4.7 VIBRATION

4.7.1 Introduction

This chapter describes the vibration analysis methodology, vibration assessment criteria, existing vibration levels, vibration impacts and mitigation measures.

4.7.1.1 Resource Definition

Ground-borne vibration, in the context of transit, refers to movement of the ground caused by train movements and is usually the result of interactions between the steel wheels of the locomotives and rail cars and the rail surfaces. Examples of such interactions (and subsequent vibration) include train wheels over jointed rail and untrue railcar wheel with "flats." Unlike noise, which travels through the air, transit vibration typically travels along the surface of the ground. Depending on the geologic properties of the surrounding ground and the type of building structure exposed to transit vibration, the vibration propagation path between the track and the structure may be more or less efficient. Buildings with a solid foundation set in bedrock are "coupled" more efficiently to the surrounding ground and experience higher vibration levels than those buildings located in sandy soil.

Vibration induced by vehicle passbys is generally discussed in terms of displacement, velocity, or acceleration. However, human responses and responses by buildings and other objects are more readily described with velocity. Therefore, the average velocity (called the root mean square (RMS) velocity) is used to assess impacts associated with the human response to vibration (e.g. annoyance). The RMS vibration velocity levels are expressed in inches per second (ips) or vibration velocity levels in decibels (VdB). Vibration levels are referenced to 1-micro inch per second (mips).

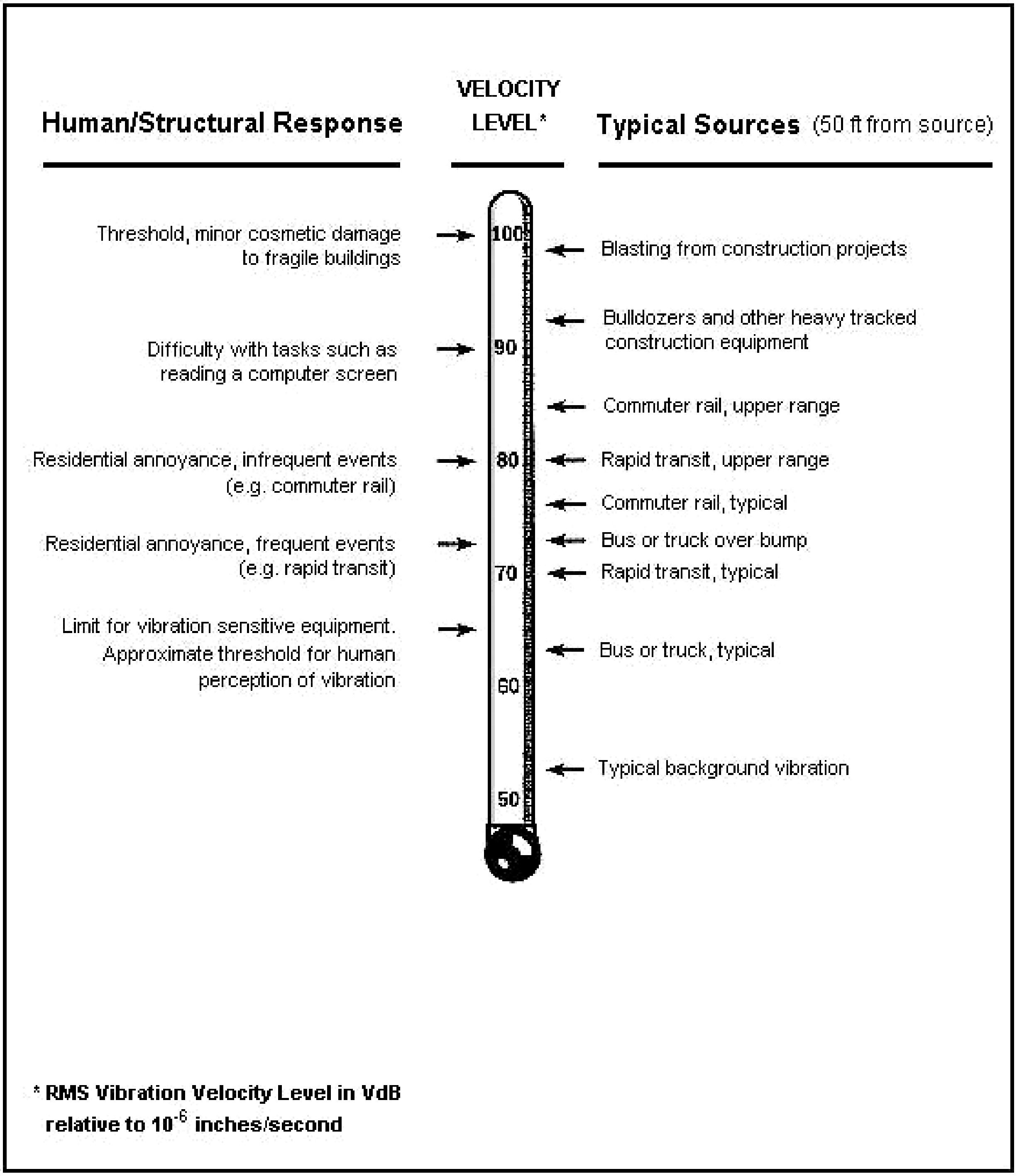
Typical ground-borne vibration levels from transit and other common sources are shown in Figure 4.7-1.

4.7.1.2 Regulatory Context

The vibration assessment for the South Coast Rail project was prepared in accordance with the FTA's Transit Noise and Vibration Impact Assessment[1] guidance manual. The FTA guidance manual sets forth the basic concepts, methodology, and procedures for evaluating vibration levels from transit operations. There are no state or local regulations regarding vibration levels.

[1] FTA-VA-90-1003-06; May 2006.

Figure 4.7-1 Typical Ground-Borne Vibration Levels



4.7.2 Existing Conditions

Existing land uses in the study area are exposed to a variety of vibration sources ranging from trucks and vehicle passbys along local roadways, MBTA commuter rail train passbys along the existing rail corridors (Stoughton commuter rail line), and freight rail operations along the existing New Bedford and Fall River freight rail corridors.

