Cape Cod Bridges Program

Bourne, Massachusetts

Appendix 4.14
Noise and Vibration Technical Report

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Acronyms and Abbreviations

Acronym/Abbreviation	Definition
CEI	Cost-Effectiveness Index
CFR	Code of Federal Regulations
CNE	Common Noise Environment
dBA	A-weighted decibel(s)
Leq	equivalent sound level
LTH	Loudest Traffic Hour
MassDOT	Massachusetts Department of Transportation
MRER/EA	Major Rehabilitation Evaluation Report/Environmental Assessment
NAC	Noise Abatement Criteria
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NRDG	Noise Reduction Design Goal
Program	Cape Cod Bridges Program
SUP	share-use path
TNM	Traffic Noise Model
USACE	U.S. Army Corps of Engineers

1 Introduction

This Noise and Vibration Technical Report has been prepared in support of the Draft Environmental Impact Statement for the Cape Cod Bridges Program (Program), in accordance with the following federal regulations and guidance:

- National Environmental Policy Act (NEPA) of 1969, as amended, 42 United States Code 4321 et seq.
- *Efficient Environmental Reviews for Project Decisionmaking and One Federal Decision,* 23 United States Code 139.
- Federal Highway Administration's regulations implementing NEPA, *Environmental Impact and Related Procedures* (23 Code of Federal Regulations [CFR] 771), and corresponding guidance, Technical Advisory (T 6640.8A): *Guidance for Preparing and Processing Environmental and Section 4(f) Documents* (October 30, 1987).

2 Summary of Findings

The Program is classified as a Type I project, in accordance with FHWA's Noise Regulations contained in Title 23 of the Code of Federal Regulation, Part 772 (23 CFR 772) — Procedures for Abatement of Highway Traffic Noise and Construction Noise, and Massachusetts Department of Transportation's (MassDOT) Type I and Type II Noise Abatement[1] Policies and Procedures (effective July 13, 2011). A Type I project is a project that involves the following:

1. The construction of a highway on new location;
2. The physical alteration of an existing highway where there is either a substantial horizontal alteration or a substantial vertical alteration;
3. The addition of a through-traffic lane(s);
4. The addition of an auxiliary lane, except for when the auxiliary lane is a turn lane;
5. The addition or relocation of interchange lanes or ramps added to a quadrant to complete an existing partial interchange;
6. Restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane; or,
7. The addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot or toll plaza.

The Program would result in a substantial change in both horizontal and vertical alignment since it would halve the distance between proposed roadways and receptors and expose new lines of sight between traffic noise sources and receptors. The Program would also add auxiliary lanes. FHWA Noise Regulations (23 CFR 772) and MassDOT noise abatement policies require that traffic noise levels

[1] Noise abatement is any measure implemented to reduce highway traffic noise levels.

associated with Type I projects be calculated, the results be compared to the noise abatement criteria (NAC),[2] and, if noise impacts are identified, noise mitigation measures be evaluated to reduce noise impacts in the study area. In addition, pursuant to 23 CFR 772, if a project is determined to be a Type I project, then the entire project area within the operational limits of the Build Alternative is considered a Type I project.

Type 1 projects also require analysis of construction noise and abatement measures in accordance with FHWA regulations and MassDOT policies. The are no FHWA regulations specific to construction-related vibration. MassDOT derived the guidance for the assessment of construction-related vibration effects from the Federal Transit Administration (FTA) Transit Noise and Vibration Impact Assessment Manual.[3]

The noise study evaluated the 2019 existing and 2050 Design Year[4] No Build Alternative and Build Alternative traffic noise conditions for noise-sensitive areas within 500 feet of operational limits for the Build Alternative at the Sagamore Bridge and Bourne Bridge (defined as the Noise Study Areas for this assessment). Monitoring of existing noise conditions was conducted in 18 locations to validate the project-specific FHWA Traffic Noise Model (TNM), version 2.5 for use in evaluating 2019 existing and 2050 future year noise levels at additional noise-sensitive locations throughout the Study Areas. Modeling accounted for existing terrain and buildings, and for existing and proposed roadways with projected loudest-hour traffic. Traffic noise was assessed for all categories of noise-sensitive land use within the Noise Study Areas. Most noise-sensitive land use within the Noise Study Areas includes residences; however, there are some recreational land uses as well as restaurants and hotels with outdoor use areas (balconies, seating areas, etc.). **Table 2-1**—organized by Study Area quadrant (Sagamore North, Sagamore South, Bourne North, and Bourne South)—summarizes the number of noise-sensitive receptors[5] exposed to traffic noise predicted to approach or exceed the FHWA NAC for the existing condition and future No Build Alternative and Build Alternative. There are no noise-sensitive receptors predicted to experience a substantial increase in traffic noise between the 2019 existing condition and the 2050 Build Alternative. Traffic noise projections are preliminary and will be reevaluated during the final design noise analysis.

Table 2-1. Number of Receptors Predicted to Approach or Exceed the Noise Abatement Criteria for the 2019 Existing Condition and 2050 No Build and Build Alternatives

Project Quadrant	FHWA Activity Category	2019 Existing Condition	2050 No Build Alternative	2050 Build Alternative
Sagamore North	B	4	7	9
	C	0	0	0

[2] The upper limit of acceptable highway traffic noise for different Activity Categories. The Noise Abatement Criteria varies according to Activity Category.

[3] Federal Transit Administration (FTA) Transit Noise and Vibration Impact Assessment Manual, September 2018.

[4] The future year used to estimate probable traffic volume for which a highway is designed. It is typically 10 to 20 years from the start of construction.

[5] A discrete or representative location of a noise-sensitive area.

Project Quadrant	FHWA Activity Category	2019 Existing Condition	2050 No Build Alternative	2050 Build Alternative
	E	0	0	0
Sagamore South	B	36	46	45
	C	3	3	0
	E	0	0	0
Bourne North	B	0	2	2
	C	0	0	0
	E	0	0	0
Bourne South	B	0	0	0
	C	1	1	2
	E	0	0	0

Within the Sagamore North quadrant, four residential dwelling units are predicted to have noise levels that approach or exceed the NAC threshold for the 2019 existing condition, and seven residential dwelling units are predicted to have noise levels that approach or exceed the NAC threshold for the 2050 No Build Alternative. Within the Sagamore South quadrant, 36 residential dwelling units are predicted to have noise levels that approach or exceed the NAC threshold for the 2019 existing condition, and 46 residential dwelling units are predicted to have noise levels that approach or exceed the NAC threshold for the 2050 No Build Alternative. In addition, one recreational use (the catcher's position on the baseball field at Keith Field) is also predicted to have noise levels that approach or exceed the NAC threshold under both the 2019 existing condition and the 2050 No Build Alternative. Within the Bourne North quadrant, there are no noise-sensitive land uses predicted to have noise levels that approach or exceed the NAC threshold for the 2019 existing condition; however, two residential dwelling units are predicted to have noise levels that approach or exceed the NAC threshold for the 2050 No Build Alternative. Within the Bourne South quadrant, there are no residential dwelling units predicted to have noise levels that approach or exceed the NAC threshold for the 2019 existing condition or for the 2050 No Build Alternative. However, one medical facility with outdoor benches is predicted to have noise levels that approach or exceed the NAC threshold under both the 2019 existing condition and the 2050 No Build Alternative.

Within the Sagamore North quadrant, nine residential dwelling units are predicted to have noise levels that approach or exceed the NAC threshold for the 2050 Build Alternative. Within the Sagamore South quadrant, 45 residential dwelling units are predicted to have noise levels that approach or exceed the NAC threshold for the 2050 Build Alternative. Within the Bourne North quadrant, two residential dwelling units are predicted to have noise levels that approach or exceed the NAC threshold for the 2050 Build Alternative. Within the Bourne South quadrant, no residential dwelling units are predicted to have noise levels that approach or exceed the NAC threshold for the 2050 Build Alternative.

However, one medical facility with outdoor benches is predicted to have noise levels that approach or exceed the NAC threshold for the 2050 Build Alternative. There are no substantial increase noise impacts predicted in the Sagamore North, Sagamore South, Bourne North, or Bourne South quadrants.

Noise abatement was considered in areas of predicted impacts for the 2050 Build Alternative. Noise abatement is evaluated to determine if it is warranted, feasible, and reasonable. Noise barriers were modeled in four areas: one in the Sagamore North quadrant, two in the Sagamore South quadrant, and one in the Bourne North quadrant. One modeled noise barrier in the Common Noise Environment (CNE) SJ was found to be acoustically feasible (i.e., achieves 5 dB reduction to at least 50% of first-row impacted receptors[6]). Barrier SJ also meets MassDOT's Noise Reduction Design Goal (NRDG)[7] of 10 dB to at least one first-row receptor, and the Cost-Effectiveness Index (CEI) is less than $10,080 per decibel of noise reduction per benefit. However, Barrier SJ was determined to be not reasonable based on various environmental impacts it would impose on the Canal View Apartments, which is eligible for listing on the National Register of Historic Places (refer to **Section 7.1.2.1** for additional information). In other areas of impact, noise barriers would not be acoustically feasible due to engineering or other constraints. For example, noise impacts along unlimited access roadways cannot be constructed to achieve sufficient noise reduction due to the frequent gaps necessary to maintain access to residential and commercial properties along those roadways. **Table 2-2** summarizes the results of the noise barrier evaluations.

Table 2-2. Noise Barrier Evaluation Summary Table

Noise Barrier ID and Location	Barrier SB Sagamore North Quadrant	Barrier SJ Sagamore South Quadrant	Barrier SK Sagamore South Quadrant	Barrier BF Bourne North Quadrant
Average Noise Reduction (dBA)	7	11	7	10
Length (feet)	1,072	380	1,200	442
Height (feet)	25	15	25	15
Surface Area (square feet)	23,821	5,704	29,994	6,626
Total Cost[a]	$1,429,260	$342,240	$1,799,640	$397,560

[6] Any receptor that experiences a noise level that approaches or exceeds the Federal Highway Administration Noise Abatement Criteria established for the receptor's activity category.

[7] The desired level of noise reduction from a noise abatement measure.

Noise Barrier ID and Location	Barrier SB Sagamore North Quadrant	Barrier SJ Sagamore South Quadrant	Barrier SK Sagamore South Quadrant	Barrier BF Bourne North Quadrant
Number of Impacted and Benefited Receptors	3	20	4	1
Number of Not Impacted and Benefited Receptors[b]	17	0	5	0
Total Benefited	20	20	9	1
MassDOT Cost-Effectiveness Index[c]	$11,489	$1,596	$29,026	$41,848
Barrier Status	Feasible and Not Reasonable	Feasible and Not Reasonable	Feasible and Not Reasonable	Feasible and Not Reasonable

[a] Total cost calculated based on a unit cost of $60 per square foot, in accordance with the Massachusetts Department of Transportation's (MassDOT) 2021 cost update, submitted to the Federal Highway Administration, pursuant to 23 Code of Federal Regulations 772.13(d)(2)(ii).

[b] A benefited receptor is a receptor in the Noise Study Area that attains at least a 5 decibel (dB) noise reduction or greater with a noise abatement measure. A benefited receptor does not have to be an impacted receptor.

[c] An index that is based on cost, the average noise level reduction provided by a noise barrier, and the number of receptors that achieve a 5 dB or more reduction in noise levels. The Cost-Effectiveness Index (CEI) is one of several criteria used to determine the reasonableness[8] of noise abatement.

[d] Barrier SJ was determined to be not reasonable based on the combination of environmental impacts this abatement measure would impose on the Canal View Apartments, which is eligible for listing on the National Register of Historic Places. Refer to **Section 7.1.2.1** for additional information.

dBA = A-weighted decibel

[8] The combination of social, economic, and acoustical factors considered in the evaluation of proposed noise abatement measures. Reasonableness implies that good judgment and common sense have been applied in arriving at a decision on the construction or installation of proposed noise abatement measures.

3 Proposed Action and Alternatives

3.1 Purpose and Need

In partnership with the FHWA and the New England District of the U.S. Army Corps of Engineers (USACE), MassDOT proposes advancing the Program in the town of Bourne, Barnstable County, Massachusetts.

The purpose of the Program is to improve cross-canal mobility and accessibility between Cape Cod and mainland Massachusetts for all road users and to address the increasing maintenance needs and functional obsolescence of the aging Sagamore and Bourne Bridges. The needs for the Program are as follows:

- Address the deteriorating structural condition and escalating maintenance demands of the Bourne and Sagamore Bridges.
- Address the substandard design elements of the Bourne and Sagamore Bridges, the immediate mainline approaches, and their adjacent interchanges and intersections.
- Improve vehicular traffic operations.
- Improve accommodations for pedestrians and bicyclists.

3.2 Build Alternative

The Build Alternative would incorporate the USACE's Major Rehabilitation Evaluation Report and Environmental Assessment's (MRER/EA) preferred alternative of replacing both highway bridges with new bridges, each with four through-travel lanes and two auxiliary lanes (in-kind bridge replacement that would be updated to comply with federal and state highway and design safety standards). The Build Alternative would replace the Bourne and Sagamore Bridges with parallel, twin tied-arch bridge structures that would be supported on delta frames with an approximate 700-foot mainline span length. At both bridge crossings, the replacement mainline alignment locations would be offline and inboard of the existing bridges on the side of the canal between the bridges. The Build Alternative would reconfigure the highway interchange approach networks north and south of Cape Cod Canal to align with the replacement bridges. The replacement bridges and their interchange approaches would accommodate shared-use pedestrian and bicycle paths that would connect to the local roadway network on both sides of Cape Cod Canal in the town of Bourne.

Table 3-1 presents a description of the Program elements/design parameters of the recommended Build Alternative: Replacement Highway Bridges Built to Modern Design Standards.

Table 3-1. Description of Design Parameters of the Recommended Build Alternative

Program Element/ Program Design Parameter	Description
Highway Bridges	Both the Bourne and Sagamore Bridges would be replaced with new bridges, with each comprising four through-travel lanes and two auxiliary lanes (i.e., an in-kind bridge replacement that would comply with federal and state highway and design safety standards).
Bridge Highway Cross-Section and Shared-Use Path	Each replacement bridge would provide four 12-foot-wide through-traffic lanes (two in each direction), two 12-foot-wide entrance/exit (auxiliary) lanes, a 4-foot-wide left shoulder, and a 10-foot-wide right shoulder. Right and left barriers would be offset an additional 2 feet beyond the limits of the shoulders.
	Each crossing location would include one bidirectional pedestrian and bicycle shared-use path (SUP), separated from vehicular traffic by the shoulder and barrier. The usable width of the SUP would be 14 feet wide on the bridge main span, 20 feet wide on the interchange approaches, and 12 feet wide on the connecting roadways.
Bridge Clearances	The replacement bridges would maintain the existing vertical clearance of 135 feet above mean high water and account for 3 feet of fluctuations in relative sea level, for a total vertical clearance of 138 feet above mean high water. The replacement bridges would provide a minimum 500 feet of horizontal channel width to be consistent with existing conditions.
Main Span Length and Bridge Pier Location	The replacement bridges would have a main span length of approximately 700 feet, which would locate the bridge piers at the waterline adjacent to the service road (shoreline piers) into the riprap slope but above the low tide line.
Bridge Deck Configuration	Each replacement bridge would have two separate decks (twin structures).
Mainline Alignment	The mainline alignment locations at both crossings would be offline inboard: the main spans of each replacement bridge would be located outside the footprint of the existing bridge, approximately 10 feet apart and parallel to each other and on the side of the canal between the existing Bourne Bridge and Sagamore Bridge. At the Bourne crossing, both main spans would be located east of the existing Bourne Bridge toward Cape Cod Bay. At the Sagamore crossing, both main spans would be located west of the existing Sagamore Bridge toward Buzzards Bay.
Bridge Type	The replacement bridges would be twin tied-arch bridges with delta frames supporting an approximate 700-foot mainline span.

Program Element/ Program Design Parameter	Description
Interchange Approach Network: Sagamore North	The Sagamore North interchange approach network would follow the "Direct Connection to State Road (Option SN-8A)" configuration. This design would provide a single exit point from a relocated U.S. Route 6/State Route 3 and eliminate the existing Sagamore Bridge northbound off-ramp connection to Scenic Highway/Meetinghouse Lane eastbound. Instead, the new connection would tie into State Road, north of Scenic Highway/ Meetinghouse Lane. The remaining ramp connections would remain similar to existing conditions. Intersections along Scenic Highway and Meetinghouse Lane would be modified to accommodate new lane configurations. The intersection of State Road at State Route 3 northbound would also be reconfigured to support the addition of the new northbound off-ramp. The design includes a SUP on the U.S. Route 6 eastbound main span, providing connections to the south side of Scenic Highway, Canal Street, and Canal Service Road. Additional SUPs would be constructed along the southern side of Scenic Highway and Meetinghouse Lane, as well as along the eastern side of State Road to Homestead Avenue.
Interchange Approach Network: Sagamore South	The Sagamore South interchange approach network would follow the "Westbound On-Ramp Under U.S. Route 6 with Sandwich Road Extension (Option SS-3.1A)" configuration. This design includes the Cranberry Highway Extension and relocates the westbound on-ramp to share the same entrance point as the eastbound on-ramp from the Mid-Cape Connector. The existing westbound ramp from Cranberry Highway to the Sagamore Bridge would be removed and replaced with a new westbound on-ramp connection from the Mid-Cape Connector. Lane arrangements at the intersections of the Mid-Cape Connector with Sandwich Road and Cranberry Highway Extension would be modified to accommodate revised traffic patterns resulting from the new Cranberry Highway Extension and changes to U.S. Route 6 access. A new connection from Cranberry Highway Extension to Sandwich Road would be provided east of the new mainline bridge structure, forming the Sandwich Road Extension. Access to Market Basket via Factory Outlet Road would be modified, and a new driveway would be added to serve the former Christmas Tree Shops property. A SUP would be constructed along the U.S. Route 6 eastbound main span, providing connections to Factory Outlet Road, Sandwich Road, and Canal Service Road. Additional bicycle and pedestrian improvements would be included along Cranberry Highway. A new connection would also be established through the Cranberry Highway Extension to the Mid-Cape Connector.

