds would not be expected to occur as a result of the installation of a submarine cable across the Federal channel. No spawning is known to occur in this section of the river, nor are the physical characteristics of the location conducive to spawning habitat. Past studies, of much larger-scale dredging projects, indicate that recolonization would occur at the impact location.

The study of impacts on fish migration as a result of EMFs associated with the project indicates that no long-term or adverse impacts are expected to occur.

Mitigation Measures: To mitigate for potential impacts of submarine cable installation to the shortnose sturgeon in the Connecticut River, all seasonal restrictions which apply to unconfined work in the river would be followed. The anticipated dates during which no work can occur in the river due to ConnDEP restrictions are April 1 through September 30; the Federal restriction is April 1 through August 15.

8.2.3(b) Connecticut-Listed Species

A state-listed endangered species, the American bittern (*Botaurus lentiginosus*), has been recorded within close proximity to the Stonington Paralleling Station site. Indirect impacts to this species could occur as a result of construction activity associated with the site, causing a potential disturbance during the nesting season. Consultation with the Connecticut Natural Diversity Database and the Connecticut Valley Wildlife Division of DEP included a field review of the American bittern location to ascertain the presence of this species and to identify mitigation measures.

At the recommendation of Jenny Dickson of ConnDEP, Wildlife Division, on June 16, 1994, at about 8:30 AM, one electronic call and an examination of the adjacent habitat were utilized to determine the presence of the bittern as well as the potential for impacts if it does occur in the vicinity of the Stonington Paralleling Station site. No American bitterns responded to the call or were noted in the field.

The best available habitat in the vicinity would appear to be located over 200 feet to the south of the tracks and over 200 feet to the southeast of the paralleling station location.

Construction Impacts to the American Bittern: Although no bitterns were located in the field, the occurrence of the species in the past and the potential for nesting habitat occurring in the vicinity indicate that construction impacts in the form of increased activity and noise levels could disrupt breeding and nesting activities in the spring and summer months.

Long-Term Impacts to the American Bittern: The long-term operation of the project would not be expected to interfere with activities of this rare species, due to its distance from the tracks. The distance combined with a dense vegetated cover type would be expected to buffer any noise or EMF impacts. No long-term impacts are expected to be associated with the rail operations.

Mitigation Measures: To mitigate for any potential impacts to nesting bitterns in the vicinity of the paralleling station, construction will not be carried out during the breeding and nesting season, which would be expected to occur from May 1 through August 15.

8.2.3(c) Rhode Island-Listed Species

No protected species were noted by Rhode Island Natural Heritage Program.

8.2.3(d) Massachusetts-Listed Species

Four Massachusetts-listed endangered species, the Spotted and Blandings turtles, the least bittern, and the elderberry longhorn beetle, have been identified in the Fowl Meadow ACEC. Although no electrification facilities would be located in this area, the catenary installation could affect these species. Consultation with the Massachusetts Natural Heritage Program and the Massachusetts DEP was carried out. The Natural Heritage Program indicated no further concerns within the Fowl Meadow ACEC if all work is done within the existing ROW.

Summary of Seasonal Restrictions on Construction Activities

Facility	Location	Dates	Species of Concern
Moveable bridges	Connecticut River	4/1-9/30	Shortnose sturgeon Anadromous fish
	Other moveable bridges	2/1-9/30	Winter flounder Anadromous fish
Electrical facilities	Stonington Paralleling Station	5/1-8/15	American bittern
Catenary installation	Great Swamp Wildlife Restoration	4/1-8/15	Osprey
	Connecticut*	4/1-8/15	Osprey

* Specific sites to be determined through consultation with Connecticut DEP, Wildlife Division.

8.2.4 Floodplains/Coastal Flood Hazard Area

Four of the electrification facilities would be located within the 100-year flood boundary: the Leetes Island and Stonington paralleling stations, the New London Substation, and Richmond Switching Station. The Leetes Island, Stonington, and Richmond facilities are on sites of less than 0.25 acre, and the New London Substation is on a site of approximately 0.50 acre. The Maskwonicut Street Bridge raising is also expected to impact floodplains.

Agency Requirements. In accordance with Executive Order 11988 - Floodplain Protection, each Federal agency must develop regulations regarding floodplain impacts, meeting the criteria of the Executive Order. FRA cites as guidance in their Procedures for Considering Environmental Impacts, Executive Order 11988 as well as Floodplains Management and Protection; Policies and Procedures, Department of Transportation Order 5650.2. The FRA procedures outline steps to be taken if the Proposed Action involves a significant encroachment on the base floodplain. Any significant encroachment has to be the only practicable alternative and it must be demonstrated why other alternatives were not practicable.