A vibration measurement program was conducted in the study area to determine the existing vibration levels along the alignments of the various project alternatives. The vibration measurements were obtained using a CEL Model 593 meter with a PCB Model 393C accelerometer. The measured vibration levels consisted of a one-second interval time history of the train passby event reported in RMS velocity level in VdB relative to 1-micro inch per second.

Vibration was measured at four locations relevant to the Stoughton and Whittenton Alternatives in 1995 and 2008. These measured vibration levels are representative of the existing vibration levels along each of the proposed South Coast Rail alternatives. The vibration measurement locations and measured vibration levels are summarized in Table 4.7-1.

Actual vibration measurements were used to evaluate existing conditions because they provide a more accurate assessment of vibration along the South Coast Rail alternatives than would modeling based on generalized soils or geologic information. Some geologic conditions are associated with efficient propagation characteristics that result in higher than normal vibration levels. For example, shallow bedrock, less than 30 feet below the surface, is likely to have efficient propagation. Other factors that can be important are soil type and stiffness. In particular, stiff clay soils have been associated with efficient vibration propagation. Investigation of soil boring records can be used to estimate the depth to bedrock and the presence of problem soil conditions. Geological maps or subsurface borings may be used at a later stage in the project if more detailed analysis of ground propagation is needed for specific sensitive receptors.

Table 4.7-1 Vibration Measurement Locations and Measurement Results (VdB)

ID	Measurement Location	City/Town	Land Use	Distance (feet)	Train Operation	Train Speed (mph)	Measured Vibration Level (VdB)
	Southern Triangle – Common to All Build Alternatives						
1	Beechwood Road	Freetown	Residential	75	Freight	20	88
2	Chace Road	Freetown	Residential	100	Freight	20	85
	Stoughton Alternative/Whittenton Alternative						
8	Pine Street (Waterfall Hills Apartments)	Canton	Residential	80	Commuter	35	95
9	1508 Central Street	Stoughton	Residential	60	Commuter	20	86

Source: KM Chng Environmental Inc., 1995 and 2008.

4.7.2.1 Southern Triangle

In 1995, vibration measurements along the Southern Triangle were obtained in Freetown (location 1 – Beechwood Road and location 2 – Chace Road). The condition of the freight rail tracks in this section of the rail corridor constrained train speeds to approximately 20 mph. The measured vibration levels from the freight rail operations ranged from 88 VdB at a distance of 75 feet at location 1, and 85 VdB at a distance of 100 feet at measurement location 2. The freight rail corridor consists of jointed track and rail cars with wheel flats, both of which contribute to higher vibration levels from freight operations. Since 1995, freight operations between New Bedford and Fall River have not changed. It was assumed therefore, that vibration along these corridors has not changed either. As a result, no new vibration measurements were obtained along these sections of the corridors during the 2008 vibration measurement data collection program.

Depending on the train speed, the condition of the vehicle wheels, and the ground propagation characteristics, the vibration levels at residences along the New Bedford and Fall River lines are expected to range from 85 to 95 VdB at a distance of 50 feet from the track, 78 to 88 VdB at a distance of 100 feet from the track, and 72 to 82 VdB at a distance of 200 feet from the track.

4.7.2.2 Stoughton/Whittenton Alternative

Vibration measurements were obtained along the Commuter Rail Stoughton Line as part of the 2008 measurement program. Vibration measurements were obtained at two locations, one in Canton (location 8 – Pine Street) and one near downtown Stoughton (location 9 – 1508 Central Street). As shown in Table 4.7-1, the measured vibration levels along this section of the Stoughton Line ranged from 86 VdB to 95 VdB at distances ranging from 60 to 80 feet from the tracks.

Vibration levels along the New Bedford Main Line (Weir Junction to Cotley Junction) are expected to range from 85 to 91 VdB at distances of 50 to 100 feet from the tracks. These vibration levels were not measured, but are expected to be similar to the freight rail vibration levels that were measured along the Southern Triangle. There are no train vibrations along the out-of-service segment of the corridor.

4.7.3 Analysis of Impacts and Mitigation

4.7.3.1 Introduction

This section addresses the vibration levels and potential impacts associated with the proposed commuter rail operations along the various corridor alignment alternatives. The remainder of this section describes the vibration analysis methodology, the assessment criteria, and the number and location of potential vibration impacts along each of the proposed alternative project corridors.

The Secretary's Certificate[2] required the DEIR to discuss consistency with applicable state and federal guidelines and regulations, and that the vibration impact assessment for the project alternatives identify impacted areas along the rail and bus routes and at the station sites. The Certificate further required the DEIR evaluate measures to avoid and minimize vibration impacts and include an assessment of impacts to wildlife.

The Secretary's Certificate on the DEIR, dated June 29, 2011, included the following requirements for the analysis of vibration.

[2] The Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, Certificate of the Secretary of Energy and Environmental Affairs on the Environmental Notification Form, South Coast Rail Project (EEA# 14346), April 3, 2009.

- "The FEIR should compare the estimated vibration levels to existing conditions and describe the actual change that will be experienced. This additional information should be provided for residential impacts along the Stoughton route as well as for historic buildings."[3]
- "The FEIR should include a mitigation plan with clear and specific commitments to address vibration impacts and an explanation of the reduction in VdB levels expected."

This section evaluates vibration impacts to residential and other buildings. Chapter 4.14, *Biodiversity, Wildlife, and Vegetation*, considers potential vibration impacts to wildlife.

4.7.3.2 Vibration Assessment Criteria

Table 4.7-2 presents FTA's vibration impact criteria for various land use categories, as well as the frequency of events. The criteria are related to ground-borne vibration causing human annoyance or interfering with the use of vibration-sensitive equipment (e.g., medical imagery equipment, audio/visual recording equipment, scientific sensing and measuring equipment). No buildings with vibration-sensitive special equipment (Category 1) were identified in the inventory of land uses in the project area. All sensitive receptors, such as residences and schools within the project area fall under Land Use Categories 2 and 3. The criteria for acceptable ground-borne vibration are expressed in terms of RMS velocity levels in VdB and are based on the maximum levels for a single event (L_{max}). In addition, vibration criteria have also been established for other specific buildings such as concert halls, recording studios, auditoriums and theaters that are also contained in Table 4.7-2.