Program Element/ Program Design Parameter	Description
Interchange Approach Network: Bourne North	The Bourne North interchange approach would follow the "Directional Interchange (Option BN-14.4b)" configuration. This design includes a combination of direct connection ramps between State Route 25 and U.S. Route 6. The ramp connecting State Route 25 eastbound to Scenic Highway would be a direct connection, providing access to Scenic Highway eastbound only. A new flyover ramp from Scenic Highway to State Route 25 would allow vehicles to bypass Belmont Circle, improving traffic flow without the need for additional intersection control. This ramp would repurpose one of the existing travel lanes on Scenic Highway and provide a free-flowing movement to reduce congestion. To accommodate this new southbound-to-eastbound movement, the existing State Route 28 bridge over State Route 25 would be relocated and widened. The existing southbound off-ramp would be reconfigured as an option lane, improving geometry and decision sight distance for drivers. Intersection control at U.S. Route 6/Nightingale Road/Andy Oliva Drive is being evaluated, with a single-lane roundabout previously considered. MassDOT continues to assess appropriate control types through the Intersection Control Evaluation (ICE) process. The design also includes a SUP and a grade-separated crossing for pedestrians and bicyclists via the new flyover ramp over Scenic Highway. U.S. Route 6 would be reduced from four lanes to three, creating space for multimodal accommodations. A continuous 12-foot-wide SUP would be provided along the south side of U.S. Route 6, connecting to Belmont Circle, with a 6-foot-wide sidewalk along the north side.
Interchange Approach Network: Bourne South	The Bourne South interchange approach network would follow the "Diamond Interchange (Option BS-2)" configuration. This design would eliminate the existing Bourne Rotary and replace it with a grade-separated diamond interchange, allowing through movements on State Route 28 to bypass intersections with local roadways. Both intersections within the diamond interchange would include appropriate intersection controls to manage traffic flow and improve safety. Changes to the Trowbridge Road and Sandwich Road underpass would include a reconfigured entrance to Upper Cape Cod Regional Technical High School, relocated to improve access and circulation. The design would also provide SUP connections to Trowbridge Road, the Cape Cod Canal Service Road, and the Bourne Recreation Area, enhancing multimodal connectivity throughout the corridor.

3.3 No Build Alternative

The Sagamore and Bourne Bridges, as components of the Cape Cod Canal Federal Navigation Project, are federal assets that are managed by the USACE's New England District. The Commonwealth of Massachusetts owns the connecting major highway corridors at the bridges, which consist of the State Route 3/U.S. Route 6 corridor at Sagamore Bridge and the State Route 25/State Route 28 corridor at Bourne Bridge.

In the No Build Alternative, the Sagamore and Bourne Bridges would retain their current configuration of four 10-foot-wide travel lanes (two in each direction) with one 6-foot sidewalk and a 2-foot safety curb. The USACE would continue to own the Sagamore and Bourne Bridges and would implement a maintenance and repair program as needed to maintain bridge operations and public safety. MassDOT would continue to own, operate, and maintain the state highway interchange approach networks at the two bridges.

The No Build Alternative would implement recently completed and proposed Commonwealth of Massachusetts-sponsored and local transportation improvement projects included in the Federal Fiscal Year 2025-2029 Transportation Improvement Program for the Cape Cod Metropolitan Planning Organization. **Table 3-2** identifies the Transportation Improvement Program projects that are part of the No Build Alternative.

The No Build Alternative represents the "Fix as Fails" Base Condition of the USACE's MRER/EA. In the No Build Alternative, the USACE would implement an ongoing program of continued inspections and maintenance and repair of both existing bridges as needed to maintain safety. No major rehabilitation efforts involving extensive repairs and replacement of major bridge components would occur. Structural components would be repaired, and critical elements would be replaced only when inspections indicate unsatisfactory reliability ratings. The MRER/EA indicates that both the Sagamore and Bourne Bridges are in deteriorated condition and well beyond the state in which actions and funding from the USACE's operations and maintenance program could correct the deficiencies and restore and sustain reliability. The USACE has indicated that as the bridges continue to age, routine maintenance and minor component replacement would result in an unacceptable structural condition. As a result, it is likely that lower vehicle weights, traffic volume restrictions, and speed limits would be required and posted to maintain continued bridge safety.

Table 3-2. Transportation Improvement Program Projects, 2025-2029

Project Number	Year	Transportation Project	Project Description	Status
606900	2020	Belmont Circle Traffic and Multimodal Improvements	Traffic and multimodal improvements at Belmont Circle at U.S. Route 6 and State Route 25 and State Route 28	Completed
608422	2022	Trail Improvements – Sandwich	Shared-use path on Service Road (State Route 130 to Chase Road)	Underway

Project Number	Year	Transportation Project	Project Description	Status
610542	2023	Bourne Rotary Improvements	• Restriping Bourne Rotary to two lanes and adding a channelized right-turn lane from State Route 28 northbound to Sandwich Road eastbound • Adding signs at Bourne Rotary • Installing flashing beacons at the Bourne Rotary approaches	Underway
613195	2024	Bridge Systematic Maintenance	Bridge deck replacement of the Quaker Meetinghouse Road Bridge over U.S. Route 6/Mid-Cape Highway as part of an overall bridge preservation strategy	Programmed
609262	2025	Bourne Rail Trail, Phase 1	First phase of four planned phases of the Bourne Rail Trail connection to the Shining Sea Bikeway to the south in Falmouth and to the Cape Cod Canal path (Canal Service Road) in the town of Bourne; Phase 1 is approximately one-half mile long within the existing right-of-way of the Old Colony Railroad (Woods Hole branch line) from the Canal Service Road to Monument Neck Road.	Programmed
610673	—	Bourne Rail Trail, Phase 2	Phase 2 of four planned phases of the Bourne Rail Trail connection to Shining Sea Bikeway to the south in Falmouth and to the Cape Cod Canal path (Canal Service Road) in the town of Bourne; Phase 2 is approximately 2 miles long from Monument Neck Road to Monk's Park/ Valley Bars Road.	Not Programmed
---	—	Bourne Rail Trail, Phase 3 and Phase 4A	Phase 3 and Phase 4A of four planned phases of the Bourne Rail Trail connection to Shining Sea Bikeway to the south in Falmouth	Not Programmed
607394/ 611998	—	Bourne Rail Trail, Phase 4B	Phase 4B of four planned phases of the Bourne Rail Trail connection to the Shining Sea Bikeway to the south in Falmouth and to the Cape Cod Canal path (Canal Service Road) in the town of Bourne; Phase 4B is approximately 1 mile long, extending the Shining Sea Bikeway from its current terminus in North Falmouth into the town of Bourne.	Not Programmed

Project Number	Year	Transportation Project	Project Description	Status
606082	2025–2028	U.S. Route 6 Scenic Highway Median Installation	• Resurfacing • Safety improvements, including a raised center median and expanded shoulders to separate eastbound and westbound travel lanes • Drainage improvements • Traffic signal improvements at two intersections • Shared-use path	Programmed
612053	2025	Bourne/Sandwich, Resurfacing and Related Work on U.S. Route 6	Improvements to pavement serviceability, condition, and roadway safety on U.S. Route 6 from Sagamore Bridge to the Sandwich town line (8.55 miles)	Programmed
613200	2026	Chase Road over U.S. Route 6 Bridge	Bridge deck replacement of Chase Road over U.S. Route 6 (Mid-Cape Highway) bridge structure in the town of Sandwich	Programmed
612063	2028	State Route 28 Resurfacing and Related Work	Improvements to pavement serviceability, condition, and roadway safety on MacArthur Boulevard (State Route 28) from Bourne Rotary to Otis Rotary	Programmed
613199	2028	U.S. Route 6 over State Route 130 Bridge	Bridge deck replacement of U.S. Route 6 (Mid-Cape Highway) bridge structure over State Route 130 in the town of Sandwich	Programmed
613271	—	Shared-use path, State Route 130 to Canal Service Road	Shared-use path from State Route 130 to Canal Service Road in the town of Sandwich	Not Programmed

Note: **Table 3-2** includes only those projects in the Study Areas that are part of the No Build Alternative. It does not include Project S13144, the replacement of the Sagamore Bridge, which was added to the Federal Fiscal Year (FFY) 2025-2029 Transportation Improvement Program as Amendment #2, December 9, 2024.

— No date available.

The No Build Alternative would not meet any of the Program's identified needs:

- It would not address the deteriorating structural condition and escalating maintenance demands of the existing bridges.
- It would not address the substandard design elements of the bridges, the immediate mainline approaches, and their adjacent interchanges and intersections.
- It would not improve vehicular traffic operations.
- It would not improve accommodations for pedestrians and bicyclists.

Per NEPA requirements, the No Build Alternative is included in the Draft Environmental Impact Statement as the base condition against which the Build Alternative is compared and evaluated.

4 Methods for Effect Evaluation

4.1 Regulatory Framework

The following provides the regulatory context and guidance for the noise and vibration analysis:

- FHWA Noise Measurement Handbook–Final Report, June 1, 2018. FHWA-HEP-18-065
- FHWA, Procedures for Abatement of Highway Traffic Noise and Construction Noise (23 CFR 772, as amended 75 FR 39820, July 13, 2010; effective date July 13, 2011)
- FHWA, "Highway Traffic Noise: Analysis and Abatement Guidance," June 2010, revised December 2011
- National Cooperative Highway Research Program Report 791, "Supplemental Guidance on the Application of FHWA's Traffic Noise Model," 2014[9]
- National Cooperative Highway Research Program Report 984, Breaking Barriers: Alternative Approaches to Avoiding and Reducing Highway Traffic Noise Impacts, 2022[10]
- MassDOT, Type I and Type II Noise Abatement Policies and Procedures, April 2011, effective July 13, 2011[11]
- 310 CMR 7.00, Air Pollution Control (Universal, Noise)[12]

[9] https://nap.nationalacademies.org/read/22284/chapter/1
[10] https://nap.nationalacademies.org/catalog/26469/breaking-barriers-alternative-approaches-to-avoiding-and-reducing-highway-traffic-noise-impacts
[11] https://studylib.net/doc/13043513/massachusetts-department-of-transportation-type-i-and-typ...
[12] https://www.mass.gov/regulations/310-CMR-700-air-pollution-control

4.2 Methodology and Study Areas

4.2.1 Operational Traffic Noise

The operational traffic noise analysis involved monitoring of existing noise conditions to validate the project-specific noise model and modeling of 2019 existing and future 2050 No Build Alternative and Build Alternative noise conditions with the FHWA-approved computerized TNM version 2.5. The noise analysis was conducted using traffic data that is representative of the Loudest Traffic Hour (LTH),[13] which MassDOT identified as the AM traffic peak hour for the Noise Study Areas except the Sagamore North quadrant where the LTH was identified as the PM peak traffic hour. Existing condition year 2019 Fall AM and PM peak-hour traffic data was used to evaluate existing noise levels within the Noise Study Areas. Future year 2050 Fall AM and PM peak-hour traffic data was used to evaluate No Build Alternative and Build Alternative noise levels. Traffic noise impacts were assessed for different categories of noise-sensitive land use using FHWA NAC (**Table 4-1**). An overview of the Noise Study Areas and methodologies used to support this analysis are provided in the following sections.

Table 4-1. Federal Highway Administration Noise Abatement Criteria

Activity Category	Leq(h)[a]	Description of Activity Category
A	57 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose
B[b]	67 (Exterior)	Residential
C[b]	67 (Exterior)	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings
D	52 (Interior)	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios
E[b]	72 (Exterior)	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A-D or F
F[c]	—	Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing

[13] The 1-hour period when the traffic characteristics regularly yield the highest traffic noise levels.

Activity Category	Leq(h)[a]	Description of Activity Category
G[c]	—	Undeveloped lands that are not permitted[d] (without building permits)

Source: Federal Highway Administration, "Procedures for Abatement of Highway Traffic Noise and Construction Noise" (23 CFR 772, as amended 75 FR 39820, July 13, 2010; Effective date July 13, 2011). https://www.ecfr.gov/current/title-23/chapter-I/subchapter-H/part-772

[a] Hourly Equivalent A-weighted Sound Level (dBA)

[b] Includes undeveloped lands permitted for this category

[c] "—" indicates no NAC value established by FHWA and MassDOT

[d] A definite commitment to develop land with an approved specific design of land use activities as evidenced through issuance of a valid building permit.

Leq = equivalent sound level

4.2.1.1 Definition of Noise Study Areas

In general, the Noise Study Areas correspond to the Transportation and Traffic Study Areas, consisting of a 2-mile area centered around the Sagamore Bridge and Bourne Bridge. Specifically, the Noise Study Areas extends approximately 500 feet beyond the operational limits of the Sagamore Bridge and Bourne Bridge.

4.2.1.2 Definition of Criteria for Traffic Noise Impact

Noise is generally defined as sound that is undesirable because it interferes with speech, causes sleep disturbance, or is otherwise annoying (unwanted sound). The individual human response to noise is subject to considerable variability as there are many emotional and physical factors that contribute to the differences in reaction to noise.

To assess the degree of traffic noise impact on human activity, the FHWA established NAC for different categories of land use (**Table 4-1**). These levels "represent the upper limit of acceptable traffic noise conditions." The NAC "represent a balancing of that which may be desirable with that which may be achievable." **Attachment 1, Description of Noise Metrics**, presents more detailed descriptions of the noise metrics used in this report. According to the FHWA highway traffic noise regulations, traffic noise impact occurs when the predicted future build condition traffic noise levels approach or exceed the NAC, or when the predicted future build condition traffic noise levels substantially exceed the existing noise levels. MassDOT defines the word "approach" in "approach or exceed" as within 1 decibel. Therefore, the threshold for noise impact for Categories B and C land uses is where exterior noise levels are within 1 decibel of 67 dBA,[14] Leq(h), or 66 dBA. The threshold for noise impact for Category E land use is where exterior noise levels are within 1 decibel of 72 dBA, Leq(h), or 71 dBA. Noise impact also would occur wherever project noise causes a substantial increase over existing noise levels. A

[14] dBA is an A-weighted decibel unit that is used to measure noise. It best corresponds to the frequency response of the human ear.

substantial noise increase[15] does not depend on whether the design year noise levels approach or exceed the absolute NAC. MassDOT defines a substantial increase as an increase of 10 decibels or more above existing noise levels.

The NAC are given in terms of the hourly, A-weighted, equivalent sound level in decibels (dBA). The A-weighted sound level is a single number measure of sound intensity with weighted frequency characteristics that correspond to human subjective response to noise. Most environmental noise (and the A-weighted sound level) fluctuates from moment to moment, and it is common practice to characterize the fluctuating level by a single number called the equivalent sound level (Leq).[16] The Leq is the value or level of a steady, non-fluctuating sound that represents the same sound energy as the actual time-varying sound evaluated over the same time period. For traffic noise assessment, Leq is typically evaluated over a 1-hour period and may be denoted as Leq(h).

In this noise study, residential developments (FHWA Activity Category B), schools with exterior use areas and other recreation areas (including Bourne Scenic Park), and Keith Field (also Category C) were evaluated. Restaurants with outdoor seating and hotels with balconies and patios (FHWA Activity Category E) were also evaluated.

When the predicted design-year build condition noise levels equal or exceed the NAC during the loudest hour of the day or cause a substantial increase in existing noise, consideration of traffic noise reduction measures is necessary and required pursuant to the FHWA traffic noise regulations. If it is found that such mitigation measures will cause adverse social, economic, or environmental effects that outweigh the benefits received, they may be dismissed from consideration. For this study, noise levels throughout the Study Areas were determined for2019 existing conditions and for the design year 2050 No Build Alternative and Build Alternative.

4.2.1.3 Identification of Noise-Sensitive Land Uses

Following FHWA and MassDOT policies and guidance, all noise-sensitive land use within the Noise Study Areas were grouped into CNEs. The definitions of the FHWA Activity Categories[17] referred to in the CNE descriptions are provided in **Section 4.2.1.2** and **Table 4-1**. **Figure 4-1** and **Figure 4-2** present the Noise Study Areas and CNE boundaries for the Sagamore North and Sagamore South quadrants, respectively, and **Figure 4-3** and **Figure 4-4** illustrate the Noise Study Areas and CNE boundaries for the Bourne North and Bourne South quadrants, respectively.

[15] An increase in the design year noise level that is greater than 10 dB over existing noise levels. A substantial noise increase is independent of the absolute existing noise level and is a secondary impact criterion used to identify design year noise impacts, even if design year noise levels do not approach or exceed the Noise Abatement Criteria.

[16] An equivalent steady-state noise level that accounts for the moment-to-moment fluctuations in noise levels from all sources during the time period under construction. For highway noise analyses, 1 hour is the typical time period used.

[17] Categories of land use and human activities, established by the FHWA, that are sensitive to noise in different ways. Each Activity Category has specific Noise Abatement Criterion.

Sagamore Bridge Common Noise Environments

The CNE boundaries delineated for Sagamore Bridge are as follows.