A "significant encroachment" as defined in DOT 5650.2 is one which results in one or more of the following construction or flood-related impacts:

- A considerable probability of loss of human life.
- Likely future damage associated with encroachment that could be substantial in cost or extent, including interruption of service.
- A notable adverse impact on "natural and beneficial floodplain values," including, but not limited to, natural moderation of floods, water quality maintenance, groundwater recharge, fish, wildlife, plants, and open space.

The Connecticut Coastal Management Act, Section 22a-93, defines coastal flood hazard areas as those land areas inundated during coastal storm events, including flood hazard areas as defined and determined by the National Flood Insurance Act, as amended (U.S.C. 42 Section 4101, C.L. 93-234). Adverse impacts to coastal resources include increasing coastal flood hazard through significant alteration of shoreline configurations or bathymetry, particularly within high velocity flood zones.

The Rhode Island Freshwater Wetland Act, Section 2-1-20(c) relates to areas adjacent to a river or stream which are likely to be flooded in the event of a 100-year frequency storm. Activities which alter this resource or other wetland functions and values would require a permit from RIDEM. A permit request will require an evaluation of impacts upon drainage characteristics and wetland values, and an analysis of proposed impacts including changes in runoff rates and flood storage capacity. Projects in Rhode Island which impact flood storage should provide compensatory flood storage.

The Massachusetts Wetlands Protection Act Regulations, General Performance Standards (310 CMR 10.57 (4)a), requires compensatory storage for all flood storage volume lost.

Long-Term Impacts of Locations in the Floodplain. Of the electrical facilities located along the rail corridor, portions of three sites in Connecticut (the Leetes Island and Stonington paralleling stations and the New London Substation) are described as occurring in coastal flood hazard areas.

An examination of impacts to the floodplains includes a review of siting alternatives. Due to the function of these facilities in maintaining the electrical current, the location of each site is critical to the overall operation. Flexibility in locating the facilities is limited to a 1,000-foot window around the current location. Given other resource impacts and accessibility to other sites within this window, the availability of optional locations is extremely limited.

Site Considerations.
Leetes Island Paralleling Station: Site plans for this location indicate that the electrical facility would be located adjacent to the tracks at an elevation of approximately 17 feet above sea level. The Flood Insurance Rate Map (FIRM) for Guilford, Community Panel 090077-0016B, indicates the site is adjacent to and would impact upon a portion of 100-year floodplain. Base elevation of this flood zone is 12 feet (National Geodetic Vertical Datum of 1929, or NGVD).

The total flood storage that would be lost at this site is estimated to be 600 cubic yards. The alteration of the existing site configuration would include filling in an area adjacent to a small wetland on the north side of the tracks. Based on the available information, this site is not in an area of high velocity flood zone. The FIRM indicates that this site is not within an area of a high velocity flood zone, nor would it result in a significant encroachment into the floodplain according to the criteria outlined in DOT Order 5650.2.

Siting alternatives for the Leetes Island Paralleling Station included a location on the south side of the ROW Milepost 85+3100. This site was considered to be impractical due to limited access.

New London Substation: Site plans for this facility place it in the Central Vermont rail yard, adjacent to the Thames River. It appears from site plans that the elevation of the site ranges from 8.8 feet to 9.5 feet above sea level. The FIRM for New London, Community Panel 090100-0001C, indicates some inconsistencies between flood elevations and flood zones. The substation appears to be located within portions of Zones A, B, and C. Zones B and C are outside the 100-year floodplain; however, the base flood elevation of this flood zone is 10 feet (NGVD). This elevation is above the location of the substation site.

The total flood storage that would be lost at this site is estimated to be 1,540 cubic yards. The alteration of existing site configurations would include fill to elevate the facility out of the flood zone. The FIRM indicates that this site is not within an area of high velocity flood zone. Due to the limited flood storage volume lost and its position in the watershed, this location would not be considered to have a significant encroachment into the floodplain according to the criteria outlined in DOT Order 5660.2.

The New London Substation location is in an industrial/commercial region with housing located to the north. The availability of upland sites within the 1,000-foot window was limited due to existing development. Alternative locations for the substation were reviewed and included placing the substation in Millstone or Waterford. These locations were deemed to be impractical since they would require additional substations or two additional paralleling stations along the route. The New London site was determined to have lesser environmental, economic, and construction impacts as well.

Stonington Paralleling Station: Site plans for this location indicate the electrical facility would be located adjacent to the tracks at the elevation of approximately 8 feet above sea level. The FIRM for the town of Stonington, Community Panel 090106-0018E, indicates that the site is located on the boundary of the 100-year flood zone and the 100-year coastal flood zone. A base flood elevation of 14 feet (NGVD) is noted for this location, well above the existing elevation of 8 feet.