Table 4.7-2 FTA Ground-Borne Vibration Impact Criteria

Receptor Land use		RMS Vibration Levels (VdB)		
Category	Description	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
1	Buildings where low vibration is essential for interior operations	65	65	65
2	Residences and buildings where people normally sleep	72	75	80
3	Daytime institutional receptors	75	78	83
Specific Buildings	TV/Recording Studios/Concert Halls	65	65	65
	Auditoriums	72	80	80
	Theaters	72	80	80

Notes:
1 "Frequent Events" defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2 "Occasional Events" defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
3 "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.
Source: Federal Transit Administration, Transit Noise and Vibration Impact Assessment, FTA-VA-90-1003-06, May 2006.

For the section of the project corridor between Stoughton Station and Myricks Junction, the total number of daily train operations is 40 (20 northbound trains and 20 southbound trains). As a result, the

[3] The vibration impact analysis was performed by determining the distance from the rail corridor within which a vibration impact is expected to occur, using the typical vibration analysis methodology defined in the FTA guidance manual. The specific existing vibration levels were not measured at each of the 369 potentially impacted receptors under the Stoughton Alternatives, although typical existing conditions vibration information is provided in Table 4.7-1.

FTA vibration impact criterion for occasional events was used to assess impacts along this section of the rail corridor. For residential receptors that experience occasional train events, the FTA vibration impact level is 75 VdB. Note that this approach to the vibration criteria differs from the DEIS/DEIR vibration analysis where an 80 VdB impact threshold was used for all areas.

For the section of the rail corridor between Myricks Junction and New Bedford, and Myricks Junction and Fall River, the total number of daily train operations is 20 for each of these lines (10 northbound trains and 10 southbound trains). As a result, the FTA vibration impact criterion for infrequent events was used to assess impacts along these sections of the rail corridor. For residential receptors that experience infrequent train events, the FTA vibration impact level is 80 VdB.

The vibration criteria in Table 4.7-2 do not take into account situations where vibration impacts occur under existing conditions. To address areas with existing vibration impacts, the FTA guidance manual presents additional criteria for projects along existing passenger rail or freight corridors.

- For heavily used rail corridors (defined as greater than 12 trains per day), the proposed project is considered to cause a vibration impact if it approximately doubles the number of vibration events per day or increases vibration levels by 3 VdB or more in comparison to the existing condition. For the South Coast Rail project, this criterion applies to the Stoughton Line north of Stoughton Station, and the Northeast Corridor.

- For existing rail corridors with infrequent use (defined as fewer than five trains per day), FTA recommends that the standard vibration impact criteria be used (Table 4.7-2). The Fall River Secondary and New Bedford Mainline in the Southern Triangle are examples of infrequently used rail corridors under FTA's definition.

Based on the FTA's guidelines for existing rail corridors, there would be no vibration impacts along the Northeast Corridor or the active Stoughton Line, since there would be no increase in the vibration levels from the project. Adding an additional track to the existing rail corridor that would move the trains approximately 20 feet closer to the residences along the rail corridor would result in an increase in vibration levels of less than 3 VdB. For example, a train locomotive traveling at 50 mph would generate a vibration level of 78 VdB at a receptor located at a distance of 100 feet from the nearest track. If an additional track were added to the rail corridor that moved the trains 20 feet closer to the receptor, the vibration level would be 80 VdB at a distance of 80 feet from the nearest track. Since the addition of the new track would not result in an increase in vibration level of more than 3 VdB, in accordance with the FTA's guidelines for an active rail corridor, there would be no appreciable vibration impact from the addition of the new track. However, a more detailed vibration analysis should be performed during final design when drawings showing the location of the proposed new tracks are available and can be used to determine the distance to the nearest receptors.

4.7.3.3 Impact Assessment Methodology

The vibration assessment was prepared in accordance with the FTA's Transit Noise and Vibration Impact Assessment[4] guidance manual. The FTA guidance manual sets forth the basic concepts, methodology and procedures for evaluating vibration levels from transit operations. Key inputs included the distance between the receptors and track, train operating speed, and adjustments accounting for special track work (turnouts, crossovers etc.), as well as the propagation of vibration into buildings.

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[4] FTA-VA-90-1003-06; May 2006

None of the alternatives have the potential to result in vibration levels that could cause minor structural damage (such as cracks in plaster walls) (e.g. 100 VdB for fragile buildings). Therefore, the focus of the analysis is on human annoyance from vibration based on the FTA criteria.

Generalized Base Vibration Curve

The FTA vibration model combines various algorithms with empirically developed ground surface curves to estimate transit vibration levels at various distances from the track for average soil conditions. FTA surface vibration curves (adjusted for speed) were used to predict ground-borne vibration levels from transit operations at receptor locations along each of the project alternative corridors (Figure 4.7-2). In general, vibration levels increase at higher train speeds. The FTA model was used to determine the impact distance from the rail corridor within which the project transit vibration levels would exceed the FTA impact criteria. As shown in Figure 4.7-2, vibration curves are specified for locomotives, lighter commuter rail passenger cars, and rubber tired vehicles (buses).

The FTA guidance manual indicates that the vibration levels generated by both diesel and electric locomotives use the same upper curve shown in Figure 4.7-2. As a result, the vibration impact assessment for both the diesel and electric alternatives for the South Coast Rail project would be the same, assuming the same operating speed. To be conservative, the slightly faster electric commuter rail speeds were assumed for the vibration impact analyses.

Using the electric train speed data along each section of the rail corridor, an impact distance was determined using the locomotive vibration curve (adjusted for train speed). The relationship between impact distance and train speed for the FTA impact criteria of 75 VdB and 80 VdB are shown in Table 4.7-3. These impact distances were then used in conjunction with the aerial photographs to determine the number and location of the impacted residential receptors.