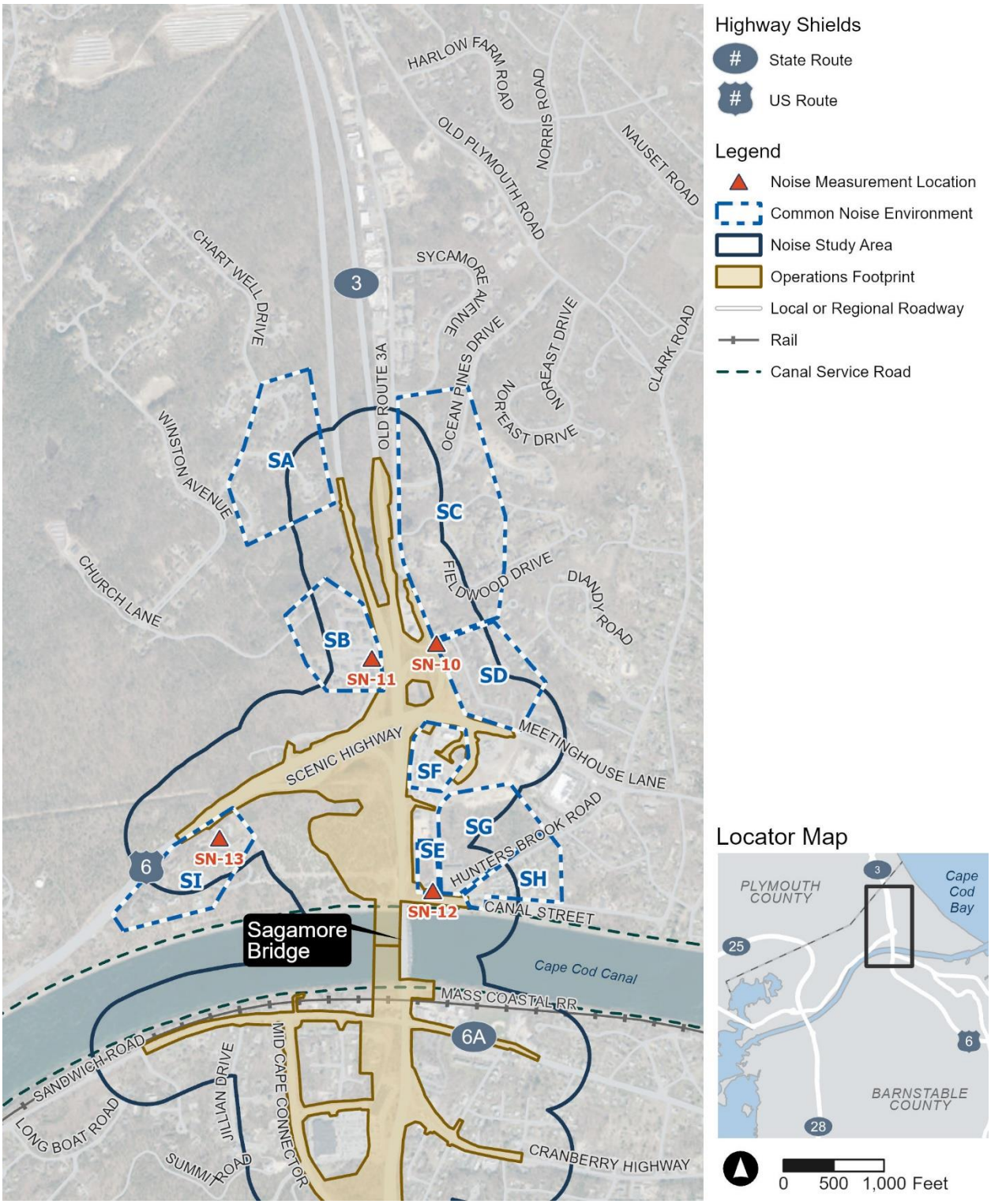
Sagamore North Quadrant

Nine CNEs are delineated in the Sagamore North quadrant (**Figure 4-1**). These CNEs include a mix of single- and multi-family residential developments (FHWA Activity Category B), a restaurant with outdoor seating (FHWA Activity Category E), and undeveloped parcels without issued building permits (FHWA Activity Category G).

- **CNE SA** is north and west of the Sagamore North quadrant State Route 3/U.S. Route 6 interchange approach network adjacent to the State Route 3 southbound travel lanes. CNE SA includes single-family residences (FHWA Activity Category B) along Sir Lancelot Drive, Dover Lane, Camelot Lane, and Salinger Way.
- **CNE SB** is adjacent to the State Route 3 southbound off-ramp to Scenic Highway, just south of CNE SA. CNE SB includes the Canalside Apartments, which is a multifamily residential development (FHWA Activity Category B) along Church Lane comprising 20 two-story buildings and 112 individual dwelling units. The apartment complex includes visible exterior common areas (benches) between some buildings as well as a basketball court, baseball field, and playground along White Pine Road on the west side of the property. Some individual dwelling units also utilize outdoor areas directly outside their unit, as evidenced during noise measurement field work and via Google Street View imagery (e.g., barbecue grills, lawn chairs, tables). CNE SB also includes three single-family residences along Church Lane, north of Canalside Apartments.
- **CNE SC** is north and east of the Sagamore North quadrant State Route 3/U.S. Route 6 interchange approach network adjacent to the State Route 3 northbound travel lanes. CNE SC includes single-family residences (FHWA Activity Category B) north of the intersection of Homestead Road and Stated Road along Fieldwood Drive, Ocean Pines Drive, and Alpine Circle.
- **CNE SD** is north and east of the Sagamore North quadrant State Route 3/U.S. Route 6 interchange approach network adjacent to the State Route 3 northbound travel lanes. CNE SC includes single-family residences (FHWA Activity Category B) south of the intersection of Homestead Road and State Road along State Road, Homestead Road, and Meetinghouse Lane. CNE SD also includes a proposed multifamily residential development (Cape View Way) that has received building permits for the construction of 42 dwelling units.
- **CNE SE** is along the U.S. Route 6 northbound travel lanes adjacent to the proposed U.S. Route 6 northbound off-ramps to Meetinghouse Lane and State Road and south of the Sagamore Circle Park and Ride lot. This CNE includes two single-family residences (FHWA Activity Category B).
- **CNE SF** is along the U.S. Route 6 northbound travel lanes adjacent to the proposed U.S. Route 6 northbound off-ramps to Meetinghouse Lane and State Road. The CNE is also south of Meetinghouse Lane and west of Canal Street. CNE SF includes one restaurant (McDonald's) with outdoor seating (FHWA Activity Category E) and the Cape Cod Visitor Center, which also has outdoor seating (FHWA Activity Category C).

- **CNE SG** is north and east of Canal Street and the U.S. Route 6 northbound travel lanes and northwest of Hunters Brook Road. CNE SG includes two multifamily residential developments (FHWA Activity Category B): Hunters Brook Condominiums and Hunters Brook Townhouses. CNE SG also includes an undeveloped parcel (FHWA Activity Category G) to the north of the condos and townhouses and two single-family residences (FHWA Activity Category B) along Hunters Brook Road.
- **CNE SH** is along Canal Street, east of the U.S. Route 6 northbound travel lanes and southeast of Hunters Brook Road. CNE SH includes single- and multifamily (Ships Way) residences (FHWA Activity Category B) along Canal Street, Hunters Brook Road, and Lucia Avenue and also includes benches and picnic tables associated with the Sagamore Recreation Area (FHWA Activity Category C).
- **CNE SI** is along Scenic Highway, west of Sagamore Bridge. This CNE includes single-family residences (FHWA Activity Category B) on Brigantine Passage Drive and Scenic Highway.

Figure 4-1. Noise Study Area and Common Noise Environment Boundaries and Noise Measurement Locations (Sagamore North Quadrant)



Source: Massachusetts Department of Transportation, 2024

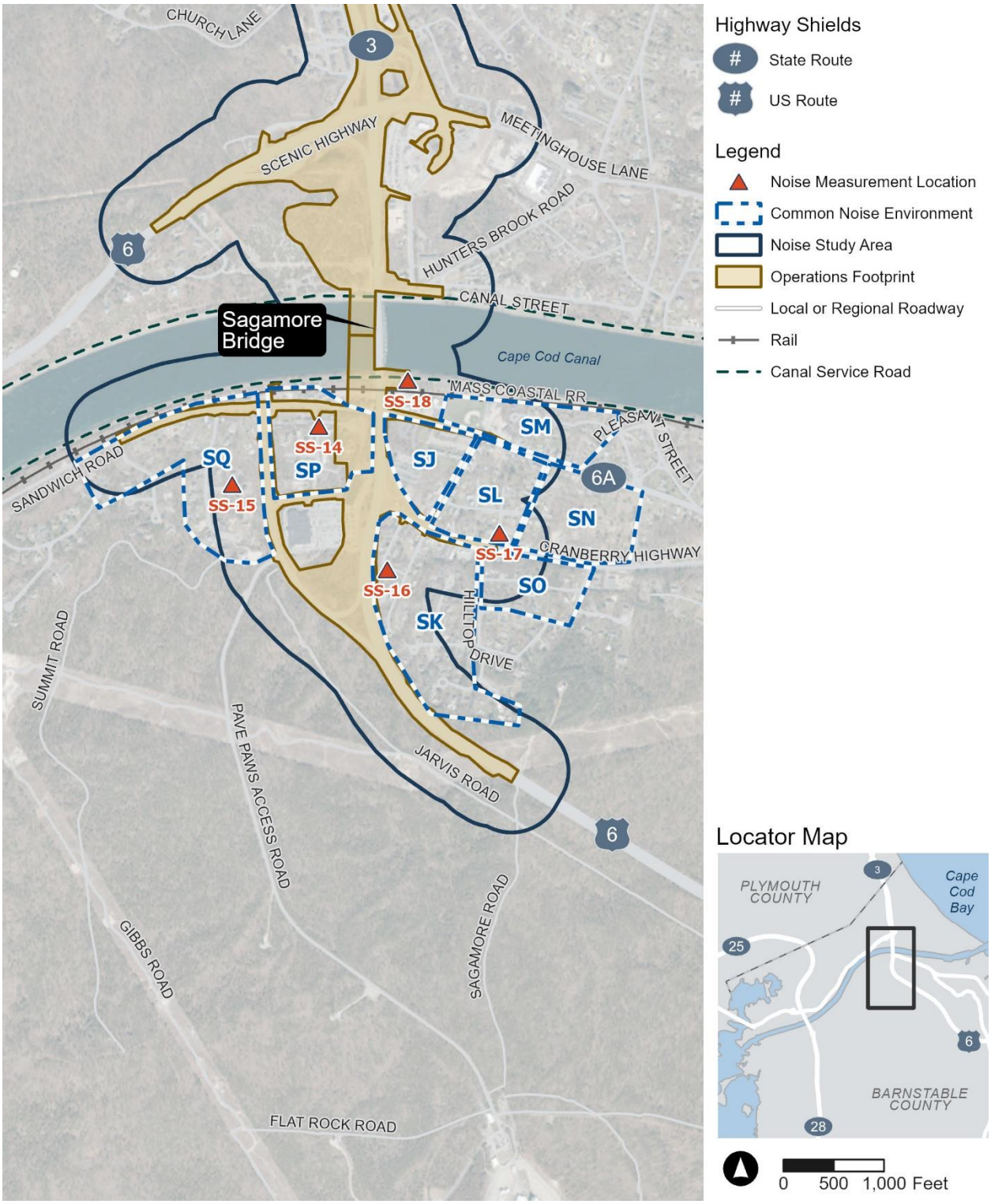
Sagamore South Quadrant

There are eight CNEs delineated in the Sagamore South quadrant, which are illustrated in **Figure 4-2.** These CNEs include a mix of single- and multifamily residential developments (FHWA Activity Category B), a baseball field and tennis courts (FHWA Activity Category C), a school with an exterior playground (FHWA Activity Category C), a cemetery (FHWA Activity Category C), and undeveloped parcels without issued building permits (FHWA Activity Category G).

- **CNE SJ** is along Sandwich Road, east of Sagamore Bridge. This CNE is generally bounded by Sandwich Road to the north, Adams Street to the east, Cranberry Highway to the south, and Sagamore Bridge to the west. CNE SJ includes the multifamily residential (FHWA Activity Category B) Canal View Apartments along Sandwich Road as well as multifamily residences (FHWA Activity Category B) along Adams Street near Cranberry Highway.
- **CNE SK** is south of Cranberry Highway, west of Hilltop Drive, and adjacent to the U.S. Route 6 northbound mainline travel lanes, the proposed U.S. Route 6 northbound off-ramp to Cranberry Highway, and the Mid-Cape Connector on-ramp to U.S. Route 6 northbound. CNE SK includes single-family residential neighborhoods (FHWA Activity Category B) along Garfield Avenue, Marconi Street, Adams Street, Woodland Road, Country Way, Hilltop Drive, and Hillcrest Drive.
- **CNE SL** is along Sandwich Road, east of Sagamore Bridge. This CNE is generally bounded by Sandwich Road to the north, Adams Street to the west, Cranberry Highway to the south, and Westdale Park to the east. CNE SL includes single-family residences (FHWA Activity Category B) along Commonwealth Avenue, West Street, Oak Street, Westdale Park, Vermont Street, Adams Street, and Cranberry Highway.
- **CNE SM** is along Sandwich Road, east of Sagamore Bridge. This CNE is generally bounded by Sandwich Road to the south, Pleasant Street to the east, and Cape Cod Canal to the north. CNE SM includes single-family residences (FHWA Activity Category B) along Pleasure Point Road, Pleasant Street, and Sandwich Road. CNE SM also includes the outdoor playground area of the Bridgeview Montessori School (FHWA Activity Category C), and the baseball field, bleachers and tennis court (FHWA Activity Category C) associated with Keith Field along Sandwich Road.
- **CNE SN** is generally bounded by Sandwich Road to the north, Cranberry Highway to the south, Westdale Park to the west, and Ben Abbey Road to the east. CNE SN includes single-family residences (FHWA Activity Category B) along Commonwealth Avenue, Westdale Park, and Sandwich Road. The Sagamore Cemetery (FHWA Activity Category C) is also within this CNE.
- **CNE SO** is generally bounded by Cranberry Highway to the north, Hilltop Drive to the west and south, and Bluff Road to the east. CNE SO includes single-family residences (FHWA Activity Category B) along Hilltop Drive and Bluff Road.
- **CNE SP** is west of Sagamore Bridge along the southbound mainline lanes. The CNE is generally bounded by Sandwich Road to the north, the Mid-Cape Connector to the south and west, and Sagamore Bridge to the east. CNE SP includes single-family residences (FHWA Activity Category B) along Louis Avenue, Cecilia Terrace, Eleanor Avenue, and John's Lane.

- **CNE SQ** is west of the Mid-Cape Connector and south of Sandwich Road. CNE SQ includes single-family residences (FHWA Activity Category B) along Sandwich Road, Tracie Lane, Jillian Drive, Autumn Way, Van Circle, and Long Boat Road.

Figure 4-2. Noise Study Area and Common Noise Environment Boundaries and Noise Measurement Locations (Sagamore South Quadrant)



Source: Massachusetts Department of Transportation, 2024

Bourne Bridge Common Noise Environments

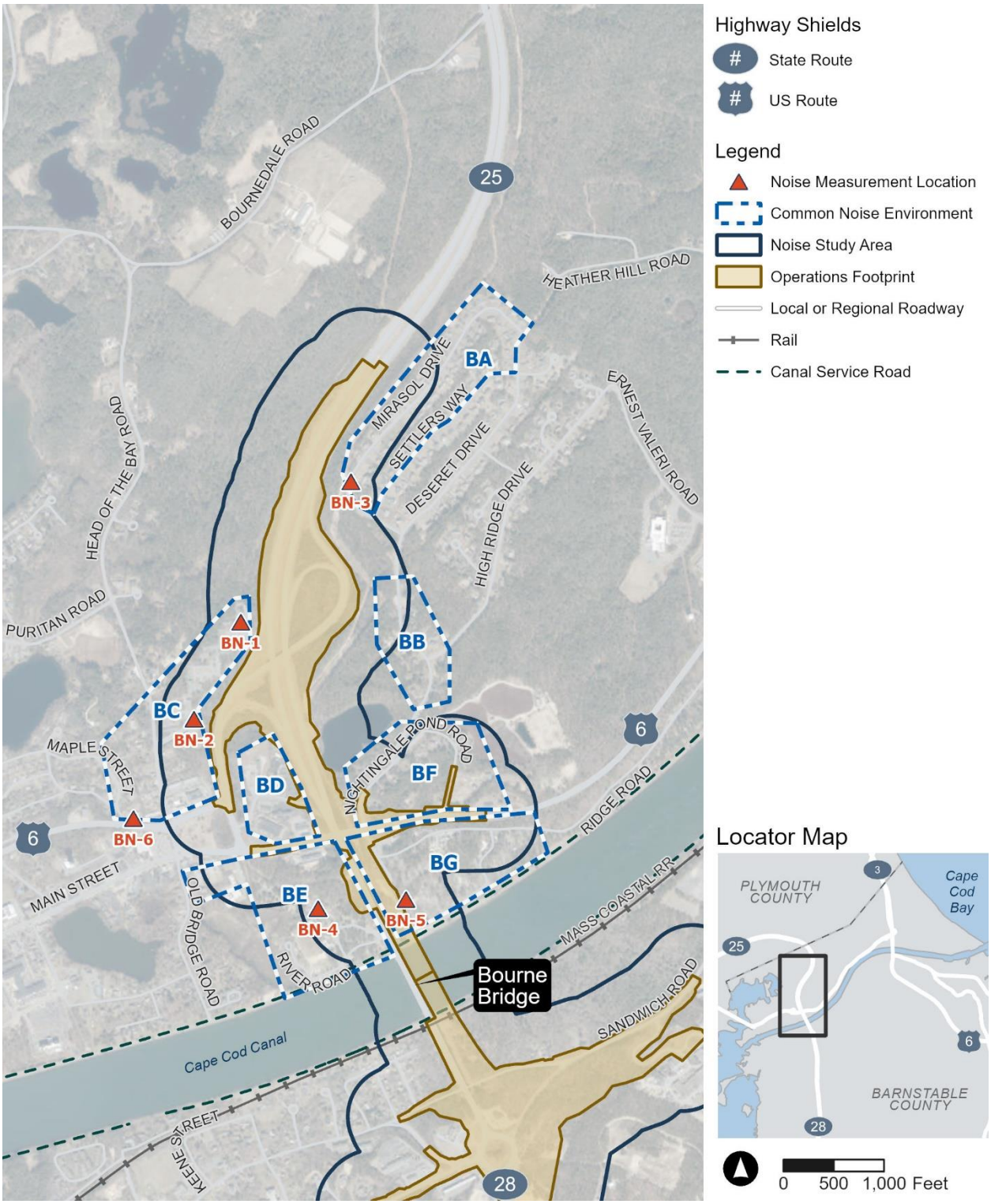
The CNE boundaries delineated for Bourne Bridge are as follows.