The total flood storage expected to be lost at this site is estimated to be 1,030 cubic yards. The alteration of existing site configurations is expected to be limited to elevating the facility with fill materials, and any associated grading. The FIRM indicates that this site is within an area identified as coastal flood with velocity. Due to the limited flood storage volume lost and its position in the watershed, this location would not be considered to have a significant encroachment into the floodplain according to the criteria outlined in DOT Order 5650.2.

No alternative sites outside the floodplain were available within the 1,000-foot window of this location.

Maskwonicut Street Bridge: This bridge is proposed to be raised to accommodate catenary structures. The raising of the bridge is expected to require alterations to the approach on the west side. The FIRM for Sharon, Community Panel 250252-0005B, indicated the 100-year floodplain crosses under Maskwonicut Street approximately 50 feet to the west of the rail line. No base flood elevation was listed on the FIRM.

The total flood storage lost at this site is dependent on final plans, and the extent of fill and grading associated with the western approach road. Any impact is expected to be minimized by retaining walls. This location would not be considered to have a significant encroachment into the floodplain according to the criteria in DOT Order 5650.2.

Long-Term Impacts to Surrounding Resources. The location of these sites in or adjacent to flood zones indicates the potential for impacts to surrounding sites through lost flood storage capabilities, and potential impacts to the electrical functions of the sites.

Given the location of the Leetes Island, New London, and Stonington sites in the lower portion of their watersheds and the limited volumes of flood storage impact (600 cubic yards; 1,540 cubic yards; and 1,030 cubic yards, respectively), the lost floodplain storage would produce no detectable increases in the flood elevations and there would be no discernible changes in flow patterns or shoreline configurations.

Impacts to the electrical facilities are expected to be minimal. The sites would be built to FEMA standards and elevated above the flood zone. Floodproofing would include the incorporation of design features in, or modifications to, individual structures and facilities, their sites, and their contents to protect against structural failure, to keep water out, or to reduce effects of water entry, so that threats to human life and property are reduced.

Mitigation Measures. Design modifications and shifting of sites would continue through the permitting process in an effort to eliminate or reduce flood zone impacts, and to ensure that policies outlined in the Connecticut Coastal Management Act, Section 22a-92, are followed and adverse impacts on coastal resources minimized.

The standards outlined in the Massachusetts Wetlands Protection Act Regulations closely follow the requirements outlined for Rhode Island; therefore, the same criteria would be followed for the Maskwonicut Street Bridge site. Compensatory storage would be required.

8.2.5 Water Resources

The facility sites and bridge modifications have the potential to affect both groundwater and surface water resources. The potential impacts on such resources are discussed below. The project would not, however, affect the existing track drainage system along the railroad ROW. Consequently, there are no anticipated changes in the quantity of stormwater flow from the track bed. The quality of the stormwater runoff should improve as a result of the elimination of the use of diesel-powered locomotives, which occasionally leak fuel.

Groundwater Resources. Groundwater resources, which could potentially be impacted, include sole source aquifers, locally designated groundwater and recharge protection districts, and water supply wells. Project facility sites and bridge modification locations sited over the aquifers or groundwater recharge protection areas, or in the immediate vicinity of water supply wells, are shown in Tables 3.12-3 and 3.12-4 of Volume I of this FEIS/R.

Branford Substation: No public wells are listed as occurring near the Branford site; however, three private wells occur within 1,000 feet, upgradient of the substation location.

State Line Paralleling Station: Located in Pawcatuck, CT, this area is part of the Pawcatuck Sole Source Aquifer. The site is not located in the vicinity of the Westerly groundwater reservoir or any public wells.

Bradford Paralleling Station: This site is located within the Pawcatuck Sole Source Aquifer. It also is an area identified on the Westerly groundwater reservoirs/public wellfield locations map in the Westerly Comprehensive Plan (1990) as occurring in the "critical portion of the recharge areas to the groundwater reservoirs as delineated by RI Department of Environmental Management." Public wells are located approximately 1,500 feet and 3,000 feet to the east and south.

Richmond Switching Station: This facility is located within the Pawcatuck Sole Source Aquifer. According to the Richmond Town Clerk and Building Inspector, no municipal wells occur in the vicinity.

Kingston Paralleling Station: This site is located within the Pawcatuck Sole Source Aquifer. No municipal wells occur in the project vicinity, and according to the Map of Critical and Environmentally Sensitive Areas in the Comprehensive Plan for South Kingston (1991), the paralleling station lies outside the Groundwater Protection Overlay district.

Exeter Paralleling Station: This paralleling station occurs within the Pawcatuck Sole Source Aquifer. The town clerk in Exeter noted that no known wells occur in the vicinity; however, the RIDEM Wellhead Protection Areas map (1993) indicates a community well occurs within 0.66 mile, and a wellhead protection area approximately 0.5 mile away from the paralleling station site.