Table 4.7-3 Impact Distance vs. Train Speed, Electric Alternatives

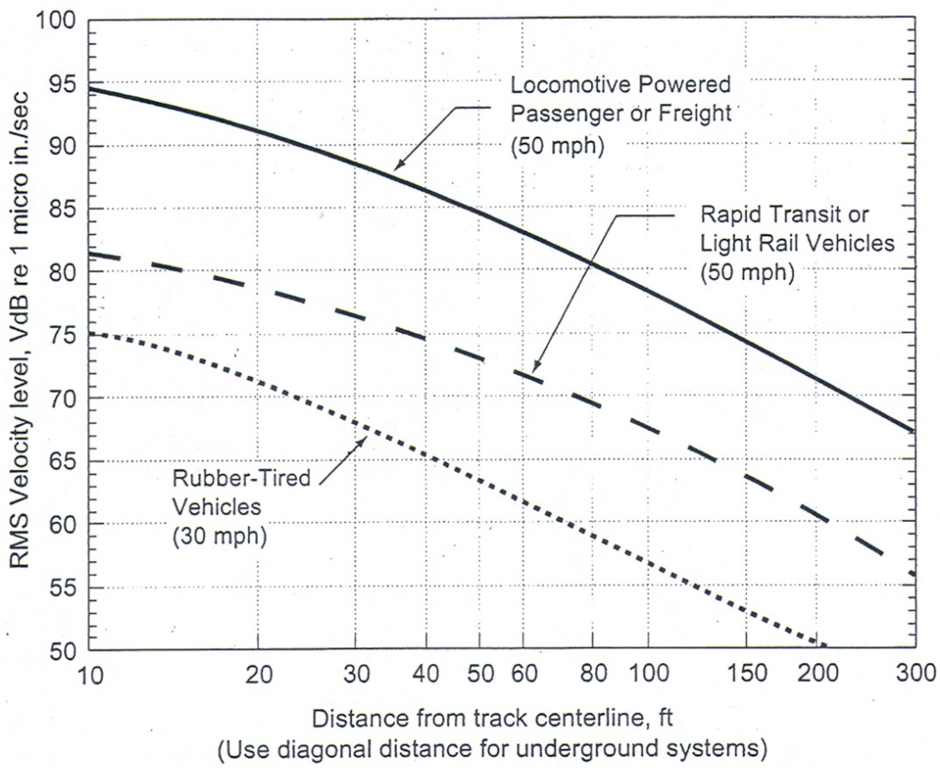
Train Speed	Impact Distance[1] to 80 VdB	Impact Distance[1] to 75 VdB
100 mph	160 feet	250 feet
90 mph	140 feet	230 feet
80 mph	130 feet	210 feet
70 mph	115 feet	185 feet
60 mph	100 feet	165 feet
50 mph	85 feet	140 feet
40 mph	70 feet	115 feet
30 mph	50 feet	90 feet
20 mph	32 feet	60 feet

1 Distance from track centerline within which a vibration impact is expected to occur.

Ground Propagation

The vibration curves shown in Figure 4.7-2 are for generalized ground propagation characteristics. Although it is known that geographic conditions have a significant effect on vibration levels, it is rarely possible to develop more than a generalized assessment of the ground vibration propagation characteristics without a much more detailed vibration measurement program. For example, there are conditions where ground-borne vibration propagates much more efficiently than normal. Shallow bedrock, less than 30 feet below the surface, is likely to have efficient propagation because much of the energy that would normally radiate down into the ground is reflected back towards the surface by the bedrock. The result is higher than normal ground surface vibration levels. Other factors that have an effect on vibration propagation are soil type and stiffness. In particular, stiff clay soils are also associated with efficient vibration propagation. However, the FTA recommends using the generalized ground propagation vibration curves in Figure 4.7-2 for Environmental Assessment and Environmental Impact Statement level analysis.

Figure 4.7-2 FTA Generalized Ground-Surface Vibration Curves



Source: Transit Noise and Vibration Impact Assessment, Federal Transit Administration, Washington, D.C., May 2006.

Special Trackwork

Trains traveling over switches or other special track work with gaps in the rail generate vibration levels that are 10 VdB higher than the levels indicated by the curves shown in Figure 4.7-2. For example, a locomotive traveling at a speed of 50 mph would generate a vibration level of 80 VdB at a distance of 80 feet from the tracks. A locomotive traveling at a speed of 50 mph over a switch would generate a vibration level of 80 VdB at a radial distance of approximately 225 feet from the switch. For the Build Alternatives, the vibration levels from switches located at each of the major junctions (Weir Junction, Myricks Junction, Cotley Junction, Whittenton Junction,) were evaluated, along with the switches associated with the proposed layover facilities.

The vibration impact assessment of the track switches along each of the project alternatives indicates that only one location has a receptor that is located within 225 feet of a switch that would result in a vibration impact of 80 VdB. A residential receptor on Ingell Street near Weir Junction would be exposed to a vibration level of 80 VdB during a train locomotive passby over the switch at Weir Junction. This impacted receptor is included in the vibration assessment for the Southern Triangle. No vibration impacts are expected to occur near any of the other switch locations associated with the other project alternatives.

Stations and Layover Facilities

At train stations and layover facilities, train-related vibration levels are generally significantly lower due to the slower train speeds. For example, a train traveling at a speed of 20 mph as it enters or leaves a train station would generate a vibration level of 80 VdB at a distance of 32 feet from the track. No vibration is generated while the trains are stopped at the stations. For a layover facility that has switches, a train traveling at 20 mph would generate a vibration level of 80 VdB at a radial distance of 100 feet from the switch. No vibration impacts were found at the two selected layover facilities (Weaver's Cove East and Wamsutta).

In the vicinity of the proposed train stations along each of the project corridors, acceleration and deceleration train speed profiles were used to account for trains stopping at the stations.

Track Condition

The vibration analysis assumed the use of continuous welded rail for each of the Build Alternatives. Continuous welded rail generates less vibration relative to other track configurations, such as jointed rail. In addition, since the heavier train locomotives generate higher vibration levels than the lighter passenger rail cars, the vibration analysis focused primarily on the vibration levels generated by the locomotives.

4.7.3.4 Impacts of Alternatives by Element

No-Build (Enhanced Bus) Alternative

The bus services added as part of the No-Build Alternative would not generate vibration levels sufficient to cause human annoyance assuming appropriate pavement maintenance over time.