Bourne North Quadrant

There are seven CNEs delineated in the Bourne North quadrant, which are illustrated in **Figure 4-3**. These CNEs include a mix of single- and multifamily residential developments (FHWA Activity Category B), restaurants with outdoor seating and a hotel with an elevated exterior deck (FHWA Activity Category E), and a proposed residential development with building permits (FHWA Activity Category B).

- **CNE BA** is adjacent to the State Route 25 northbound mainline lanes and includes the single-family residential (FHWA Activity Category B) development on Mirasol Drive and Settlers Way.
- **CNE BB** is adjacent to the State Route 25 northbound on-ramp from Main Street/U.S. Route 6 and the State Route 25 Southbound on-ramp from Belmont Circle. This CNE includes single-family residences (FHWA Activity Category B) on Deseret Drive.
- **CNE BC** is along the State Route 25 southbound mainline travel lanes and State Route 25 southbound off-ramp to Belmont Circle. CNE BC includes the multifamily residential apartment complex, Bourne Oaks, along Finch Lane, the two-story Continental Apartments complex along Head of the Bay Road, and single-family residences along Head of the Bay Road and Maple Street, all of which are classified as FHWA Activity Category B.
- **CNE BD** is along the Bourne Bridge Approach roadway adjacent to the State Route 25 southbound mainline travel lanes. This CNE includes two outdoor seating areas at dining establishments (FHWA Activity Category E), including Starbucks and Sandy's Famous Seafood Restaurant, as well as an outdoor elevated deck associated with the Eastern Inn (FHWA Activity Category E).
- **CNE BE** is adjacent to the State Route 28 southbound mainline travel lanes, south of U.S. Route 6/Main Street. This CNE includes a proposed new residential development (FHWA Activity Category B) with a building permit at 328 Main Street and 340 Main Street, a portion of the Bourne Scenic Park camp sites and recreational activity areas (FHWA Activity Category C), and outdoor seating at the Grill & More restaurant (FHWA Activity Category E) along U.S. Route 6/Main Street.
- **CNE BF** is north of U.S. Route 6/Main Street and adjacent to the State Route 28 northbound mainline travel lanes. This CNE includes single-family residences (FHWA Activity Category B) along Nightingale Road and Deseret Drive.
- **CNE BG** is south of U.S. Route 6/Main Street and adjacent to the State Route 28 northbound mainline travel lanes. This CNE includes a portion of the Bourne Scenic Park camp sites and recreational activity areas (FHWA Activity Category C).

Figure 4-3. Noise Study Area and Common Noise Environment Boundaries and Noise Measurement Locations (Bourne North Quadrant)



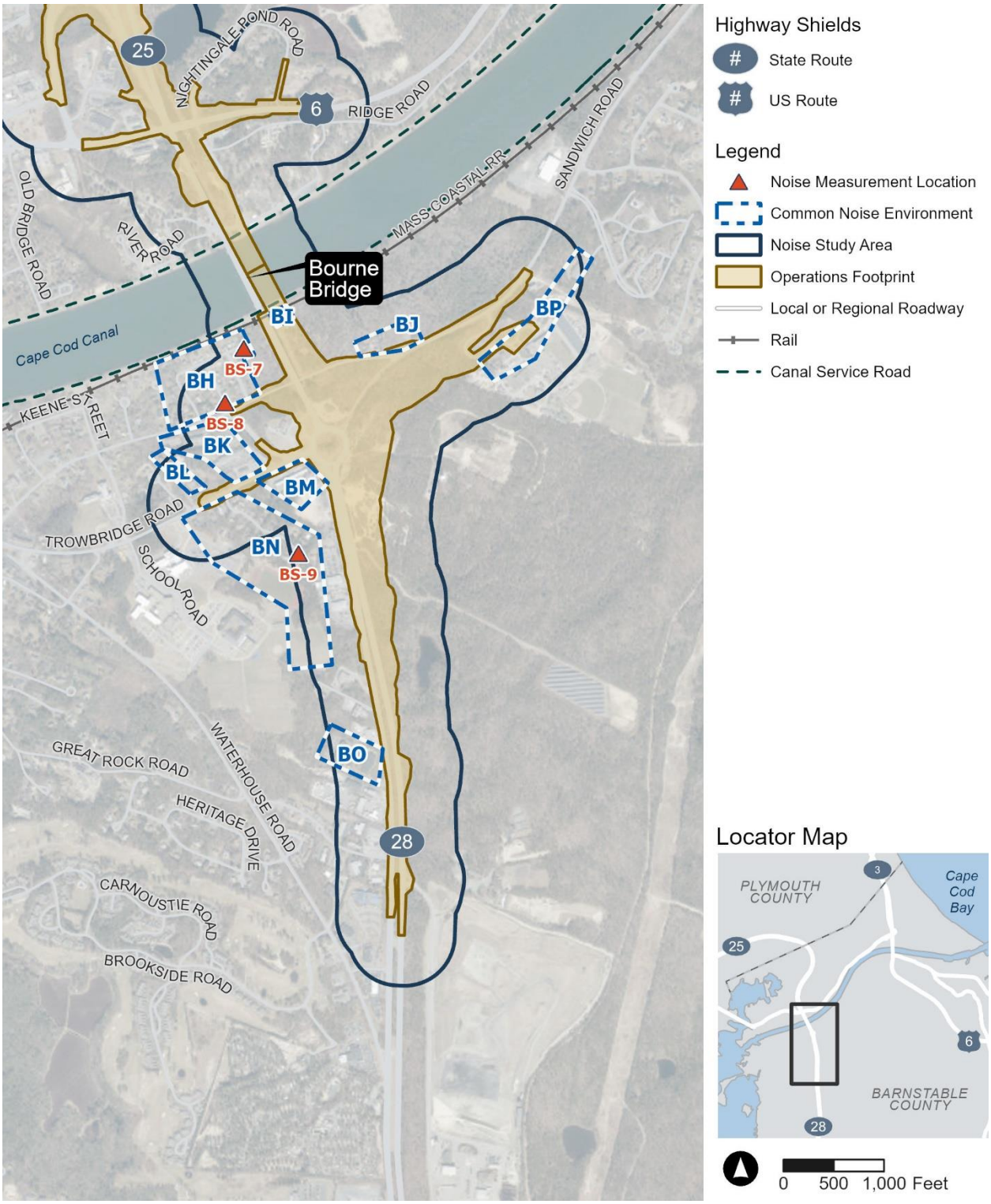
Source: Massachusetts Department of Transportation, 2024

Bourne South Quadrant

There are nine CNEs delineated in the Bourne South quadrant, which are illustrated in **Figure 4-4**. These CNEs include a mix of single- and multi-family residential developments (FHWA Activity Category B), schools with exterior use areas, as well as a medical facility with outdoor use areas, restaurants and hotels with outdoor use areas (FHWA Activity Category E), and two undeveloped parcels without building permits.

- **CNE BH** is adjacent to the State Route 28 southbound mainline lanes, north of Sandwich Road. This CNE includes single-family residences (FHWA Activity Category B) on Emerson Avenue, Winslow Street, Freeman Street, Farnum Road, and Maritime Way.
- **CNE BI** is adjacent to the State Route 28 southbound mainline lanes, east of Bourne Bridge Road and south of the Canal Service Road. This CNE represents the train station and picnic area of the existing Bourne Recreation Area (FHWA Activity Category C). The USACE is evaluating a relocation site for the Bourne Recreation Area for the Build Alternative. In the Final Environmental Impact Statement, CNE BI will be expanded to include the relocation site.
- **CNE BJ** is east of Bourne Bridge and north of Sandwich Road. This CNE includes three single-family residences (FHWA Activity Category B) along Sandwich Road.
- **CNE BK** is west of Bourne Bridge between Sandwich Road and Trowbridge Road. This CNE includes multifamily residences (FHWA Activity Category B) along Sandwich Road (Tudor Hill Apartments and Waterview Hill Condominiums), outdoor seating areas at the Bridge View Grill as well as first-floor patios and second-floor balconies at the Quality Inn hotel (FHWA Activity Category E).
- **CNE BL** is west of Bourne Bridge between Sandwich Road and Trowbridge Road, and comprises three single-family residences (FHWA Activity Category B) off Sandwich Road and Deboer Lane.
- **CNE BM** is southwest of the existing Bourne Rotary Bourne Bridge, south of Trowbridge Road and west of State Route 28 southbound mainline travel lanes. This CNE includes the All Seasons Inn & Suites hotel with outdoor seating areas (FHWA Activity Category E) and outdoor seating associated with the Lobster's Fish Market restaurant (FHWA Activity Category E).
- **CNE BN** is south of Trowbridge Road and west of the State Route 28 mainline travel lanes. This CNE includes single-family residences (FHWA Activity Category B) along Sandy Lane as well as outdoor use areas associated with the Bourne Intermediate School, Bourne Middle School, and Bourne High School (FHWA Activity Category C). Outdoor use areas within the Bourne South quadrant at the school complex include the tennis courts, track, and a multi-purpose field.
- **CNE BO** is west of the State Route 28 mainline travels lanes and includes the outdoor use areas associated with the Bourne Manor Extended Care facility (FHWA Activity Category C).
- **CNE BP** is south of Sandwich Road, east of the State Route 28 mainline travels lanes and includes the Upper Cape Cod Regional Technical High School (FHWA Activity Category C). This CNE also includes a small portion of the multifamily residential development (FHWA Activity Category B), Schooner Pass, along Admirals Way.

Figure 4-4. Noise Study Area and Common Noise Environment Boundaries and Noise Measurement Locations (Bourne South Quadrant)



Source: Massachusetts Department of Transportation, 2024

4.2.1.4 Determination of Existing Noise Levels

Existing Noise Measurement Methodology

A noise measurement program was conducted, consistent with FHWA and MassDOT recommended procedures, to document existing ambient noise levels in noise-sensitive locations in the Study Areas, which consisted of primarily residential areas.

Noise measurements were conducted at 18 sites (nine sites at each bridge) on May 16, May 17, and May 18, 2023. One short-term (30-minute duration) measurement per site was conducted using an HMMH-owned Bruel & Kjaer Model 2245 (ANSI Type I, "Precision") integrating sound level meter. HMMH's noise measurement instruments are calibrated annually at a certification laboratory, with calibrations traceable to the National Institute of Standards and Technology. During the monitoring program, the sound level meters were calibrated in the field using a handheld acoustic calibrator at the beginning and end of each measurement period.

Noise monitoring was performed in general accordance with the FHWA's Procedures for Abatement of Highway Traffic Noise and Construction Noise (23 CFR 772), and the FHWA reports, Highway Traffic Noise: Analysis and Abatement Guidance,[18] and Noise Measurement Handbook–Final Report.[19] **Figure 4-1, Figure 4-2, Figure 4-3**, and **Figure 4-4** illustrate the noise monitoring locations relative to the Sagamore North, Sagamore South, Bourne North, and Bourne South quadrants' improvements, respectively.

The short-term data collection procedure involved continuous monitoring and logging of the one-second sound levels. Concurrent with each noise measurement, vehicle classification counts were conducted, and average travel speeds were identified. Traffic conditions during measurements were normalized to 1 hour and used as input to the noise prediction model for validation. Vehicles were classified into the following categories, which are used within the FHWA's TNM version 2.5: (1) automobiles and light trucks, (2) medium trucks (2 axles, 6 tires), and (3) heavy trucks (3 or more axles). Bus and motorcycle pass-bys, which are typically less frequent than the other vehicle types, were also noted.

The dominant source of noise at all measurement sites was traffic on State Route 25, State Route 28, State Route 3, and U.S. Route 6 as well as other major arterials within the Noise Study Areas. Contributions from sources other than traffic on the affected roadways were present, including insects and birds chirping at several sites, traffic on local streets, aircraft overflights, and general activity in the community. Periods that included events that were not representative of the ambient noise environment, or were not traffic-related, were noted so that they could be later separated or excluded from the data set. **Attachment 2, Noise Measurement Program Files**, includes laboratory calibration certificates for the noise monitoring equipment, photos of each measurement site, and traffic data collected during noise measurements.

[18] http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/
[19] https://www.fhwa.dot.gov/environment/noise/measurement/handbook.cfm

The total measurement period Leq was determined both with (total Leq) and without ("traffic-only" Leq) the periods that included these events. The Leq is a sound-energy average of the fluctuating sound level (in A-weighted decibels, dBA) measured over a specified period of time (i.e., 30 minutes in this case). By comparing the two Leq totals, the significance of non-traffic events to the overall noise level was determined for the measurement period. In general, the short-term measurements characterized existing noise levels in the Noise Study Areas but were not necessarily conducted during the loudest hour of the day.

Traffic Noise Model Validation Methodology

The FHWA TNM incorporates state-of-the-art sound emissions and sound propagation algorithms, based on well-established theory or on accepted international standards. The acoustical algorithms contained within the FHWA TNM have been validated with respect to carefully conducted noise measurement programs and show excellent agreement in most cases for sites with and without noise barriers.

According to FHWA and MassDOT policies, the accuracy of the noise prediction model must be verified on a project-by-project basis. The noise model validation process compares existing noise levels monitored in the field with predicted noise levels from the FHWA TNM using the traffic conditions during the monitoring period as input to the model. The purpose of the noise model validation is to evaluate the success of the model in representing the important acoustical characteristics of the Noise Study Areas. This is determined by examining the overall trend of the differences between measured and predicted noise levels at each measurement site. Individual site-to-site differences may vary significantly, depending on factors that may affect either the measured noise level or the predicted noise level at a given site.

The traffic volumes and speeds collected during noise measurements along with existing basemaps and topographic GIS data from MassGIS were used to create a three-dimensional model in the TNM of the geometry of the existing roadway configurations and the surrounding terrain.[20]

Methodology for the Determination of 2019 Existing Condition Noise Levels

The noise measurements provide valuable information on current noise conditions and the effects of terrain and shielding on sound propagation from the roadways to the nearby noise-sensitive land uses. However, existing noise levels are not always measured during the loudest hour of the day and can only be conducted at a limited number of locations. Therefore, many additional receiver locations in noise-sensitive areas were added to the measurement sites in the noise prediction model to provide a comprehensive basis of comparison for the analysis of noise impacts from the existing project conditions during the loudest hour.

In accordance with FHWA and MassDOT regulations and policies, the noise assessment was performed using traffic data that is representative of the LTH. The LTH is dependent upon several factors, including traffic volumes, vehicle speeds, and vehicle mix (i.e., the percentage of automobiles, medium trucks, heavy trucks, buses and motorcycles in the traffic flow). The LTH can coincide with the peak

[20] MassGIS (Bureau of Geographic Information). https://www.mass.gov/orgs/massgis-bureau-of-geographic-information

hour or an off-peak hour, and it can vary across alternatives. Traffic volumes covering a 24-hour period were not available for all Study Area roadways to identify the LTH; therefore, the Fall AM and PM traffic peak-hour volumes prepared as part of the traffic study for the Program were used in the noise prediction model with posted roadway speeds to conservatively identify the loudest hour. Based on modeling results, the LTH was identified as the AM traffic peak hour for all Noise Study Areas except the Sagamore North quadrant where the LTH was identified as the PM peak traffic hour.

4.2.1.5 Prediction of Future Design Year Traffic Noise Levels

For the 2050 No Build Alternative, no roadway improvements would be made; therefore, the noise model geometry remained the same as 2019 existing conditions. Traffic volumes reflective of the 2050 design year were used in the noise model with the existing geometry. In addition, pursuant to 23 CFR 772.11(c)(2)(vii), undeveloped lands with issued building permits for future development were identified through coordination with the Town of Bourne. Proposed site plans for these developments were used to add receivers to the noise model representing exterior areas of frequent human use. Permitted noise-sensitive developments were included in the 2050 No Build Alternative noise modeling since they represent sites with a definite commitment to build.

The proposed roadway design data, including horizontal and vertical geometries, were used to develop the 2050 Build Alternative noise models. The 2050 design year traffic volumes developed as part of the traffic study for the Program and included within **Appendix 4.2, Traffic Engineering Technical Report**, were also included in the model. Roadway design speeds were reduced by 5 miles per hour to reflect potential posted speeds.

4.2.1.6 Identification of Traffic Noise Impacts

The noise impact of the Program was assessed pursuant to FHWA's federal traffic noise regulation and both FHWA and MassDOT noise assessment guidelines. As discussed in **Section 4.2.1.2**, noise impacts would occur wherever noise levels are predicted to approach or exceed each NAC (where approach is defined by MassDOT as one decibel less than each NAC). Noise impacts would also occur wherever predicted noise levels would substantially increase, relative to existing condition noise levels. MassDOT defines a substantial increase as 10 dB or more.

In addition to evaluating the impact of the Program from highway traffic noise on adjacent noise-sensitive land use, the effects of structure-reflected noise and expansion joint noise were also considered. A qualitative discussion of structure-reflected and expansion joint noise is provided in **Section 6.2.5**.