East Greenwich Paralleling Station: This North Kingstown site is associated with numerous groundwater resource categories. The location lies within the Hunt-Annoquatucket-Pettaquamscott Sole Source Aquifer as well as within a local groundwater recharge area and a designated wellhead area. Two public water supply wells occur within 1,500 feet of the site and one is within 4,000 feet, including wells for the town of North Kingstown, the Kent County Water Authority, and the Rhode Island Port Authority.

Burdickville Road Bridge: This bridge which is proposed to be raised to accommodate the catenary structure is located within the Pawcatuck Sole Source Aquifer Area. No municipal wells or wellhead protection areas occur in the vicinity.

Kenyon School Road Bridge: This bridge is also located within the Pawcatuck Sole Source Aquifer Area. No municipal wells or water protection districts occur in the project vicinity according to the town building inspector.[14]

Norton Switching Station: The Attleboro engineer's office noted no public wells in the vicinity of the site. The site is, however, within the Bungay River Resource Protection District, according to a plan entitled "Water Resource Protection Districts, City of Attleboro, Massachusetts, 1991."

Maskwonicut Street Bridge: This bridge is located within the Groundwater Protection District, according to the Town of Sharon Zoning map (1989). Public wells are located within 1,000 feet and 3,000 feet of the site, adjacent to Beaver Brook.

Wellhead Protection Areas Along the ROW. Wellhead protection areas for public and community well systems occurring along the NEC have been identified at all proposed facilities or bridges to be raised. Additional wells occur along the corridor close enough to the tracks to be considered a sensitive resource. However, no activities are proposed outside the ROW in these areas, and potential impacts are limited. Unless otherwise noted, well locations in Connecticut were obtained from the *Atlas of Public Water Supply Sources and Watersheds in Connecticut* (1984). Information sources for wells in Rhode Island included the draft RIDEM map, Wellhead Protection Areas (1993). Other sources included towns, water companies, and water districts.

The following list indicates, by town, wellhead protection areas or wells occurring within 1,000 feet of the railroad ROW:

- Madison, CT: According to the town of Madison wellfield map, the initial setback distance radius of 3,450 feet for the Rettich wellfield for wells numbers 5 and 11 overlaps the railroad ROW. These wells, however, are located over 1,000 feet from the rail line.

- Westbrook, CT: The well for the Connecticut Turnpike public rest area is located within 1,000 feet of the railroad ROW.

- Old Lyme, CT: Numerous community wells are located in the Old Lyme area. Those wells occurring within 500 feet of the railroad ROW include Mile Creek well, Old Lyme Shores wells, Hawk Nest Beach well III, and Point O'Wood Water Company well. Other wells occurring within 1,000 feet of the railroad would appear to include Soundview and Miami Beach wells.

- East Lyme, CT: Rocky Neck State Park contains wells within 1,000 feet of the railroad ROW.

- Stonington, CT: The Lord's Point area between Mystic and Stonington village has two wells located approximately 500 feet from the railroad ROW. A community water system wellhead protection area is associated with the Noyes Avenue pump station in Pawcatuck.

- Westwood, MA: Four wells associated with the Dedham-Westwood Water District occur between the rail line and University Avenue. Three of the four wells (numbers 2, 3, and 4) were described by the Water District office as occurring close enough that the wellhead protection areas overlap the railroad ROW.

- Sharon, MA: Town wells numbers 4 and 6 have "well development" areas overlapping the railroad ROW. Wells numbers 2 and 3 occur approximately 1,000 feet to the west of the ROW.

- Mansfield, MA: According to the Town of Mansfield Water Supply Protection Districts map, the railroad ROW passes through the Wading River water supply protection district.

- Attleboro, MA: The Bungay River Water Resource Protection District and Ten Mile River buffer are both located within the study area.

- North Kingstown, RI: In addition to the wellhead protection areas and wells in the vicinity of the East Greenwich Paralleling Station, a large community water system wellhead protection area occurs on the south side of town, as noted on RIDEM Wellhead Protection Areas map (1993).

- Exeter, RI: One noncommunity water system wellhead protection area is noted on the RIDEM Wellhead Protection Areas map (1993).

- South Kingstown, RI: The South Kingstown Comprehensive Plan (1991) indicates that the railroad ROW crosses a groundwater overlay district. The RIDEM Wellhead Protection Areas map (1993) indicates that four separate wellhead protection areas exist in that area.

- Charlestown, RI: The Charlestown Comprehensive Plan (1991) identifies one well located at the Charlestown School on Route 112, approximately 1,000 feet from the railroad ROW. One high-yield aquifer and two recharge areas are also crossed by the rail line in Charlestown.

- Westerly, RI: In addition to the wells noted near the Bradford Paralleling Station, one wellhead protection area is crossed by the railroad ROW.

- Dedham, MA: The proposed Fowl Meadow well occurs north of Route 128.