Southern Triangle (Common to All Build Alternatives)

Portions of the rail lines within the southern part of the South Coast Rail study area are common to all Build Alternatives. These rail lines form a rough triangular shape running south from Myricks Junction to Fall River (the Fall River Secondary) and from Weir Junction through Myricks Junction to New Bedford (the New Bedford Main Line), and are therefore referred to as the Southern Triangle. Although there is no commuter rail in the Southern Triangle, the existing tracks in this area are used by freight rail resulting in associated vibration levels under existing conditions, as described in Section 4.7.2.1.

As shown in Table 4.7-4, there are a total of 215 impacted receptors along the Southern Triangle section of the project corridor. The majority of the vibration impacts would occur in Fall River, where there is dense development in close proximity to the rail alignment. Eight of these impacted receptors are multi-unit apartment buildings and the rest are single-family homes. There are no institutional receptors or buildings with vibration sensitive equipment that would be impacted along the Southern Triangle. The general location of these impacted receptors (by municipality) is described in Table 4.7-5. Table 4.7-5 also shows the results of the vibration mitigation analysis for the impacted receptors along the Southern Triangle. The locations where ballast mats are recommended are shown in Figures 4.6-5f through 4.6-5i, and 4.6-4d through 4.6-4h in Chapter 4.6, *Noise* (the figures show both noise and vibration mitigation together to reduce the number of maps required).

Table 4.7-4 Summary of Potential Vibration Impacts—Southern Triangle

Segment	Municipality	Impacted Residences[1]
New Bedford Main Line -	Taunton	24
Weir Junction to Myricks Junction	Berkley	12
New Bedford Main Line -	Berkley	0
Myricks Junction to New Bedford	Lakeville	7
	Freetown	9
	New Bedford	10
Fall River Secondary	Berkley	8
	Lakeville	0
	Freetown	22
	Fall River	123
Totals		215

1 Impact = vibration levels equal to or greater than 80 VdB

Table 4.7-5 Potential Vibration Impacts by Sensitive Receptor—Southern Triangle

Segment	Municipality	Street	Impacted Receptors	Length of Ballast Mat	Cost at $180/ft.	Cost per Receptor	Cost Effective
Weir Junction to Myricks Junction	Taunton	Ingell Street	2	400 feet	$72,000	$36,000	No
	Taunton	Hart Street/	6	900 feet	$162,000	$14,730	Yes
	Taunton	Alegi Avenue	5				
	Taunton	Williams Avenue/	1	1150 feet	$207,000	$29,570	Yes
	Taunton	Plain Street	6				
	Taunton	Debra Drive/	3	1200 feet	$216,000	$54,000	No
	Taunton	Plain Street West	1				
	Berkley	Crabapple Drive/	2	550 feet	$99,000	$49,500	No
	Berkley	Cotley Street	1	200 feet	$36,000	$36,000	No
	Berkley	Padelford Street	3	500 feet	$90,000	$30,000	Yes
	Berkley	Mill Village Road	1	200 feet	$36,000	$36,000	No
	Berkley	Myricks Street/	2	1300 feet	$234,000	$46,800	No
	Berkley	Grove Street	3				
Myricks Junction to New Bedford	Lakeville	Malbone Street	1	200 feet	$36,000	$36,000	No
	Lakeville	Howland Street	3	900 feet	$162,000	$54,000	No
	Lakeville	Howland Street	3	900 feet	$162,000	$54,000	No
	Freetown	Braley Road	5	700 feet	$126,000	$25,200	Yes
	Freetown	Braley Road	3	600 feet	$108,000	$36,000	No
	Freetown	Chipaway Drive	1	200 feet	$36,000	$36,000	No
	New Bedford	Lynn Street	2	300 feet	$54,000	$27,000	Yes
	New Bedford	Purchase Street	6	700 feet	$126,000	$21,000	Yes
	New Bedford	Purchase Street	2	250 feet	$45,000	$22,500	Yes
Myricks Junction to Fall River	Berkley	Mill Street	6	900 feet	$162,000	$27,000	Yes
	Berkley	Adams Lane	2	250 feet	$45,000	$22,500	Yes
	Freetown	Richmond Road	3	500 feet	$90,000	$30,000	Yes
	Freetown	Richmond Road	2	400 feet	$72,000	$36,000	No
	Freetown	Colonial Drive	1	200 feet	$36,000	$36,000	No
	Freetown	Richmond Road	1	200 feet	$36,000	$36,000	No
	Freetown	Richmond Road	1	200 feet	$36,000	$36,000	No
	Freetown	Richmond Road	1	200 feet	$36,000	$36,000	No
	Freetown	Forge Road	4	600 feet	$108,000	$27,000	Yes
	Freetown	Elm Street	1	200 feet	$36,000	$36,000	No
	Freetown	Elm Street	2	450 feet	$81,000	$40,500	No
	Freetown	Green Lane/	3	1000 feet	$180,000	$45,000	No
	Freetown	Sampson Lane	1				
	Freetown	High Street/	1	300 feet	$54,000	$27,000	Yes
	Freetown	Alexander Drive	1				

Segment	Municipality	Street	Impacted Receptors	Length of Ballast Mat	Cost at $180/ft.	Cost per Receptor	Cost Effective
	Fall River	Leeward Road	9	1200 feet	$216,000	$24,000	Yes
	Fall River	Rolling Green Drive	3*	1100 feet	$198,000	<$30,000	Yes
	Fall River	North Main Street	19	2600 feet	$468,000	$24,630	Yes
	Fall River	North Main Street	1	200 feet	$36,000	$36,000	No
	Fall River	Wayland Street	2	250 feet	$45,000	$22,500	Yes
	Fall River	Alton Street	1	200 feet	$36,000	$36,000	No
	Fall River	North Main Street	13	1000 feet	$180,000	$13,850	Yes
	Fall River	Pickering Street/	3*				
	Fall River	Clinton Street/	2	1000 feet	$180,000	$25,715	Yes
	Fall River	St. James Street	2				
	Fall River	Murry Street/	17				
	Fall River	Cory Street/	6				
	Fall River	Ballard Street/	3				
	Fall River	Almy Street/	9				
	Fall River	Railroad Avenue/	1	2000 feet	$360,000	$7,350	Yes
	Fall River	North Court Street/	7				
	Fall River	Brownell Street/	4				
	Fall River	Thompson Street	2				
	Fall River	Dyer Street	3	400 feet	$72,000	$24,000	Yes
	Fall River	Durfee Street/	4	700 feet	$126,000	$18,000	Yes
	Fall River	Cedar Street	3				
	Fall River	Maple Street	2*	400 feet	$72,000	$18,000	Yes
	Fall River	Meadow Street	7	600 feet	$108,000	$15,430	Yes
Totals			215				

* This impacted receptor is a multi-unit apartment buildings.