4.2.1.7 Evaluation of Noise Abatement Measures and MassDOT Criteria for Recommending Noise Barriers

FHWA has identified certain noise abatement measures that may be incorporated in projects to reduce traffic noise impacts. In general, mitigation measures can include alternative measures (traffic management and the alteration of horizontal and vertical alignment), in addition to the construction of noise barriers.

Alternative Mitigation Measures

Traffic management measures that are sometimes effective include reduced speeds and truck restrictions for the design-year Build Alternative; however, neither of these measures is planned for the Build Alternative. Reduced speeds along Build Alternative roadways would not be an effective noise mitigation measure because a substantial decrease in speed would be necessary to provide a significant noise reduction. A reduction of 10 miles per hour in speed would result in only a 2-decibel decrease in noise level. Truck restrictions would not be considered a feasible noise abatement measure since it would be incompatible with the Program purpose and need, as outlined in **Section 3.1**.

The alteration of horizontal alignment would be limited by right-of-way constraints. Significant noise reduction at noise-sensitive locations would require substantial alignment shifts, which would necessitate additional property acquisitions and could expose additional sites to highway traffic noise. Also, the alteration of vertical alignment of the proposed roadway is not considered to be a feasible noise abatement measure. Depressing the roadway could require taking of additional property for the sloped embankments, or excessive costs for the construction of sound-absorptive retaining walls or a tunnel; elevating the roadway could allow noise to propagate farther into local communities at higher levels.

The use of buffer zones as a mitigation measure would be costly and impractical. The acquisition of property for buffer zones would increase the distance between the bridges and interchange approach roadways and noise-sensitive land use. Such a mitigation measure is beyond the scope of the Program.

Noise Barriers

The only remaining abatement alternative investigated was the construction of noise barriers. Where the construction of noise barriers is found to be potentially feasible, the noise reduction provided by the barrier is estimated based on roadway, barrier, and receiver geometry. The FHWA TNM is used for all noise barrier analysis. MassDOT 2011 noise policy requires that noise barriers must be both feasible and cost reasonable to receive further consideration. The following sections discuss both of these evaluation criteria.

Feasibility

To be feasible, a barrier must be effective; that is, it must provide a significant noise reduction at those noise-sensitive land uses that would be exposed to noise impact. Every effort should be made to attain a 10-decibel (or higher) noise reduction at first-row receivers; however, for a barrier to be feasible, the majority, or greater than 50 percent, of first-row, impacted residential (Category B) receivers must receive a minimum noise reduction of five decibels. For recreation areas, the majority, or greater than 50 percent, of the impacted receptors (assessed as impacted person-hours of use) within the recreation area is required for a barrier to be considered feasible. Along unlimited access roadways that connect to arterial roadways, the large number of openings required for driveways frequently prevents noise barriers from being feasible, because sufficient noise reduction cannot be achieved with such gaps. Further, such corridors often have limited right-of-way on which to construct noise barriers. Other engineering considerations that can influence the ability of a noise barrier to provide a significant noise reduction include topographic effects and traffic on cross streets. Safety and other

environmental impacts (such as wetland conflicts) are important considerations in determining the feasibility of a noise barrier.

Reasonableness

Reasonableness considers the combination of social, economic, and environmental factors in the evaluation of a noise abatement measure and implies that good judgment and common sense were used in making a decision about barrier construction. The three primary reasonableness factors that must be achieved include cost effectiveness, achieving a noise reduction design goal, and gaining the support of property owners and residents for the abatement measures.[21]

The NRDG that noise barriers are required to meet is a minimum noise reduction of at least 10 decibels at one benefited, first-row receiver location for both residential (Category B) and recreation areas (Category C).

MassDOT has established criteria for cost-effectiveness, known as the CEI. For residential and commercial properties, the CEI is computed by dividing the total cost of a noise barrier first by the average-weighted noise reduction provided by the barrier, and then by the number of dwelling units protected by the barrier (all homes in the study zone that receive at least 5 dB of noise reduction). In these calculations, the total barrier cost is based on a unit cost of $60.00 per square foot. MassDOT has set a threshold for cost reasonableness where the CEI is less than or equal to $10,0080 per decibel of noise reduction (insertion loss[22]) per dwelling unit protected or benefited.

For Categories C and D land uses, which are outdoor recreation and interior institutional common-use areas, the CEI is computed similarly, except that the protected use is determined by the estimated number of "persons that are frequently active" using the facility daily by section of the activity area if that breakdown is known. Receivers (receptors) are in different portions of an activity area, and each may be assigned a value associated with its usage. This usage value is based on the number of people times hours (or person-hours) per day that it is in use. The CEI for Categories C and D land uses is computed by dividing the total barrier cost by the average insertion loss (weighted by person-hours) and then by the total number of person-hours of use at all impacted receivers (dividing by person-hours is identical to MassDOT's stated policy, which is to divide first by people, then by hours). MassDOT has set a threshold for cost reasonableness for Categories C and D uses, where the CEI is less than or equal to $138 per decibel of noise reduction per person per hour of use.

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[21] FHWA, "Procedures for Abatement of Highway Traffic Noise and Construction Noise" (23 Code of Federal Regulations 772, as amended 75 FR 39820, July 13, 2010; Effective date July 13, 2011). https://www.ecfr.gov/current/title-23/chapter-I/subchapter-H/part-772

[22] The amount of noise reduction provided by a noise abatement measure, which is calculated by subtracting the predicted future design year noise level with abatement from the predicted future design year noise level without abatement.

4.2.2 Construction Noise

Pursuant to 23 CFR 772.19 Construction Noise, construction noise effects shall be considered for all Type I highway projects to:

- Identify land uses or activities that may be impacted by noise from construction of the project, and
- Determine the measures that are needed in project plans and specifications to minimize or eliminate adverse construction noise impacts.

The level of construction noise analysis is generally based on the scale and scope of the project. A construction noise analysis was conducted to generally disclose potential impacted receptors, describe potential ranges in construction noise levels, and identify measures to be included in project plans and specifications. MassDOT will reassess construction noise as part of the Final Environmental Impact Statement. Data on construction equipment noise levels for the analysis is derived from the FHWA's Roadway Construction Noise Model Version 1.1 database.[23]

4.2.3 Construction Vibration

FHWA does not regulate construction-induced vibration. However, certain heavy construction activities (e.g., pile driving, demolition, excavation, etc.) may result in vibration-induced annoyance and/or structural damage. On a federal level, the best available and most commonly used guidance on evaluating effects of construction-related vibration is provided within the FTA's Transit Noise and Vibration Impact Assessment Manual.[24] According to FTA guidance, construction-induced vibration should be quantitatively assessed for activities such as pile driving, vibratory compaction, demolition, drilling, and excavation in close proximity to sensitive structures, as these activities have the greatest potential to generate vibration impacts. Based on the scale and scope of the Program, a quantitative construction vibration assessment was conducted.

The FTA vibration calculation method is dependent on equipment vibration source level and distance between the equipment and vibration-sensitive receptor. The calculation may also account for different soil characteristics, if known. A "distance to impact" assessment was conducted using equations provided within the FTA's guidance manual, which predict peak particle velocity (ppv) of the vibrations in inches per second ("in/sec" or "ips"), and vibration velocity levels (Lv) measured in units of VdB for the assessment of potential structural damage and vibration-induced annoyance, respectively.

Vibration levels were calculated in 1-foot increments for an impact pile driver, vibratory pile driver, auger drill, a hoe ram, a large bulldozer, and loaded trucks to determine the distance beyond which there would no longer be a potential for structural damage or vibration annoyance during construction phases in which these pieces of equipment are anticipated to be used. In general, properties greater

[23] https://www.fhwa.dot.gov/environment/noise/construction_noise/rcnm/

[24] https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/118131/transit-noise-and-vibration-impact-assessment-manual-fta-report-no-0123_0.pdf

than 300 feet in distance do not experience elevated vibration levels unless significant pile driving occurs.

Structural damage is based on the building material. **Table 4-2** summarizes the different categories of buildings and the FTA impact criteria for structural damage potential. The vibration-induced structural damage analysis conservatively assumes that most structures in the vicinity of proposed construction activities are FTA Category III structures. These are structures made of non-engineered timber and masonry buildings.

Table 4-2. Federal Transit Administration Construction Vibration Damage Criteria

Building Category	Peak Particle Velocity (inches/second, ips)
I. Reinforced concrete, steel or timber (no plaster)	0.5
II. Engineered concrete and masonry (no plaster)	0.3
III. Non-engineered timber and masonry buildings	0.2
IV. Buildings extremely susceptible to vibration damage	0.12

Source: Federal Transit Administration. 2018. Transit Noise and Vibration Impact Assessment Manual. September.

Table 4-3 summarizes the impact criteria for vibration-induced annoyance, which is dependent on the sensitive receptor type and frequency of vibration-inducing events.

Table 4-3. Federal Transit Administration Ground-Borne Vibration Impact Criteria (VdB re: 1 micro-inch/second

Vibration Land Use Category	Frequent Events[a]	Occasional Events[b]	Infrequent Events[c]
Category 1: Buildings where vibration will interfere with interior operations.	65	65	65
Category 2: Residences and buildings where people normally sleep.	72	75	80
Category 3: Institutional land uses with primarily daytime use.	75	78	83

Source: Federal Transit Administration. 2018. Transit Noise and Vibration Impact Assessment Manual. September.

[a] Frequent events is defined as more than 70 vibration events of the same source per day.

[b] Occasional events is defined as between 30 and 70 vibration events of the same source per day.

[c] Infrequent events is defined as fewer than 30 vibration events of the same kind per day.

5 Affected Environment

5.1 Existing Noise Measurements

5.1.1 Noise Measurement Results (Sagamore Bridge)

The total and "traffic-only" short-term Leq noise levels measured at sites in the Sagamore North and Sagamore South quadrants are summarized in **Table 5-1** and **Table 5-2**, respectively. **Table 5-3** and **Table 5-4** summarize total and "traffic-only" short-term Leq noise levels measured at sites in Bourne North and Bourne South quadrants, respectively.

Table 5-1 presents the total Leq noise levels within the Sagamore North quadrant, which ranged from a low of 56 dBA at the Canalside Apartments (SN11) to a high of 67 dBA at 38 Homestead Road (SN10). The "traffic-only" noise levels also ranged between a low of 56 dBA and a high of 67 dBA, confirming that State Route 3 highway traffic and local road traffic noise were the dominant noise sources during the measurements, despite the presence of other intermittent noise sources.

Table 5-1. Short-term Noise Monitoring Results (Sagamore North Quadrant)

Site Number	Address/Name	Land Use	Total Leq	Traffic-Only Leq	Observed Noise Sources
SN10	38 Homestead Road	Residential	67	67	State Route 3 and State Road traffic, birds
SN11	Canalside Apartments, #15	Residential	56	56	State Route 3 and Scotch Pine Road traffic, birds, insects
SN12	34 Canal Street	Residential	58	58	State Route 3, birds, distant construction noise
SN13	2 Brigantine Passage	Residential	61	61	Scenic Highway traffic, birds, insects

Leq = equivalent sound level

Table 5-2 illustrates the total Leq noise levels within the Sagamore South quadrant, which ranged from a low of 52 dBA at 3 Tracie Lane (SS15) to a high of 62 dBA at 2 Garfield Avenue (SS16). The "traffic-only" noise levels ranged between a low of 52 dBA and a high of 60 dBA. The similarity in total and "traffic-only" noise level indicates that U.S. Route 6 and local road traffic were the dominant noise sources during the measurements. At Site SS16, some community activity and insects may have contributed more to the total noise level than at other sites.

Table 5-2. Short-term Noise Monitoring Results (Sagamore South Quadrant)

Site Number	Address/Name	Land Use	Total Leq	Traffic-Only Leq	Observed Noise Sources
SS14	Cecilia Terrace (end of street)	Residential	58	58	U.S. Route 6 and Sandwich Road traffic, birds
SS15	3 Tracie Lane	Residential	52	52	Mid-Cape Connector traffic, birds
SS16	2 Garfield Avenue	Residential	62	60	U.S. Route 6 traffic, birds, insects
SS17	2 Vermont Street	Residential	56	55	Cranberry Highway traffic, birds
SN18	South side of bridge– bike/pedestrian path	Recreational	59	59	U.S. Route 6 traffic, birds, insects

Leq = equivalent sound level

5.1.2 Noise Measurement Results (Bourne Bridge)

Table 5-3 illustrates the total Leq noise levels within the Bourne North quadrant, which ranged from a low of 55 dBA at the Canal Sportsman Club (BN4) to a high of 59 dBA at 54A Poplar Court (BN1), Grove Street Lot G-24 camp site (BN-5), and at 97 Maple Street (BN6). The "traffic-only" noise levels ranged between a low of 54 dBA and a high of 59 dBA, which indicates that State Route 25 and local road traffic was the dominant noise source during the measurements, despite other intermittent noise sources.

Table 5-3. Short-term Noise Monitoring Results (Bourne North Quadrant)

Site Number	Address/Name	Land Use	Total Leq	Traffic-Only Leq	Observed Noise Sources
BN1	54A Poplar Court	Residential	59	59	State Route 25 traffic, birds
BN2	Ash Court Apartments 1-22	Residential	56	56	State Route 25 traffic, birds, insects
BN3	14 Mirasol Drive	Residential	56	56	State Route 25 traffic, birds, insects, dirt bike, wood saw
BN4	Canal Sportsman Club Inc.	Recreational	55	54	State Route 25 traffic, birds, insects
BN5	Grove Street, Lot G-24 (campsite)	Recreational	59	58	State Route 25 traffic, birds, insects, golf cart
BN6	97 Maple Street	Residential	59	56	Grand Army of the Republic Highway traffic, birds, insects

Leq = equivalent sound level

Table 5-4 illustrates the total Leq noise levels within the Bourne South quadrant, which ranged from a low of 54 dBA on Sandy Lane (BS9) to a high of 59 dBA at 18 Emerson Avenue (BS7). The "traffic only" noise levels ranged between a low of 53 dBA and a high of 57 dBA. The similarity in total and "traffic only" noise level indicates that State Route 25, State Route 28, and local road traffic was the dominant noise source during the measurements. At Site BS7, some community activity (i.e., a lawn mower) and insects may have contributed more to the total noise level than at other sites.

Table 5-4. Short-term Noise Monitoring Results (Bourne South Quadrant)

Site Number	Address/Name	Land Use	Total Leq	Traffic-Only Leq	Observed Noise Sources
BS7	18 Emerson Avenue	Residential	59	57	State Route 25 traffic, birds, insects, lawn mower
BS8	4 Freeman Street	Residential	56	56	State Route 25 and Sandwich Road traffic, birds, insects
BS9	Sandy Lane (cul-de-sac)	Residential	54	53	State Route 28 traffic, birds

Leq = equivalent sound level

5.2 Noise Model Validation

Table 5-5 and Table 5-6 present site-by-site comparisons of measured noise levels and the corresponding TNM-computed noise levels for the Sagamore North and Sagamore South quadrants, respectively. Table 5-7 and Table 5-8 present site-by-site comparisons of measured noise levels and the corresponding TNM-computed noise levels for the Bourne North and Bourne South quadrants, respectively.

At all 18 sites, the differences between measured and predicted noise levels fall within 3 dB, which is the accepted level of accuracy in the noise model. The average difference between calculated noise levels and monitored noise levels is 1.7 dB north of Sagamore Bridge, 1.4 dB south of Sagamore Bridge, 1.1 dB north of Bourne Bridge, and -1.5 dB south of Bourne Bridge. Project-wide, the average difference between measured versus modeled noise levels is therefore less than 1 dB. This shows good agreement between monitored and modeled sound levels, suggesting confidence in the modeling assumptions. Therefore, the validated project-specific noise models are acceptable for use in predicted noise levels at additional noise-sensitive land use in the Noise Study Areas.

Table 5-5. Noise Measurement and Model Validation Results Comparison (Sagamore North Quadrant)

Site Number	Address/Name	Land Use	Measured Traffic-Only Leq	Modeled Leq	Modeled minus Measured Leq	Average Difference[a]
SN10	38 Homestead Road	Residential	67.2	67.6	0.4	1.7
SN11	Canalside Apartments, #15	Residential	55.9	58.9	3.0	
SN12	34 Canal Street	Residential	58.2	61.2	3.0	
SN13	2 Brigantine Passage	Residential	61.3	61.7	0.4	

[a] The average sound level difference is calculated by summing the difference in measured and modeled noise levels and dividing by the number of measurement sites.

Leq = equivalent sound level

Table 5-6. Noise Measurement and Model Validation Results Comparison (Sagamore South Quadrant)

Site Number	Address/Name	Land Use	Measured Traffic-Only Leq	Modeled Leq	Modeled minus Measured Leq	Average Difference[a]
SS14	Cecilia Terrace (end of street)	Residential	57.7	57.8	0.1	1.4
SS15	3 Tracie Lane	Residential	51.8	52.4	0.6	
SS16	2 Garfield Avenue	Residential	60.1	63.1	3.0	
SS17	2 Vermont Street	Residential	55.0	56.8	1.8	
SN18	South side of bridge–bike/pedestrian path	Recreational	59.4	60.5	1.1	

[a] The average sound level difference is calculated by summing the difference in measured and modeled noise levels and dividing by the number of measurement sites.