Construction Impacts to Aquifer Areas: No large-scale construction operations are planned as part of the project. Consequently, impacts to groundwater quality would be limited. Consultation with EPA revealed that three Sole Source Aquifer Areas were located in the project corridor: (1) Pawcatuck and (2) Hunt-Anaquatucket-Pettaquamscutt (HAP), both in Rhode Island; and (3) Canoe River, in Massachusetts (designated May 1993).

As noted in the DEIS/R, construction work in a Sole Source Aquifer Area has the potential to impact the resource, primarily because of contamination from equipment operated on-site. Any impacts would be minimized or eliminated by staging construction equipment, performing vehicle maintenance off-site, and generally following Best Management Practices for working in aquifer protection areas.

A potential impact to water quality could arise during the installation of the catenary poles. These impacts could be mitigated by the use of proper erosion and sedimentation control measures including but not limited to mulching, reseeding, and placement of haybales downslope in areas adjacent to wetlands. Consultation with agencies handling water quality certification would be consulted during the permitting process to determine if further action is required.

Long-Term Impacts to Aquifers: Potential long-term impacts to groundwater include contamination that would reach the water resource through the soil, particularly from accidental spills or releases of contaminants during operation of facilities and stormwater runoff from facilities.

Mitigation Measures: All procedures outlined in the Best Management Practices for working in Sole Source Aquifer Areas would be followed to avoid impact or contamination during facility construction. Long-term control of impacts would include development of site-specific spill contingency plans. The quantities of fluids, which are mineral oils, vary according to the facility type, as follows:

- all substations - 40,000 liters
- all paralleling stations - 4,000 liters
- Richmond/Westbrook switching stations - 12,000 liters
- Norton Switching Station - 8,000 liters

Pursuant to requirements of 40 CFR 112, all facilities would be designed to include impermeable oil collection pits around the perimeter of all transformer foundations. If transformers should leak or burst due to electrical overload, the oil would be collected in the pit. These pits would be capable of containing all the oil in the facility plus the associated runoff from a 100-year design storm. If a spill occurs, work crews would pump out any oil and associated contaminated waters. Failure of the system or any leaks associated with equipment malfunction would result in an inoperable facility, alerting workers to a potential problem.

Any facilities located in Sole Source Aquifer Areas or adjacent to water wells which are expected to generate stormwater runoff would include vegetated swales and other measures to minimize water quality impacts.

Southwest Corridor Project Area: The MBTA has expressed a special concern relative to Amtrak proposals to lower the present track profile under bridge structures between Back Bay Station and South Station in Boston. During the decade of the 1980s, the MBTA managed the construction of the Southwest Corridor Project (SWCP) which involved reconstruction of the NEC route from a point east of Back Bay Station to a point west of Forest Hills (approximately 4.7 miles). This project involved placement of three high-speed railroad tracks in a depressed alignment to replace the previous ground-level and embankment line segment.

For most of the length of this project, a "U" shaped, reinforced concrete structure, supported by prestressed 100-foot-long concrete piles, was installed. This structural configuration is commonly called a boat section.

Concurrently with construction of the SWCP, FRA determined to improve the track structure between the east end of the SWCP and South Station as part of NECIP. This track segment improvement activity became known as Project MUD. For this segment, a membrane was placed upon the subbase, then rock ballast and the track assembly installed over the membrane. Both the SWCP and Project MUD were designed so as to avoid adverse changes to the drainage patterns and the water table level within the two project areas.

Despite the drainage work constructed as part of Project MUD, and inspections verifying that the drainage improvements are functioning as designed, changes in the water table in the Back Bay area apparently continue. It is unclear what is the cause of such changes. The MBTA is concerned that activities to increase clearance under bridges in the Project MUD area could adversely impact the groundwater levels in the vicinity.

Amtrak plans to lower the three tracks at the Arlington/Tremont Streets overhead bridge (MP 228.13) and at the Albany/Broadway overhead bridge (MP 228.51) within the Project MUD area to provide adequate clearance for the catenary. To accomplish this, Amtrak plans to remove a maximum of 5 inches of ballast in an area where the current depth of ballast under the ties ranges between 14 and 33 inches. The catenary will be either hung from bridges or from arms attached to existing concrete walls. Amtrak's proposal for increasing clearances and installing the catenary in the Project MUD area will not affect, either positively or negatively, the drainage system in this area or groundwater levels.

Adjusting the depth of ballast section should not have any impact on the groundwater levels. A ballast section is designed to allow for maximum drainage, and groundwater levels do not regularly extend into the ballast section. Amtrak also will use construction techniques to avoid damaging the membrane. Amtrak does not plan to use the undercutters in this area; instead, it will use front end loaders and similar construction equipment. (In a previous inspection of the membrane, all of the ballast was removed using the same procedures, with no damage to the membrane.)