Stoughton Alternatives

The Stoughton Alternatives (Electric and Diesel) would provide commuter rail service to South Station using the Northeast Corridor, Stoughton Line, New Bedford Main Line, and Fall River Secondary.

Along the Stoughton line between Stoughton Station and Weir Junction, the vibration assessment indicates that there are a total of 154 impacted receptors (see Table 4.7-6). Eight of these impacted receptors are multi-unit apartment buildings and the rest are single-family homes. The general locations of these impacted receptors (by street) are described in Table 4.7-7. Table 4.7-7 also shows the results of the vibration mitigation analysis for the impacted receptors along the Stoughton Line. The locations where ballast mats are recommended are shown in Figures 4.6-6a through 4.6-6g in Chapter 4.6, *Noise* (the figures show both noise and vibration mitigation together to reduce the number of maps required).

There are no institutional receptors or buildings with vibration sensitive equipment that would be impacted by the Stoughton Alternatives. In addition, the vibration levels at the Easton Historic Train

Station (which experienced train-related vibration in the past) and other historic buildings in Easton Village would be below the 100 VdB vibration threshold for the onset of minor structural damage (such as small cracks in plaster walls) to fragile and historic buildings.

Table 4.7-6 Summary of Potential Vibration Impacts—Stoughton Alternative (Diesel and Electric)

Segment	Municipality	Impacted Residences[1]
Stoughton Station to Weir Junction	Stoughton	22
	Easton	76
	Raynham	34
	Taunton	22
Total		154

1 Impact = vibration levels equal to or greater than 80 VdB

As discussed further in the methodology section, there would be no project related vibration impacts north of Stoughton Station.

Table 4.7-7 Potential Vibration Impacts by Sensitive Receptor—Stoughton Alternative

Segment	Municipality	Street	Impacted Receptors	Length of Ballast Mat	Cost at $180/ft.	Cost per Receptor	Cost Effective
Stoughton Station to Weir Junction	Stoughton	Brock Street	1	400 feet	$72,000	$24,000	Yes
	Stoughton	Washington Street	2				
	Stoughton	Rogers Drive/	8	1,200 feet	$216,000	$21,600	Yes
	Stoughton	Plain Street	2				
	Stoughton	Columbus Avenue	2	600 feet	$108,000	$54,000	No
	Stoughton	Smyth Street/	2	400 feet	$72,000	$24,000	Yes
	Stoughton	Washington Street	1				
	Stoughton	Morton Street/	1	800 feet	$144,000	$48,000	No
	Stoughton	Washington Street	2				
	Stoughton	Washington Street	1	200 feet	$36,000	$36,000	No
	Easton	Partridge Way	1	200 feet	$36,000	$36,000	No
	Easton	Mullen Lane	1	200 feet	$36,000	$36,000	No
	Easton	Linden Street/	1	700 feet	$126,000	$42,000	No
	Easton	Elm Street	2				
	Easton	Main Street	1	200 feet	$36,000	$36,000	No
	Easton	Center Street/	10	3,000 feet	$540,000	$20,770	Yes
	Easton	Williams Street/	2				
	Easton	Avis Circle/	1				
	Easton	Baldwin Street/	13				
	Easton	off Center Street	1	200 feet	$36,000	$36,000	No
	Easton	Tait Avenue	4	800 feet	$144,000	$36,000	No

Segment	Municipality	Street	Impacted Receptors	Length of Ballast Mat	Cost at $180/ft.	Cost per Receptor	Cost Effective
	Easton	Gary Lane	2	500 feet	$90,000	$45,000	No
	Easton	Laurel Drive	3	400 feet	$72,000	$24,000	Yes
	Easton	Short Street/	6	1,300 feet	$234,000	$23,400	Yes
	Easton	Lantern Lane	4				
	Easton	Depot Street	1	200 feet	$36,000	$36,000	No
	Easton	Purchase Street/	4	1,100 feet	$198,000	$33,000	No
	Easton	Granite Lane	2				
	Easton	Kennedy Circle	11	1,800 feet	$324,000	$29,455	Yes
	Easton	Prospect Street	3	400 feet	$72,000	$24,000	Yes
	Easton	Justin Drive	1	200 feet	$36,000	$36,000	No
	Easton	Foundry Street	2	400 feet	$72,000	$36,000	No
	Raynham	off Bridge Street	1	200 feet	$36,000	$36,000	No
	Raynham	Bridge Street	3	400 feet	$72,000	$24,000	Yes
	Raynham	Elm Street West	6	600 feet	$108,000	$18,000	Yes
	Raynham	Carver Street	2	250 feet	$45,000	$22,500	Yes
	Raynham	Britton Street	9	500 feet	$90,000	$10,000	Yes
	Raynham	Wampanoag Road/	5	2,100 feet	$378,000	$29,075	Yes
	Raynham	King Philips Street/	5				
	Raynham	Chickering Road	3				
	Taunton	Thrasher Street/	4	600 feet	$108,000	$15,430	Yes
	Taunton	Malcolm Circle	3				
	Taunton	Longmeadow Road	1	200 feet	$36,000	$36,000	No
	Taunton	Dean Street	1	200 feet	$36,000	$36,000	No
	Taunton	Summer Street	5	500 feet	$90,000	$18,000	Yes
	Taunton	High Street/	5*	1,200 feet	$216,000	$27,000	Yes
	Taunton	Paul Bunker Drive	3*				
Totals			154				

* This impacted receptor is a multi-unit apartment buildings.