Leq = equivalent sound level

Table 5-7. Noise Measurement and Model Validation Results Comparison (Bourne North Quadrant)

Site Number	Address/Name	Land Use	Measured Traffic-Only Leq	Modeled Leq	Modeled minus Measured Leq	Average Difference[a]
BN1	54A Poplar Court	Residential	59.0	60.0	1.0	1.1
BN2	Ash Court Apartments 1-22	Residential	56.2	55.2	-1.0	
BN3	14 Mirasol Drive	Residential	56.3	57.7	1.4	
BN4	Canal Sportsman Club Inc.	Recreational	54.0	56.9	2.9	
BN5	Grove Street, Lot G-24 (camp site)	Recreational	58.4	59.4	1.0	
BN6	97 Maple Street	Residential	56.3	53.7	-2.6	

[a] The average sound level difference is calculated by summing the difference in measured and modeled noise levels and dividing by the number of measurement sites.

Leq = equivalent sound level

Table 5-8. Noise Measurement and Model Validation Results Comparison (Bourne South Quadrant)

Site Number	Address/Name	Land Use	Measured Traffic-Only Leq	Modeled Leq	Modeled minus Measured Leq	Average Difference[a]
BS7	18 Emerson Avenue	Residential	56.6	56.4	-0.2	-1.5
BS8	4 Freeman Street	Residential	56.1	54.8	-1.3	
BS9	Sandy Lane (cul-de-sac)	Residential	53.4	50.4	-3.0	

[a] The average sound level difference is calculated by summing the difference in measured and modeled noise levels and dividing by the number of measurement sites.

Leq = equivalent sound level

5.3 Existing Noise Levels

5.3.1 2019 Existing: Loudest Traffic Hour Noise Levels (Sagamore North Quadrant)

Table 5-9 summarizes the predicted ranges in existing noise levels as well as number of equivalent dwelling units that approach or exceed the FHWA NAC within each CNE in the Sagamore North quadrant.

Table 5-9. 2019 Existing: Loudest Traffic Hour Noise Levels (Sagamore North Quadrant)

Common Noise Environment	Adjacent Roadways	2019 Existing Condition Noise Level Ranges Leq	Federal Highway Administration Activity Category	2019 Existing Condition Approach or Exceed Noise Abatement Criteria
SA	State Route 3 Southbound	44–60	B	0
SB	State Route 3 Southbound	51–65	B	0
SC	State Route 3 Northbound	49–67	B	3
SD	State Route 3 Northbound	46–68	B	1
SE	U.S. Route 6 Northbound	60–61	B	0
SF	U.S. Route 6 Northbound	61–63	C	0
			E	0
SG	U.S. Route 6 Northbound Canal Street	55–60	B	0
SH	U.S. Route 6 Northbound	49–60	B	0
	Canal Street		C	0
SI	Scenic Highway	52–65	B	0

Source: Massachusetts Department of Transportation, 2024

Note: Refer to **Figure 4-1** for Common Noise Environment locations.

Leq = equivalent sound level

In the Sagamore North quadrant for the 2019 existing conditions, four single-family residential dwelling units within CNEs SC and SD approach or exceed the FHWA Category B NAC. No Activity Categories C, D, or E land uses approach or exceed the respective NAC thresholds for the 2019 existing conditions in the Sagamore North quadrant.

5.3.2 2019 Existing: Loudest Traffic Hour Noise Levels (Sagamore South Quadrant

Table 5-10 summarizes the predicted ranges in existing noise levels as well as number of equivalent dwelling units that approach or exceed the FHWA NAC within each CNE in the Sagamore South quadrant.

Table 5-10. 2019 Existing: Loudest Traffic Hour Noise Levels (Sagamore South Quadrant)

Common Noise Environment	Adjacent Roadways	2019 Existing Condition Noise Level Ranges Leq	Federal Highway Administration Activity Category	2019 Existing Condition Approach or Exceed Noise Abatement Criteria
SJ	Sandwich Road	54–68	B	20
SK	U.S. Route 6 Northbound	53–71	B	5
	Sandwich Road		C	0
SL	Sandwich Road	51–67	B	2
	Cranberry Highway		E	0
SM	Sandwich Road	48–67	B	7
			C	3
SN	Sandwich Road Cranberry Highway	49–65	B C E	0 0 0
SO	Cranberry Highway	50–64	B	0
SP	U.S. Route 6 Southbound	53–61	B	0
	Mid-Cape Connector			
	Sandwich Road			
SQ	Mid-Cape Connector	49–69	B	2
	Sandwich Road			

Source: Massachusetts Department of Transportation, 2024

Note: Refer to **Figure 4-2** for Common Noise Environment locations.

Leq = equivalent sound level

In the Sagamore South quadrant for the 2019 existing conditions, 36 residential dwelling units approach or exceed the FHWA Category B NAC. Existing noise levels also approach or exceed the FHWA Activity Category C NAC at Keith Field on the field at home plate in the catcher's position. To determine the number of equivalent receptors predicted to experience noise levels that approach or exceed the

FHWA Category C NAC at Keith Field, a schedule of events on the Bourne Recreation website was reviewed.[25] The calendar for booking usage of Keith Field shows that, on average, there is either one game or practice at the field per day. Behind home plate, a maximum of three people per day (i.e., the batter, catcher, and potentially one umpire if the field is being used for a game) for a total of approximately three hours would experience noise levels that approach or exceed the FHWA Category C NAC. No Activity Category E land uses approach or exceed the respective NAC thresholds for the 2019 existing conditions in the Sagamore South quadrant.

5.3.3 2019 Existing: Loudest Traffic Hour Noise Levels (Bourne North Quadrant)

Table 5-11 summarizes the predicted ranges in existing noise levels as well as number of equivalent dwelling units that approach or exceed the FHWA NAC within each CNE in the Bourne North quadrant.

Table 5-11. 2019 Existing: Loudest Traffic Hour Noise Levels (Bourne North Quadrant)

Common Noise Environment	Adjacent Roadways	2019 Existing Noise Level Ranges Leq	Federal Highway Administration Activity Category	2019 Existing Condition Approach or Exceed Noise Abatement Criteria
BA	State Route 25 Northbound	45–63	B	0
BB	State Route 25 Northbound and northbound/southbound on-ramps	52–55	B	0
BC	State Route 25 Southbound	48–65	B	0
			E	
BD	State Route 25 Southbound	60–65	E	0
BE	State Route 28 Southbound	53–63	B	0
			C	
			E	
BF	State Route 28 Northbound	53–65	B	0
	U.S. Route 6/Main Street			
BG	State Route 28 Northbound	53–62	C	0
	U.S. Route 6/Main Street			

Source: Massachusetts Department of Transportation, 2024

Note: Refer to **Figure 4-3** for Common Noise Environment locations.

Leq = equivalent sound level

[25] https://bournema.myrec.com/info/facilities/details.aspx?FacilityID=14558

In the Bourne North quadrant for the 2019 existing conditions, five residential dwelling units approach or exceed the FHWA Category B NAC, which are all along Mirasol Drive adjacent to the State Route 25 northbound mainline travel lanes. No Activity Category C, D, or E land uses approach or exceed the respective NAC thresholds for the 2019 existing conditions in the Bourne North quadrant.

5.3.4 2019 Existing: Loudest Traffic Hour Noise Levels (Bourne South Quadrant)

Table 5-12 summarizes the predicted ranges in existing noise levels as well as number of equivalent dwelling units that approach or exceed the FHWA NAC within each CNE in the Bourne South quadrant.

Table 5-12. 2019 Existing: Loudest Traffic Hour Noise Levels (Bourne South Quadrant)

Common Noise Environment	Adjacent Roadways	2019 Existing Noise Level Ranges Leq	Federal Highway Administration Activity Category	2019 Existing Condition Approach or Exceed Noise Abatement Criteria
BH	State Route 28 Southbound	52–60	B	0
BI	State Route 28 Northbound	57–58	C	0
BJ	Sandwich Road	59–64	B	0
BK	Veterans Way	42–64	B	0
	Sandwich Road		C	0
	Trowbridge Road		E	0
BL	Sandwich Road	51–53	B	0
	Trowbridge Road			
BM	State Route 28 Southbound	52–64	E	0
	Trowbridge Road			
BN	State Route 28 Southbound	46–60	B	0
	Trowbridge Road		C	0
BO	State Route 28 Southbound	54–67	C	1
BP	Sandwich Road	28–55	B	0
			C	0

Source: Massachusetts Department of Transportation, 2024

Note: Refer to **Figure 4-4** for Common Noise Environment locations.

Leq = equivalent sound level

In the Bourne South quadrant for the 2019 existing conditions, no residences approach or exceed the FHWA Category B NAC. One bench on the north side of the Bourne Manor Extended Care facility approaches or exceeds the FHWA Activity Category C NAC for the 2019 existing condition. No FHWA

Activity Category D or E land uses approach or exceed the respective NAC thresholds for the 2019 existing conditions in the Bourne South quadrant.

6 Environmental Consequences

6.1 No Build Alternative

6.1.1 No Build Alternative Noise Levels (Sagamore North Quadrant)

Table 6-1 summarizes the predicted ranges in 2050 No Build Alternative noise levels as well as number of equivalent dwelling units that approach or exceed the FHWA NAC within each CNE. **Table 6-1** also includes predicted 2050 No Build Alternative noise levels at one permitted future development identified within the Sagamore North quadrant.

Table 6-1. 2050 No Build Alternative: Loudest Traffic Hour Noise Levels (Sagamore North Quadrant)

Common Noise Environment	Adjacent Roadways	2050 No Build Alternative Noise Level Ranges Leq	Federal Highway Administration Activity Category	2050 No Build Alternative Approach or Exceed Noise Abatement Criteria
SA	State Route 3 Southbound	45–61	B	0
SB	State Route 3 Southbound	52–67	B	2
SC	State Route 3 Northbound	51–69	B	3
SD	State Route 3 Northbound	47–69	B	2
SE	U.S. Route 6 Northbound	61–62	B	0
SF	U.S. Route 6 Northbound	61–65	C	0
			E	0
SG	U.S. Route 6 Northbound	56–61	B	0
	Canal Street			
SH	U.S. Route 6 Northbound	49–61	B	0
	Canal Street		C	0
SI	Scenic Highway	53–65	B	0
Permitted Development – Cape View Way[a]	Meetinghouse Lane	49–52	B	0

[a] Cape View Way is a proposed residential development (FHWA Activity Category B) that received a building permit on September 24, 2024, to construct 42 residential dwelling units.

Note: Refer to **Figure 4-1** for Common Noise Environment locations.

Leq = equivalent sound level

For the 2050 No Build Alternative in the Sagamore North quadrant, seven residential dwelling units within CNEs SB, SC, and SD would approach or exceed the Activity Category B NAC for the 2050 No Build Alternative. In addition, one permitted development (Cape View Way) was identified and includes a plan for 42 residential apartment units (FHWA Activity Category B) on five parcels north of Meetinghouse Lane (refer to **Figure 6-1**). A building permit was issued for this development on September 24, 2024, and construction is underway. Due to the development's distance from the State Route 3/U.S. Route 6 mainline travel lanes and Meetinghouse Lane, noise levels would not approach or exceed the Activity Category B NAC for the 2050 No Build Alternative at this development. No Activity Categories C, D, or E land uses would approach or exceed the respective NAC thresholds for the 2050 No Build Alternative in the Sagamore North quadrant.

6.1.2 No Build Alternative Noise Levels (Sagamore South Quadrant)

Table 6-2 summarizes the predicted ranges in 2050 No Build Alternative noise levels as well as number of equivalent dwelling units that approach or exceed the FHWA NAC within each CNE in the Sagamore South quadrant. There are no permitted future developments within the Sagamore South quadrant.

In the Sagamore South quadrant for the 2050 No Build Alternative, 46 residential dwelling units would approach or exceed the FHWA Category B NAC within CNEs SJ, SK, SL, SM, SN, and SQ. The 2050 No Build Alternative noise levels would approach or exceed the FHWA Activity Category C NAC at Keith Field on the field at home plate in the catcher's position. To determine the number of equivalent receptors predicted to experience noise levels that approach or exceed the FHWA Category C NAC at Keith Field, a schedule of events on the Bourne Recreation website was reviewed.[26] The calendar for booking usage of Keith Field shows that, on average, there is either one game or practice at the field per day. Behind home plate, a maximum of three people per day (i.e., the batter, catcher, and potentially one umpire if the field is being used for a game) for a total of approximately three hours would experience noise levels that approach or exceed the FHWA Category C NAC. No Activity Category E land uses would approach or exceed the respective NAC thresholds for the 2050 No Build Alternative in the Sagamore South quadrant.

[26] https://bournema.myrec.com/info/facilities/details.aspx?FacilityID=14558

Table 6-2. 2050 No Build Alternative: Loudest Traffic Hour Noise Levels (Sagamore South Quadrant)

Common Noise Environment	Adjacent Roadways	2050 No Build Alternative Noise Level Ranges Leq	Federal Highway Administration Activity Category	2050 No Build Alternative Approach or Exceed Noise Abatement Criteria
SJ	Sandwich Road	55–69	B	20
SK	U.S. Route 6 Northbound	54–72	B	7
	Sandwich Road		C	0
SL	Sandwich Road	52–68	B	4
	Cranberry Highway		E	0
SM	Sandwich Road	50–69	B	8
			C	3
SN	Sandwich Road Cranberry Highway	51–67	B	3
			C	0
			E	0
SO	Cranberry Highway	51–65	B	0
SP	U.S. Route 6 Southbound	54–63	B	0
	Mid-Cape Connector			
	Sandwich Road			
SQ	Mid-Cape Connector	51–70	B	4
	Sandwich Road			

Note: Refer to **Figure 4-2** for Common Noise Environment locations.

Leq = equivalent sound level

6.1.3 No Build Alternative Noise Levels (Bourne North Quadrant)

Table 6-3 summarizes the predicted ranges in existing noise levels as well as a number of equivalent dwelling units that approach or exceed the FHWA NAC within each CNE in the Bourne North quadrant. **Table 6-3** also includes predicted 2050 No Build Alternative noise levels at one permitted development identified within the Bourne North quadrant.

Table 6-3. 2050 No Build Alternative: Loudest Traffic Hour Noise Levels (Bourne North Quadrant)

Common Noise Environment	Adjacent Roadways	2050 No Build Alternative Noise Level Ranges Leq	Federal Highway Administration Activity Category	2050 No Build Alternative Approach or Exceed Noise Abatement Criteria
BA	State Route 25 Northbound	46–63	B	0
BB	State Route 25 Northbound and northbound/southbound on-ramps	53–56	B	0
BC	State Route 25 Southbound	49–65	B	0
			E	
BD	State Route 25 Southbound	61–66	E	0
BE	State Route 28 Southbound	54–65	B	0
			C	
			E	
BF	State Route 28 Northbound	54–66	B	2
	U.S. Route 6/Main Street			
BG	State Route 28 Northbound	54–63	C	0
	U.S. Route 6/Main Street			
Permitted Development – 340 Main Street[a]	State Route 28 Northbound	58–65	B	0
	U.S. Route 6/Main Street			

[a] 340 Main Street is a part of a mixed-use development, where Phase I has been completed and includes six second-story apartment units above first floor commercial property. Phase II includes construction of 24 rental townhome style units behind the commercial property. Phase II building permit was issued on March 5, 2022.

Note: Refer to **Figure 4-3** for Common Noise Environment locations.

Leq = equivalent sound level

For the 2050 No Build Alternative in the Bourne North quadrant, seven residential dwelling units would approach or exceed the FHWA Category B NAC within CNE BA (five residences along Mirasol Drive) and CNE BF (two residences along U.S. Route 6/Main Street westbound). In addition, one permitted future development (340 Main Street – refer to **Figure 6-3**) was identified that includes a plan for 24 townhome style residences (FHWA Activity Category B) along U.S. Route 6/Main Street behind and west of Bourne Bridge and behind the Sav-On gas station. A building permit was issued for this

development on March 5, 2022, and construction is anticipated to commence in winter 2025. Noise levels are not predicted to approach or exceed the Activity Category B NAC for the 2050 No Build Alternative at this permitted development due to their distance from U.S. Route 6/Main Street and the Bourne Bridge mainline travel lanes. No Activity Categories C, D or E land uses would approach or exceed the respective NAC thresholds for the 2050 No Build Alternative in the Bourne North quadrant.

6.1.4 No Build Alternative Noise Levels (Bourne South Quadrant)

Table 6-4 summarizes the predicted ranges in existing noise levels as well as number of equivalent dwelling units that approach or exceed the FHWA NAC within each CNE in the Bourne South quadrant. No permitted developments were identified in the Bourne South quadrant.

Table 6-4. 2050 No Build Alternative: Loudest Traffic Hour Noise Levels (Bourne South Quadrant)

Common Noise Environment	Adjacent Roadways	2050 No Build Alternative Level Ranges Leq	Federal Highway Administration Activity Category	2050 No Build Alternative Approach or Exceed Noise Abatement Criteria
BH	State Route 28 Southbound	53–60	B	0
BI	State Route 28 Northbound	59–60	C	0
BJ	Sandwich Road	60–65	B	0
BK	Veterans Way	42–63	B	0
	Sandwich Road		C	0
	Trowbridge Road		E	0
BL	Sandwich Road	52–55	B	0
	Trowbridge Road			
BM	State Route 28 Southbound	53–65	E	0
	Trowbridge Road			
BN	State Route 28 Southbound	47–61	B	0
	Trowbridge Road		C	
BO	State Route 28 Southbound	54–67	C	3
BP	Sandwich Road	29–55	B	0
			C	

Note: Refer to **Figure 4-4** for Common Noise Environment locations.

Leq = equivalent sound level

In the Bourne South quadrant for the 2050 No Build Alternative, no residences would approach or exceed the FHWA Category B NAC. One bench on the north side of the Bourne Manor Extended Care facility would approach or exceed the FHWA Activity Category C NAC for the 2050 No Build Alternative. No FHWA Activity Categories D or E land uses would approach or exceed the respective NAC thresholds for the 2050 No Build Alternative in the Bourne South quadrant.