The installation of catenary also should not have any impact on the groundwater levels, since no poles would be used in the Project MUD area. By eliminating the need for catenary poles and their foundations in this area, the membrane or adjacent ballast would not be disturbed.

Surface Water Resources. Four of the 25 facility sites and one of the seven bridges to be modified are located within the buffer of surface waters, or are considered to be close enough to be susceptible to impacts.

- Branford Substation is located over 1,200 feet from Lake Saltonstall, a water supply reservoir.
- Noank Paralleling Station is considered to be susceptible to impacts due to a hydrologic connection to an important tidal stream restoration project.
- Exeter Paralleling Station is located just beyond the 50-foot buffer zone of Yawgoo Mill Pond.
- Attleboro Paralleling Station is considered to be susceptible to impacts with drinking water supplies located downstream on the Ten Mile River.
- Maskwonicut Street Bridge is located immediately adjacent to Beaver Brook.

Potential short-term indirect impacts of the facilities on surface waters include sedimentation, and runoff of contaminants. Installation of the submarine cables at the five moveable bridges would also create surface water impacts.

Other Surface Waters along the ROW: Numerous watercourses are crossed by the railroad ROW; however, no activities outside the ROW in these areas are proposed, and potential impacts are limited.

Construction Impacts to Surface Waters. The principal impacts expected from construction activities are erosion and sedimentation. Contaminants could also be released from equipment operation.

Potential erosion and sedimentation impacts would be minimized by following Best Management Practices identified in the appropriate state erosion and sediment control handbooks. Best Management Practices would be inspected frequently during construction to ensure proper functioning and protection of resources. Potential impacts from equipment operation would be minimized by staging construction equipment and performing vehicle maintenance off-site.

As discussed in the section on aquifer impacts, catenary pole installation would be expected to require erosion and sedimentation control measures, including mulching and/or seeding and haybales in sensitive locations. Other measures may be required during the permitting process.

Long-Term Impacts to Surface Waters: Potential long-term impacts to surface waters include contamination resulting from accidental spills or release of contaminants during operation of the facility.

Mitigation Measures: Any facilities occurring adjacent to surface waters are expected to include site-specific spill contingency plans, as outlined above in plans for working in protected aquifers. Also as discussed above, facilities would have impermeable oil collection pits around the perimeter of all transformer foundations. These pits would be capable of containing all the mineral oil in the facility plus runoff from a 100-year storm. If spills occur, the oil and any contaminated waters would be pumped out and properly disposed of. Any facilities located within the vicinity of surface water resources which are expected to operate stormwater runoff would include vegetated swales or other measures to minimize water quality impacts.

Construction Impacts at Moveable Bridges. Installation of submarine cables would result in disturbance to bottom sediments, the potential reintroduction of contaminated sediments to the water column, and potential erosion and sedimentation occurring as a result of on-shore activities.

The alternatives analysis of methods of cable installation presented in the section on fisheries indicates that the proposed method for installation has the advantage of a short duration of work in the river (10 days each location), limited area of disturbance, and limited disturbance of shoreline and adjacent wetlands, since the cable is submersed only in the Federal channel area.

ConnDEP indicates that seasonal restrictions on work activity are the primary means of mitigating impacts to the rivers. Other measures which would be expected to be undertaken include:

- Stage construction equipment at least 25 feet from the edge of rivers and any associated wetlands.
- Perform all vehicle maintenance away from the staging area and resource areas.
- Develop and update any spill contingency plans in case of an accidental release in the cable crossing area or in the staging area.
- Stabilize slopes and control any erosion associated with construction activities, including but not limited to mulching, haybales, silt fencing, and vegetated swales, if necessary.

Long-Term Impacts at Moveable Bridges: Long-term impacts associated with the installation of submarine cables are not expected, since the Proposed Action calls for backfilling trenches with dredged materials and restoring the bottom configuration to the maximum extent practicable.

Mitigation Measures: All seasonal restrictions applied to unconfined work in the river crossings would be adhered to. The anticipated dates to avoid are February 1 through September 30 in rivers with winter flounder and April 1 through September 30 in rivers without winter flounder. No work would be proposed during these seasonal restriction dates.

All associated work activity would be staged at least 25 feet away from the edge of the river and associated wetlands. Disturbed areas would be stabilized and Best Management Practices applied.

Existing Rail Lines Effects on Coastal Coves. Several commenters on the DEIS/R expressed their concern that the existing Amtrak road bed and bridges are constricting the tidal flow into coves along the Connecticut coast, adversely affecting these coves and surrounding wetlands. USACE, under the auspices of Coastal America, conducted an investigation of the affect of transportation structures on these coves.[15] The study concluded that overall bridge/embankment complexes are not a primary cause of saltmarsh degradation, nor were they causing significant tidal flow constrictions. The study did cite undersized culverts and tidegates associated with transportation facilities as a primary cause of saltmarsh degradation.