Whittenton Alternatives

The Whittenton Alternatives (Electric and Diesel) would provide commuter rail service to South Station through Stoughton, connecting to the existing Stoughton Line using the Whittenton Branch through the City of Taunton.

The Whittenton Alternatives would result in 202 vibration impacts along the Stoughton Line, Whittenton Branch and Attleboro Secondary (see Table 4.7-8). Five of these impacted receptors are multi-unit apartment buildings on Bay Street in Taunton. The rest of the impacted receptors are single-family residences. There are no institutional receptors or buildings with vibration sensitive equipment that would be impacted by the Whittenton Alternative. The general locations of the impacted receptors along the Attleboro Secondary and Whittenton Branch (by street) are shown in Table 4.7-9.

The vibration impacts along the Stoughton line in Stoughton, Easton, and Raynham are common to both the Stoughton and Whittenton Alternatives. The Whittenton Alternatives have greater total vibration impacts than the Stoughton Alternatives because of the dense development close to the Attleboro Secondary through downtown Taunton that is used by the Whittenton Alternatives, but not by the Stoughton Alternatives.

Table 4.7-8 Summary of Potential Vibration Impacts—Whittenton Alternative (Diesel and Electric)

Segment	Municipality	Impacted Residences
Stoughton Line	Stoughton	22
	Easton	76
	Raynham	12
Whittenton Branch	Raynham	5
	Taunton	12
Attleboro Secondary	Taunton	75
Totals		**202**

Table 4.7-9 Potential Vibration Impacts by Sensitive Receptor—Whittenton Alternative

Segment	Municipality	Street	Impacted Residences
Stoughton Line	See Table 4.7-7, for Brock Street in Stoughton to Carver Street in Raynham		110
Whittenton Branch	Raynham	King Philip Street	3
	Raynham	Regan Circle	2
	Taunton	Redwood Drive	3
	Taunton	Bay Street	5
	Taunton	Whittenton Street	4
Attleboro Secondary	Taunton	Edwards Avenue	6
	Taunton	Horton Street	14
	Taunton	Granite Street	1
	Taunton	Walnut Street	15
	Taunton	Cohannet Street	10
	Taunton	East Walnut Street	20
	Taunton	Weir Street	8
	Taunton	Weir Avenue	2
Totals			**202**

As discussed in the methodology section, there would be no project related vibration impacts north of Stoughton Station.

4.7.3.5 Temporary Construction Impacts

Typical vibration levels from construction equipment at a reference distance of 25 feet are: 104 VdB for an impact pile driver; 87 VdB for a bulldozer; 86 VdB for a loaded truck; and 79 VdB for a jackhammer. In general, if most construction activity is located more than 75 feet from the nearest sensitive receptors, the estimated vibration levels would be expected to be below the FTA annoyance criterion of 80 VdB. However, pile driving is the major impact device that generates the highest vibration levels during construction. Pile driving located within 50 feet of a building could result in vibration impacts, if pile driving is required for this project. At this distance, the vibration levels from pile driving would be below the onset of minor building damage (cracks in plaster walls) threshold of 100 VdB for fragile buildings. To get the vibration levels below the human annoyance level of 80 VdB, the pile driving activity would require approximately 175 feet from the nearest sensitive receptor.

Construction-period vibration impacts would be assessed for each alternative during the final design phase, when construction methods and the locations of specific types of construction equipment have been identified.

During construction, if pile driving is required, vibration impacts can be reduced by pre-augering the hole so that the actual impact driving of the pile would only occur during the last few feet of installation. Another mitigation measure is sonic or vibratory pile driving (93 VdB at 25 feet), where the pile is vibrated into the ground eliminating the need for an impact hammer. These measures for reducing vibration impact would be considered in the development of construction plans for areas where pile driving could be required in proximity to sensitive receptors.

4.7.4 Summary of Impacts

The results of the vibration impact assessment for each of the South Coast Rail alternatives are summarized in Table 4.7-10. This summary includes the vibration impacts from the Southern Triangle from Weir Junction to New Bedford and Fall River that are common to all Build Alternatives.

The Whittenton Alternatives result in 48 more impacted receptors than the Stoughton Alternatives, with the Attleboro Secondary segment of the Whittenton Alternatives being the primary cause of the greater impacts. The noted vibration levels reflect annoyance and would not rise to a level considered to cause structural damage.

Table 4.7-10 Summary of Potential Vibration Impacts without Mitigation by Alternative

Alternative	Impacted Residences
No-Build (Enhanced Bus) Alternative	0
Stoughton Alternatives	369
Whittenton Alternatives	417

4.7.5 Mitigation

4.7.5.1 Overview of MBTA Vibration Mitigation Policy

The need for vibration mitigation in a specific location is determined based on the magnitude of the impacts and consideration of other factors such as feasibility and cost-effectiveness. The U.S. Army Corps of Engineers does not have mitigation evaluation criteria for commuter rail projects and therefore relies on the guidance of the federal agency with special expertise in this area, the FTA. The FTA guidance requires consideration of mitigation for vibration impacts and outlines the available mitigation options. FTA allows transit providers to develop local agency-specific noise and vibration mitigation policies detailing the analysis process and criteria for their projects.

MBTA has developed a noise mitigation policy consistent with the FTA guidance (See Section 4.6.3.6). The MBTA noise mitigation policy establishes a cost effectiveness criterion of $30,000 per dwelling unit. MBTA also utilizes this same cost effectiveness criterion ($30,000 per benefited receptor) for assessing potential vibration mitigation measures.

4.7.5.2 Stoughton Alternatives Vibration Mitigation Plan

Several mitigation measures were assumed to be incorporated in the project design and were included in the vibration modeling analysis:

- Continuously welded rail would be used to minimize vibrations caused by wheels impacting rail joints.
- Ballast (the crushed rock under the tracks) and sub-ballast (gravel base) would be placed to standard depths established by the MBTA to reduce transmission of vibration from the tracks to the ground.
- Turnouts would be located at least 100 feet away from homes and other sensitive buildings, to minimize higher vibration levels due to passage of wheels over the gap in turnout frogs.
- Trains and track would be maintained in such a manner as to minimize vibration generated by the trains, including regular wheel re-truing to eliminate wheel flats.