6.2 Build Alternative

Attachment 3, Predicted 2019 Existing Condition and 2050 No Build and Build Alternative Noise Levels, includes summary tables of predicted 2019 existing condition, 2050 No Build Alternative, and 2050 Build Alternative noise levels by receptor. **Figure 6-1** to **Figure 6-4** provide location maps for the CNEs, noise-sensitive receptors, and barriers evaluated (refer to **Section 7.1** for a discussion of evaluated noise barriers) within the Sagamore North, Sagamore South, Bourne North, and Bourne South quadrants, respectively. On each figure, triangles represent noise measurement locations, while squares, pentagons, and hexagons all represent impacted receptors with different noise level reductions from evaluated noise barriers (insertion loss). Squares represent impacted receptors as well as impacted receptors that achieve less than 5 dB noise reduction with noise abatement measures, pentagons represent impacted receptors that achieve noise level reductions ranging between 5 and 9 dB, and hexagons represent impacted receptors that achieve 10 dB or greater noise reduction. Large circles represent receptors that are not impacted but achieve at least a 5 dB noise reduction with a noise barrier, while small circles represent receptors that are not impacted and also do not achieve a 5 dB noise reduction.

6.2.1 Build Alternative Operational Traffic Noise Impacts (Sagamore North Quadrant)

Table 6-5 summarizes the predicted ranges in 2019 existing conditions and 2050 Build Alternative noise levels as well as the number of impacted equivalent dwelling units within each CNE in the Sagamore North quadrant. The 2019 existing conditions noise levels are presented for comparison to 2050 Build Alternative noise levels to evaluate the substantial increase impact criterion. **Table 6-5** also includes predicted 2050 Build Alternative noise levels at one permitted development identified within the Sagamore North quadrant. **Figure 6-1** provides location maps for the CNEs, noise-sensitive receptors and barriers evaluated within the Sagamore North quadrant.

For the 2050 Build Alternative in the Sagamore North quadrant, two parcels would be acquired to accommodate the proposed alignment, one of which includes a residential property within CNE SE, east of Sagamore Bridge along Canal Street. The other property acquisition is west of the State Route 3/U.S. Route 6 southbound on-ramp from Scenic Highway and does not include noise-sensitive land use.

Table 6-5 shows that, relative to the 2019 existing condition, noise levels are predicted to increase in some CNEs and decrease in others. The horizontal alignment shift away from noise-sensitive land use as well as an increase in the elevations of bridge and approach roadways in some areas also contribute

to decreases in predicted 2050 Build Alternative noise levels. In addition, no substantial noise increases are predicted within the Sagamore North quadrant.

Table 6-5. 2050 Build Alternative: Loudest Traffic Hour Noise Levels (Sagamore North Quadrant)

Common Noise Environment	Adjacent Roadways	2019 Existing Condition Noise Level Ranges Leq	2050 Build Alternative Noise Level Ranges Leq	Federal Highway Administration Activity Category	2050 Build Alternative Approach or Exceed Noise Abatement Criteria
SA	State Route 3 Southbound	44–60	46–61	B	0
SB	State Route 3 Southbound	51–65	52–66	B	3
SC	State Route 3 Northbound	49–67	51–68	B	3
SD	State Route 3 Northbound	46–68	48–66	B	2
SE	U.S. Route 6 Northbound	60–61	62–62	B	0
SF	U.S. Route 6 Northbound	61–63	58–62	C	0
				E	0
SG	U.S. Route 6 Northbound Canal Street	55–60	57–61	B	0
SH	U.S. Route 6 Northbound	49–60	50–62	B	0
	Canal Street			C	0
SI	Scenic Highway	52–65	54–66	B	1
Permitted Development – Cape View Way[a]	Meetinghouse Lane	N/A	50–52	B	0

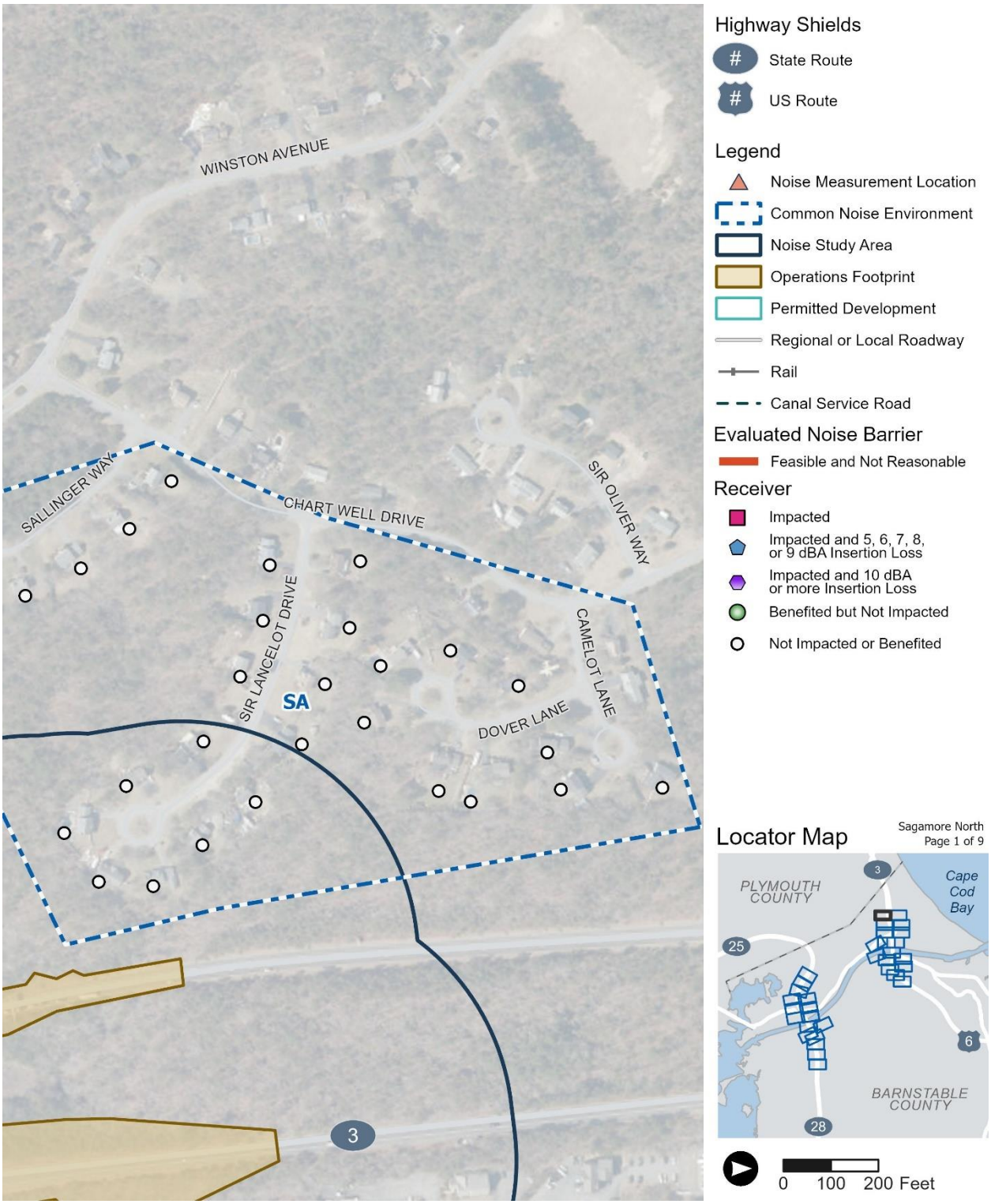
[a] Cape View Way is a proposed residential development (Federal Highway Administration Activity Category B) that received a building permit on September 24, 2024, for construction of 42 residential dwelling units. The 2019 existing noise levels are not reported for permitted developments because they do not yet exist.

Note:Refer to **Figure 6-1** for Common Noise Environment locations.

Leq = equivalent sound level

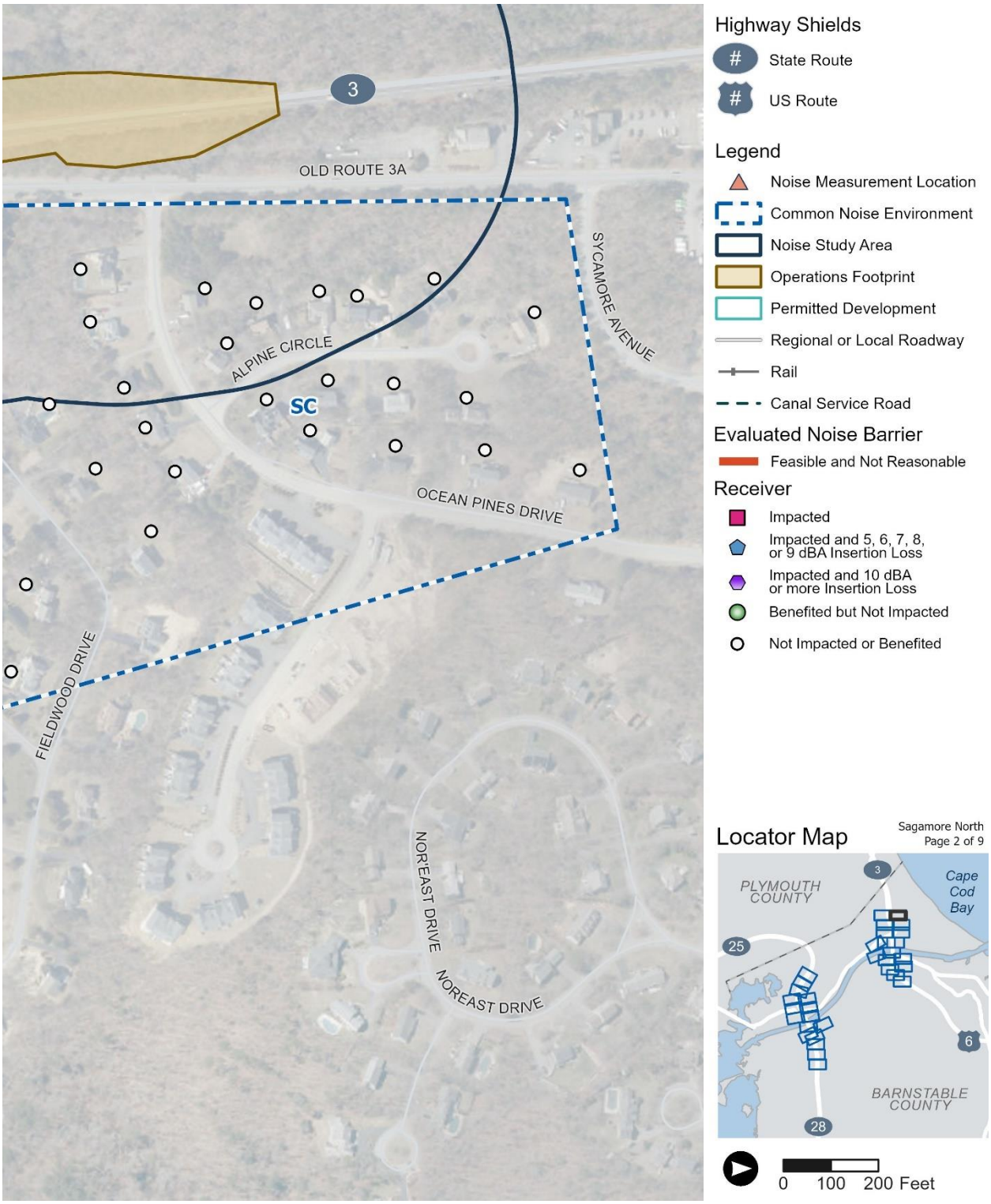
There are nine residential dwelling units within CNEs SB, SC, and SD that would approach or exceed the Activity Category B NAC. The 2050 Build Alternative noise levels are not predicted to approach or exceed the Activity Category B NAC at the proposed Cape View Way permitted development. There are no Activity Categories C, D, or E land uses that approach or exceed the respective NAC thresholds for the 2050 Build Alternative in the Sagamore North quadrant. In addition, there are no substantial noise level increases within the Sagamore North quadrant.

Figure 6-1. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore North Quadrant) (1 of 9)



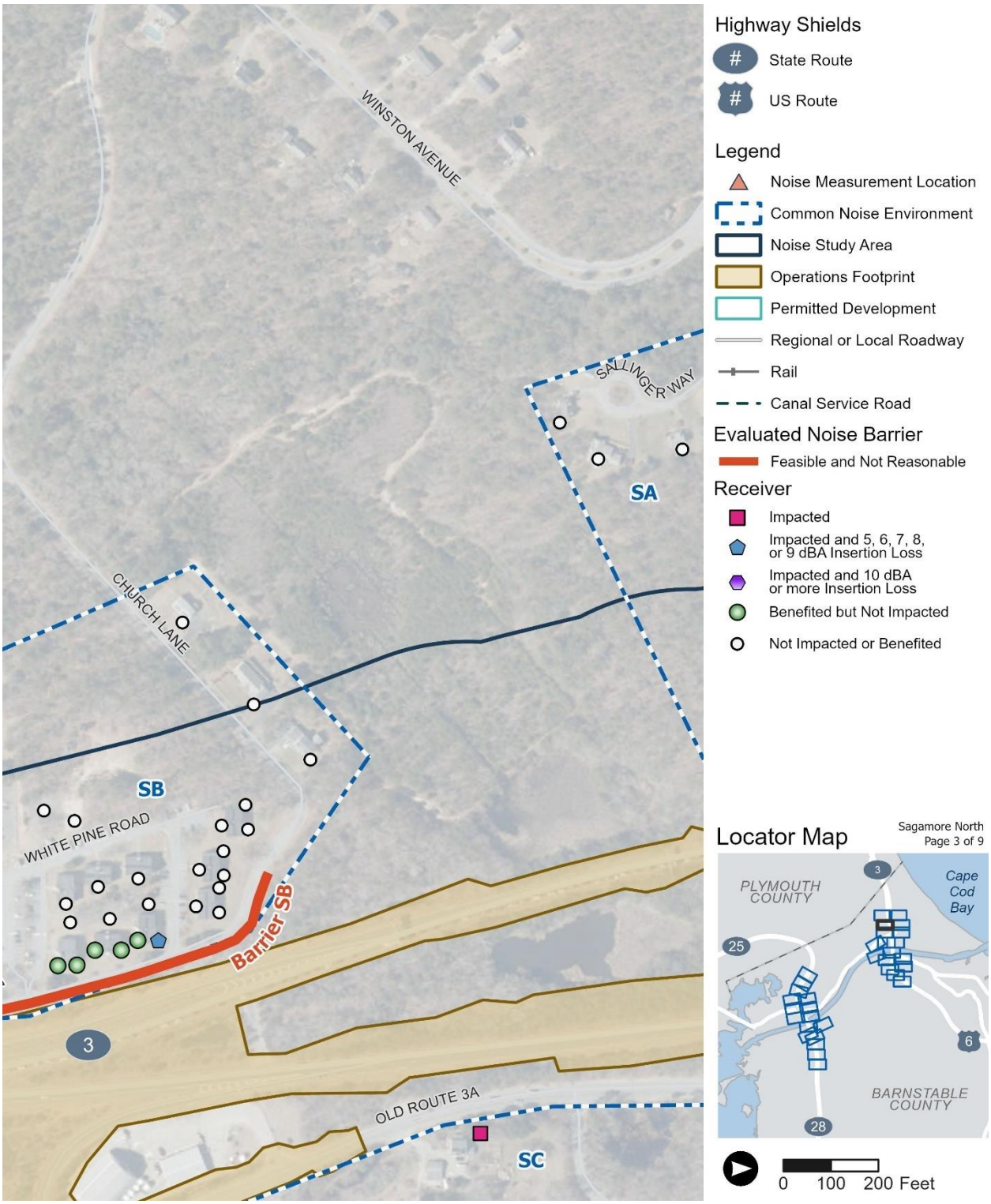
Source: Massachusetts Department of Transportation, 2024

Figure 6-1. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore North Quadrant) (2 of 9)