Endnotes

1. Smart Associates, Inc. *Natural Resources: Freshwater Wetlands Evaluation Report.* Concord, NH, March 1993.

2. Ibid.

3. Parsons Brinckerhoff Quade & Douglas, Inc. *Dredging, Portsmouth Naval Shipyard, Portsmouth, New Hampshire.* A Candidate Environmental Impact Statement. Department of the Navy, Philadelphia, Pennsylvania, 1978.

4. Roy F. Weston, Inc. *Electromagnetic Impacts on Fish,* Waltham, MA, 1994.

5. Personal communication with Boyd Kynard, U.S. Fish and Wildlife Service, Conte Anadromous Fish Research Center, 1 Migratory Way, P.O. Box 796, Turners Fall, MA 01376. 1994.

6. Personal communication with John Volk, Connecticut Department of Environmental Protection, Department of Aquaculture, 1994.

7. Personal communication with Pat Kelly, East Lyme-Waterford Shellfish Commission, 1994.

8. Parsons, et al., op. cit.

9. Parsons, et al., op. cit.

10. Volk, personal communication, 1994.

11. Smart Associates, op. cit.

12. Buckley, J., and B. Kynard. *Annual Movements of Shortnose and Atlantic Sturgeons in the Merrimack River, Massachusetts.* Transactions of the American Fisheries Society 122:1088-1103. 1993.

Buckley, J., and B. Kynard. *Yearly Movements of Shortnose Sturgeons in the Connecticut River.* Transactions of the American Fisheries Society. 114:813-820. 1985a.

13. Personal communication with Tom Savoy, Connecticut Department of Environmental Protection, Bureau of Natural Resources, Fisheries Division. Marine Fisheries, P.O. Box 719, Old Lyme, CT 06371. 1994.

14. Personal communication with Town of Richmond (RI) Building Inspector, 1993.

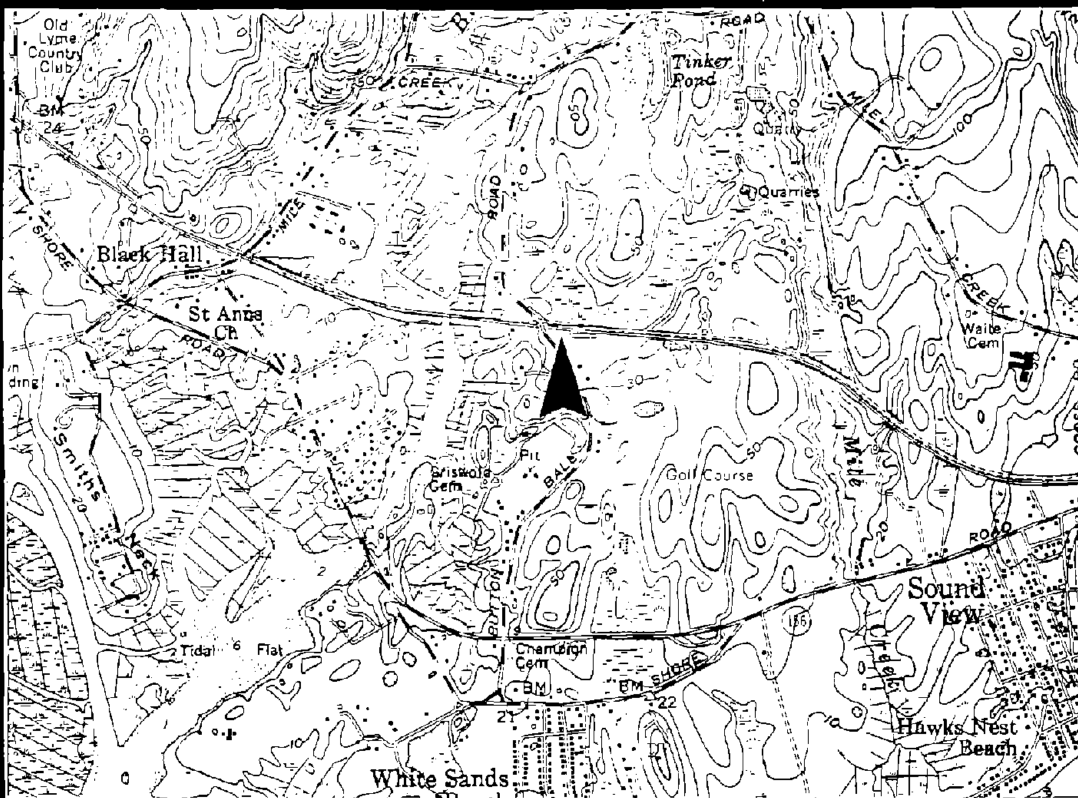
15. *Section 22, Coastal America Connecticut Wetlands Restoration Investigation*, Planning Directorate, Basin Management Division, Long Range Planning Branch, Department of the Army Corps of Engineers, New England Division, Waltham, MA. May 1994.