Additional mitigation measures, such as ballast mats (rubber mats placed under the ballast) would be provided where vibration mitigation is justified, and soil conditions are appropriate, as determined by on-site inspection of each potential mitigation location. Ballast mats can give vibration reductions of between 3 and 10 VdB. Ballast mats are very effective in attenuating frequencies of greater than 100 Hz found in vibrations near the source, and for track-receptor geometries traveling through dense soil and rock. They are not particularly effective at attenuating lower frequencies, especially those in the 10-30 Hz range found at distances greater than 60 feet and expected at sites with soft or sandy soil conditions. Therefore, a more detailed evaluation of the source-receiver soil conditions would be required during final design to assess the effectiveness of the ballast mat at impacted receptor locations along the corridor. Ballast mats cannot be installed within 50 feet of grade crossings; exact distances from each grade crossing would be determined at the time of final design.

The vibration analysis identified a total of 369 residences likely to be impacted by the Stoughton Electric Alternative. Based on the length of the ballast mat, and the cost of this mat at $180 per track foot, a mitigation price was determined for each receptor location. Any mitigation priced more than $30,000 per receptor was considered to not be cost-effective, based on the same MBTA cost-effectiveness criteria used for noise impacts (see Section 4.6.3.6). Those under $30,000 were considered cost-effective. Of the total impacted receptors, 296 (39 locations) were considered to be cost-effective for vibration mitigation. Approximately 33,350 linear feet of ballast mat would be required along the rail corridor at a cost of approximately $6,003,000. The locations of the proposed ballast mats for the Stoughton Electric Alternative are discussed by town below.

Stoughton

Ballast mats were considered cost-effective at three locations in Stoughton (Figures 4.6-6a and 4.6-6b):

- along Brock Street/Washington Street;
- along Rogers Drive/Plain Street; and
- along Smyth Street/Washington Street.

Easton

Ballast mats were considered cost-effective at five locations in Easton (Figures 4.6-6b, 4.6-6d, 4.6-6e):

- along Center Street/Williams Street/Avis Circle/Baldwin Street;
- along Laurel Drive;
- along Short Street/Lantern Lane;
- along Kennedy Circle; and
- along Prospect Street.

Raynham

Ballast mats were considered cost-effective at five locations in Raynham (Figure 4.6-6f):

- Bridge Street;
- Elm Street West;
- Carver Street;
- Britton Street; and
- Wampanoag Road/King Phillip Street/Chickering Road.

Taunton

Ballast mats were considered cost-effective at five locations in Taunton (Figure 4.6-6g):

- along Thrasher Street/Malcolm Circle;
- along Summer Street;
- along High Street/Paul Bunker Drive;
- along Hart Street/Alegi Avenue; and
- along Williams Avenue/Plain Street.

Berkley

Ballast mats were considered cost-effective at three locations in Berkley (Figures 4.6-5f and 4.6-4d):

- along Padelford Street;
- along Mill Street; and
- along Adams Lane.

Lakeville

Ballast mats were not considered cost-effective in Lakeville.

Freetown

Ballast mats were considered cost-effective at four locations in Freetown (Figures 4.6-5h and 4.6-4d):

- along Braley Road;
- along Richmond Road;
- along Forge Road; and
- along High Street/Alexander Drive.

New Bedford

Ballast mats were considered cost-effective at three locations in New Bedford (Figure 4.6-5i):

- along Lynn Street; and
- along Purchase Street.

Fall River

Ballast mats were considered cost-effective at eleven locations in Fall River (Figures 4.6-4d-h):

- along Leeward Road;
- along Rolling Green Drive;
- along North Main Street;
- along Pickering Street/Clinton Street/St. James Street;
- along Murry Street/Cory Street/Ballard Street/Almy Street/Railroad Avenue/North Court Street/Brownwell Street/Thompson Street;
- along Dyer Road;
- along Durfee Street/Cedar Street;

- along Maple Street; and
- along Meadow Street.

For the impacted receptor located within 225 feet of the switch at Weir Junction, “frogs” (sections of railroad track at a switch that guide rail car wheels from one track to the other) with spring-loaded mechanisms can be used rather than conventional frogs without spring-loaded mechanisms. The spring-loaded mechanism closes the gaps between the running rails. This substantially reduces the vibration emanating from switches and thus eliminates the impact at this receptor.

4.7.5.3 Whittenton Alternatives Vibration Mitigation Plan

Along shared segments, the vibration mitigation under the Whittenton Alternatives would be the same as described above for the Stoughton Alternatives (e.g. Southern Triangle and portion of Stoughton Line). Table 4.7-11 below presents the vibration mitigation analysis for the Whittenton Branch and Attleboro Secondary portions of the Whittenton Alternatives. A total of 6,300 feet of ballast mat costing $1,134,000 was found to be cost effective for these segments.

Table 4.7-11 Whittenton Alternatives Vibration Mitigation—Whittenton Branch/Attleboro Secondary

Municipality	Street	Impacted Receptors	Length of Ballast Mat	Cost at $180/ft	Cost per receptor	Cost Effective
Raynham	King Philip Street	3	400 ft	$72,000	$24,000	Yes
Raynham	Regan Circle	2	400 ft	$72,000	$36,000	No
Taunton	Redwood Drive	3	600 ft	$108,000	$36,000	No
Taunton	Bay Street	5	700 ft	$126,000	$25,200	Yes
Taunton	Whittenton Street	4	2,300 ft	$414,000	$103,500	No
Taunton	Edwards Avenue	6	1,200 ft	$216,000	$36,000	No
Taunton	Horton Street	14	1,700 ft	$306,000	$21,857	Yes
Taunton	Granite Street	1	200 ft	$36,000	$36,000	No
Taunton	Walnut Street	15	900 ft	$162,000	$10,800	Yes
Taunton	Cohannet Street	10	900 ft	$162,000	$16,200	Yes
Taunton	East Walnut Street	20	1,000 ft	$180,000	$9,000	Yes
Taunton	Weir Street	8	700 ft	$126,000	$15,750	Yes
Taunton	Weir Avenue	2	400 ft	$72,000	$36,000	No
Total for Cost-Effective Segments			6,300 ft	$1,134,000		