Appendix 8A

4.6 OLD LYME, CT: Paralleling Station

4.6.1 Site Location

OLD LYME, CT USGS Quadrangle
1958, Photorevised 1970, Scale 1"=2,000'



SITE DESCRIPTION

NAME: OLD LYME

TYPE: PARALLELING STATION

TOWN: OLD LYME, CT

LOCATION: AMTRAK MILEPOST 109.28
JOINT VENTURE CHAINAGE 109+2600
JOINT VENTURE DECIMAL 109.49

4.6.2 Field Investigation Findings

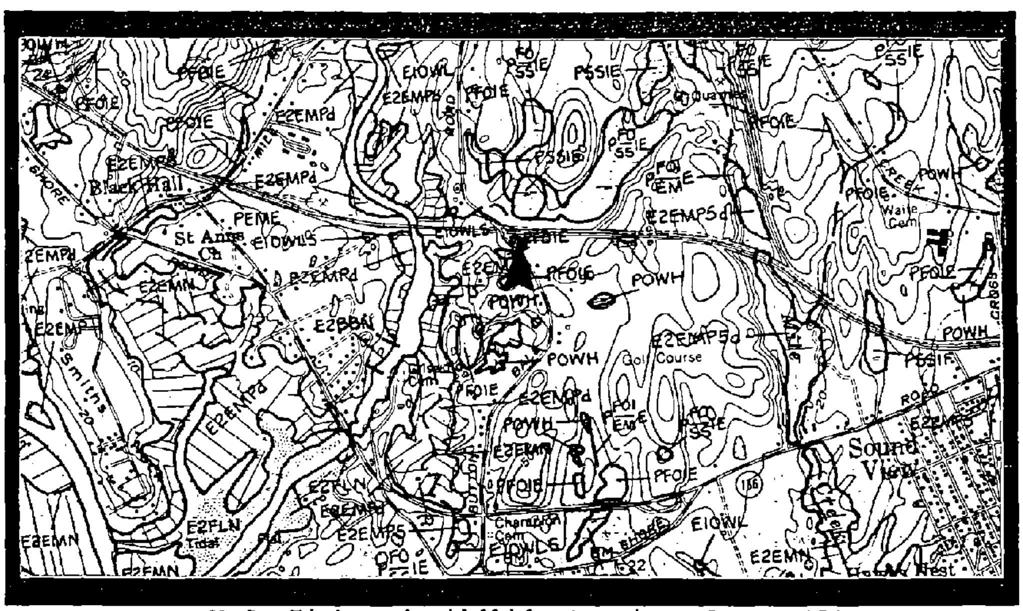
Field investigation indicates that a wetland (wooded swamp) area is located across the track from the station site. In addition, a small pond with limited associated wetlands is located to the south of the station site. Both wetland area have been flagged in the field and are located on the appended site plan.

4.6.3 Vegetation

The selected site location is comprised of upland vegetation, dominated by Oaks. The wooded swamp north of the tracks is classified as a Red Maple Swamp with vegetation typical of such an association. Selected representative vegetation surrounding the small pond to the south of the station site include: Sweet Pepperbush (Clethra alnifolia); Arrowwood (Viburnum sp.); Spice Bush (Lindera benzoin); and Red Maple (Acer rubrum).

4.6.4 National Wetlands Inventory

National Wetlands Inventory Map



U.S. Fish and Wildlife Service, Dec. 1979

The NWI and the USGS Maps both show the wetland area to the north to be a freshwater wetland. The NWI Map identifies the wetland as Palustrine shrub/scrub broad leaved deciduous seasonally saturated and Palustrine forested/shrub/scrub broad leaved deciduous seasonally saturated. The NWI does not identify any wetlands in the area of the selected station.

4.6.5 Soil Survey

Soil Survey Map

U.S.D.A., Soil Conservation Service July 1981

The soil in the station location is identified as Sf (Scarboro mucky fine sandy loam) on the Soil Survey of New London County, CT, Sheet 85. This soil is on the list of soil units that qualify as Hydric Soils. Field verification of the soils associated with the selected station site found that they are more well drained and sandy than reported in the Survey. This is probably due to filling associated with the railroad.

4.6.6 <u>Flood Plain Information</u>

The Old Lyme station site is located in the Zone B flood hazard boundary, or in between the 100 and 500 year flood hazard boundary. In addition the 100 year flood hazard boundary is located approximately 100 feet north of the railroad tracks. This information was obtained from Old Lyme, CT FIRM Map 090103-0016.

4.6.7 <u>Certification of Wetland Status</u>

Two wetland areas are located within 200 feet of the selected station location.