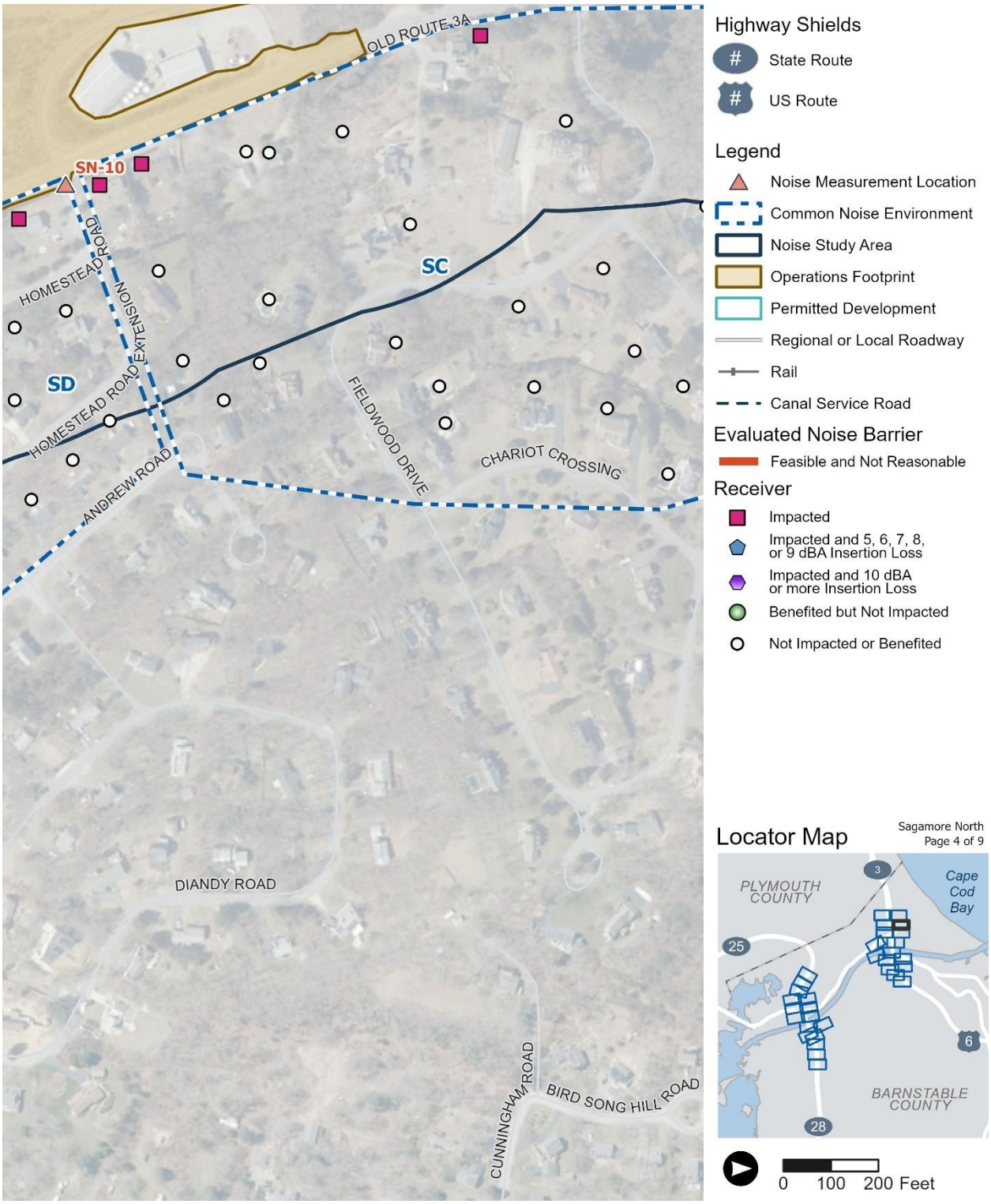
Source: Massachusetts Department of Transportation, 2024

Figure 6-1. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore North Quadrant) (3 of 9)



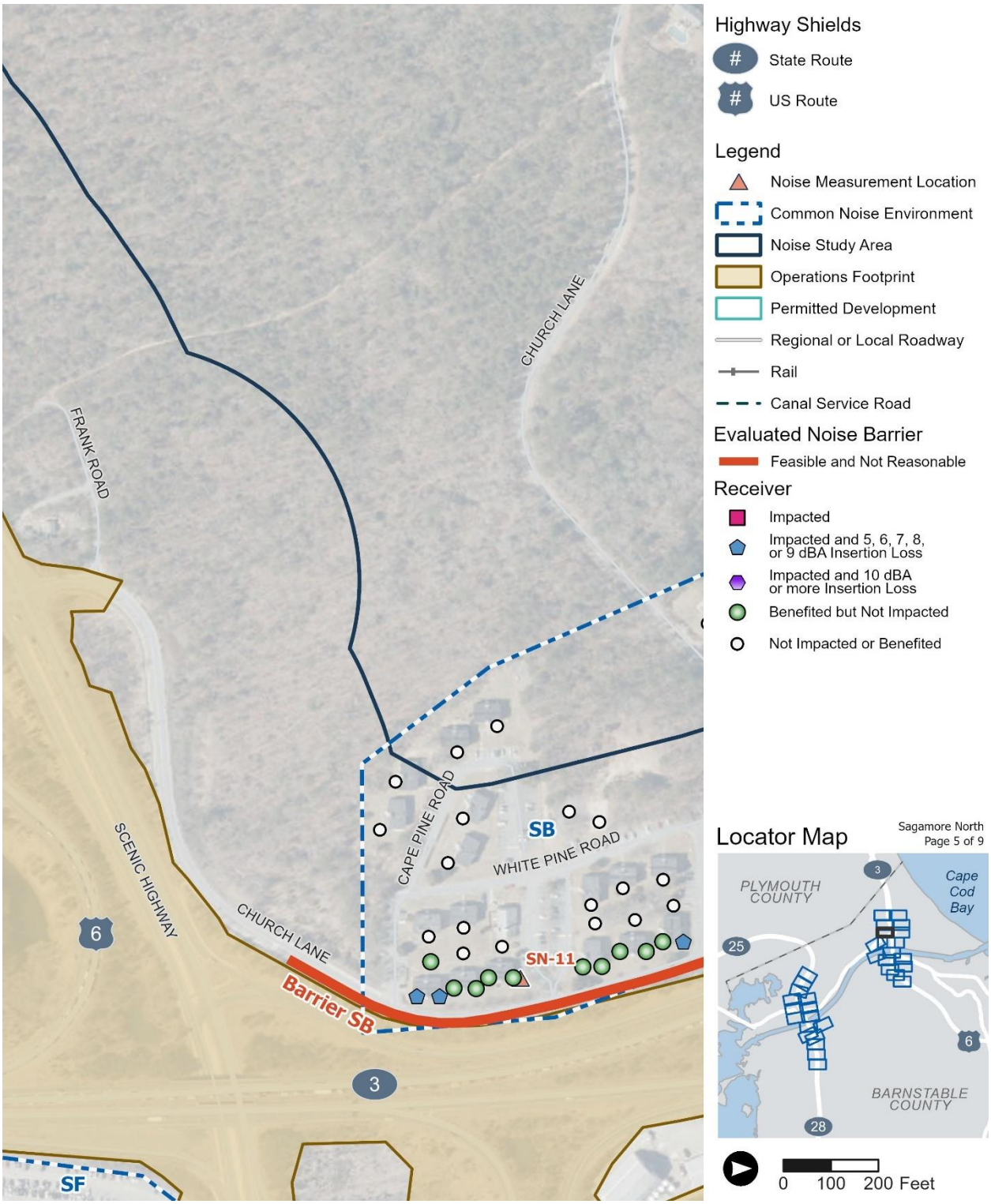
Source: Massachusetts Department of Transportation, 2024

Figure 6-1. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore North Quadrant) (4 of 9)



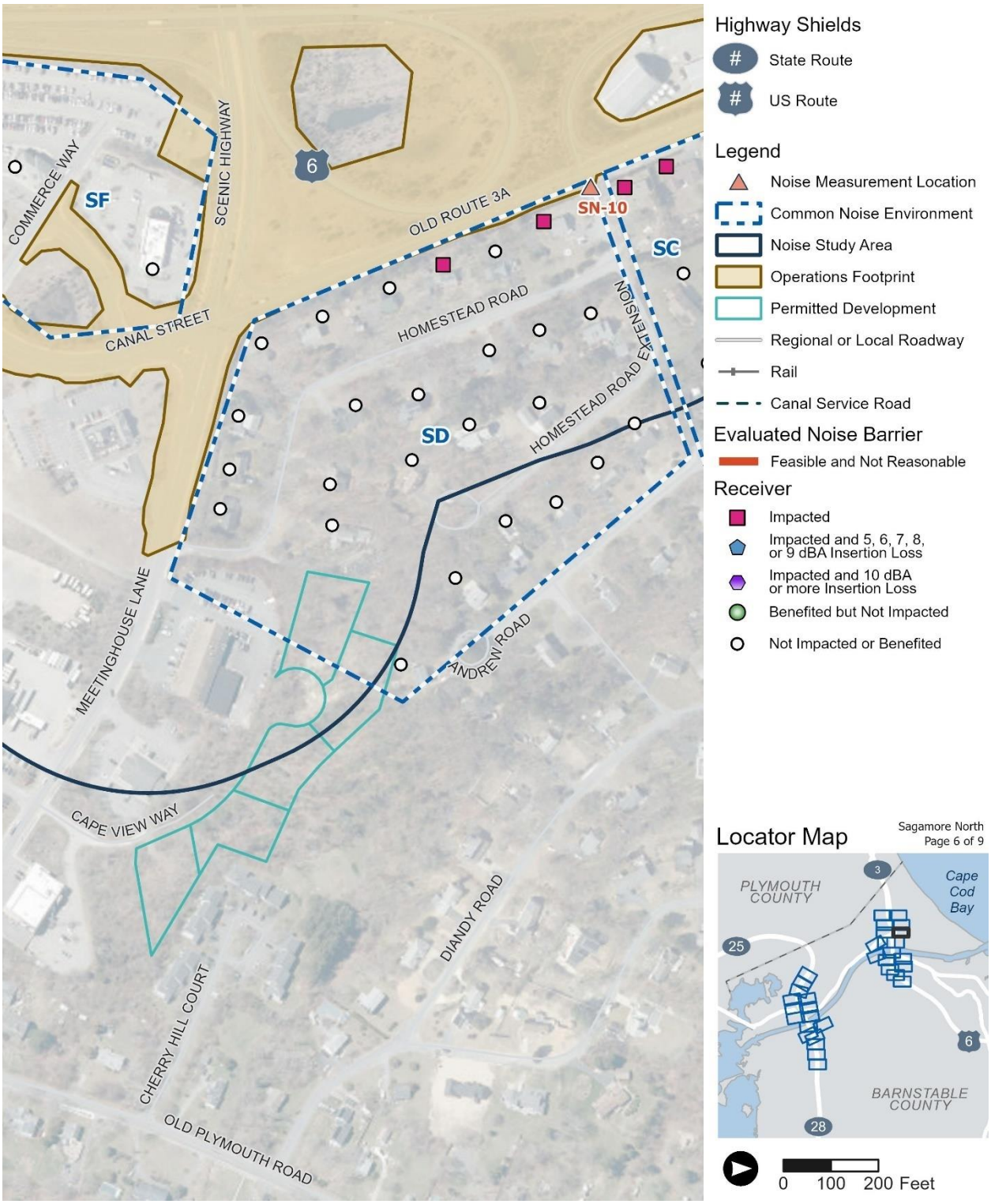
Source: Massachusetts Department of Transportation, 2024

Figure 6-1. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore North Quadrant) (5 of 9)



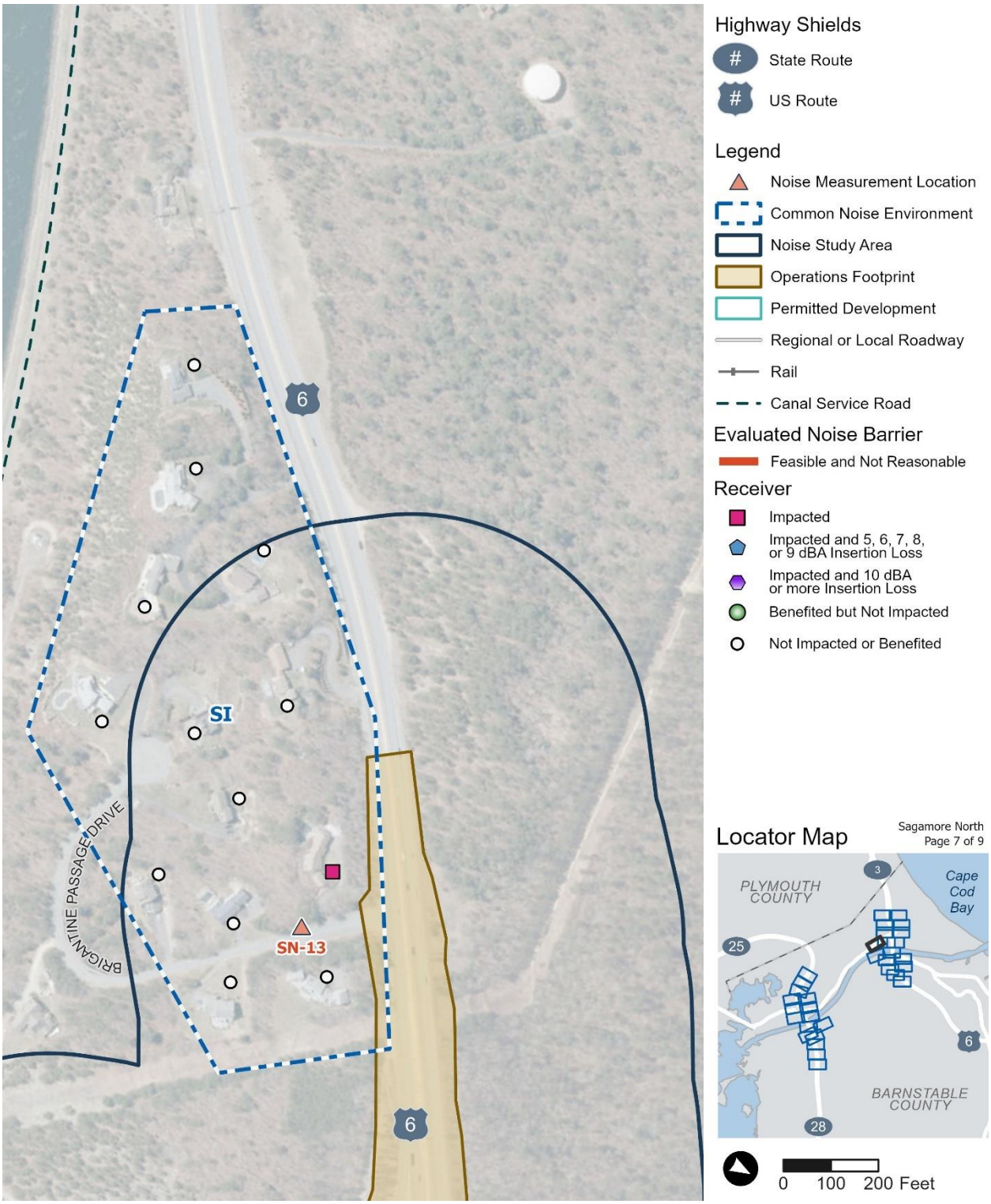
Source: Massachusetts Department of Transportation, 2024

Figure 6-1. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore North Quadrant) (6 of 9)



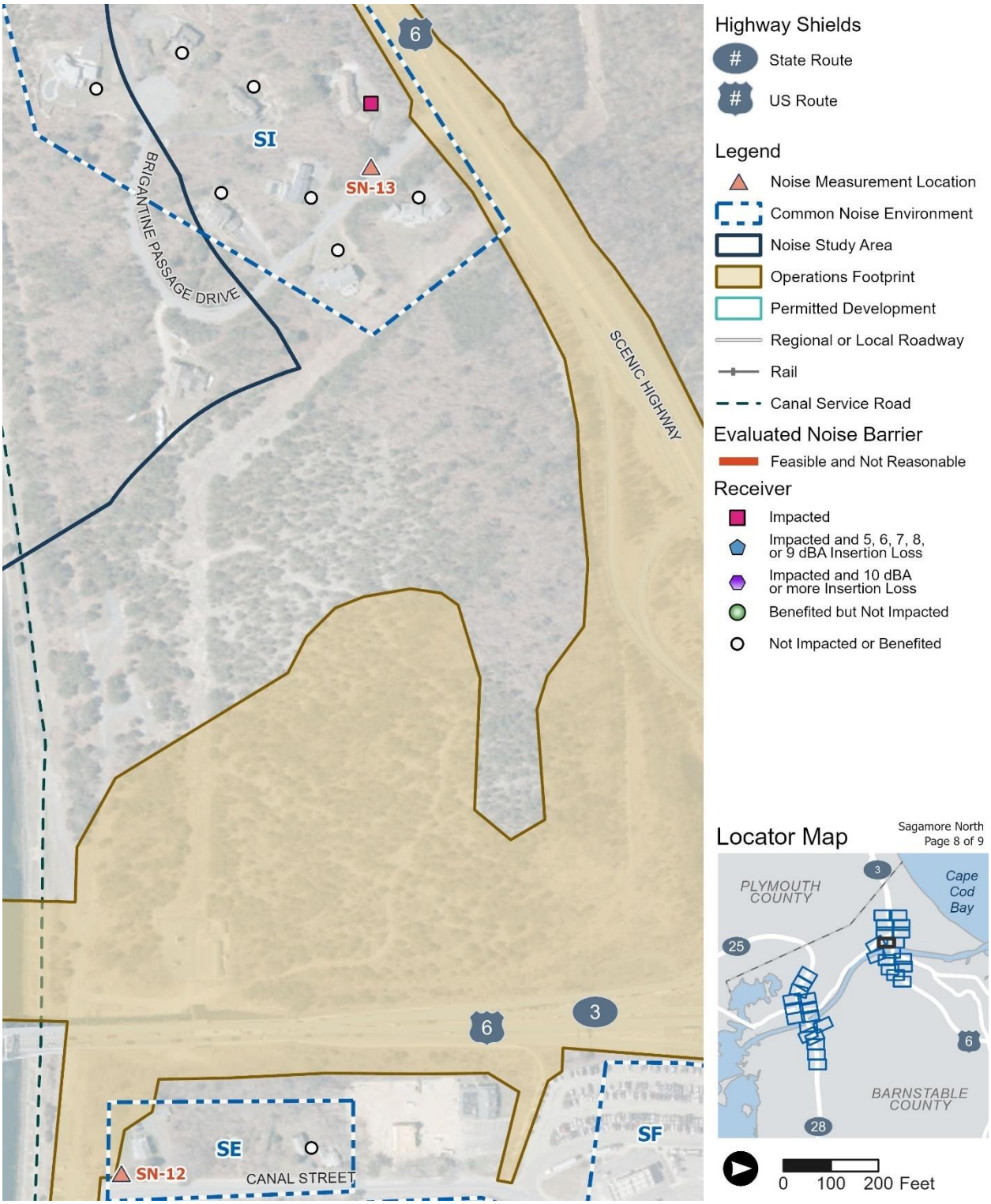
Source: Massachusetts Department of Transportation, 2024

Figure 6-1. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore North Quadrant) (7 of 9)



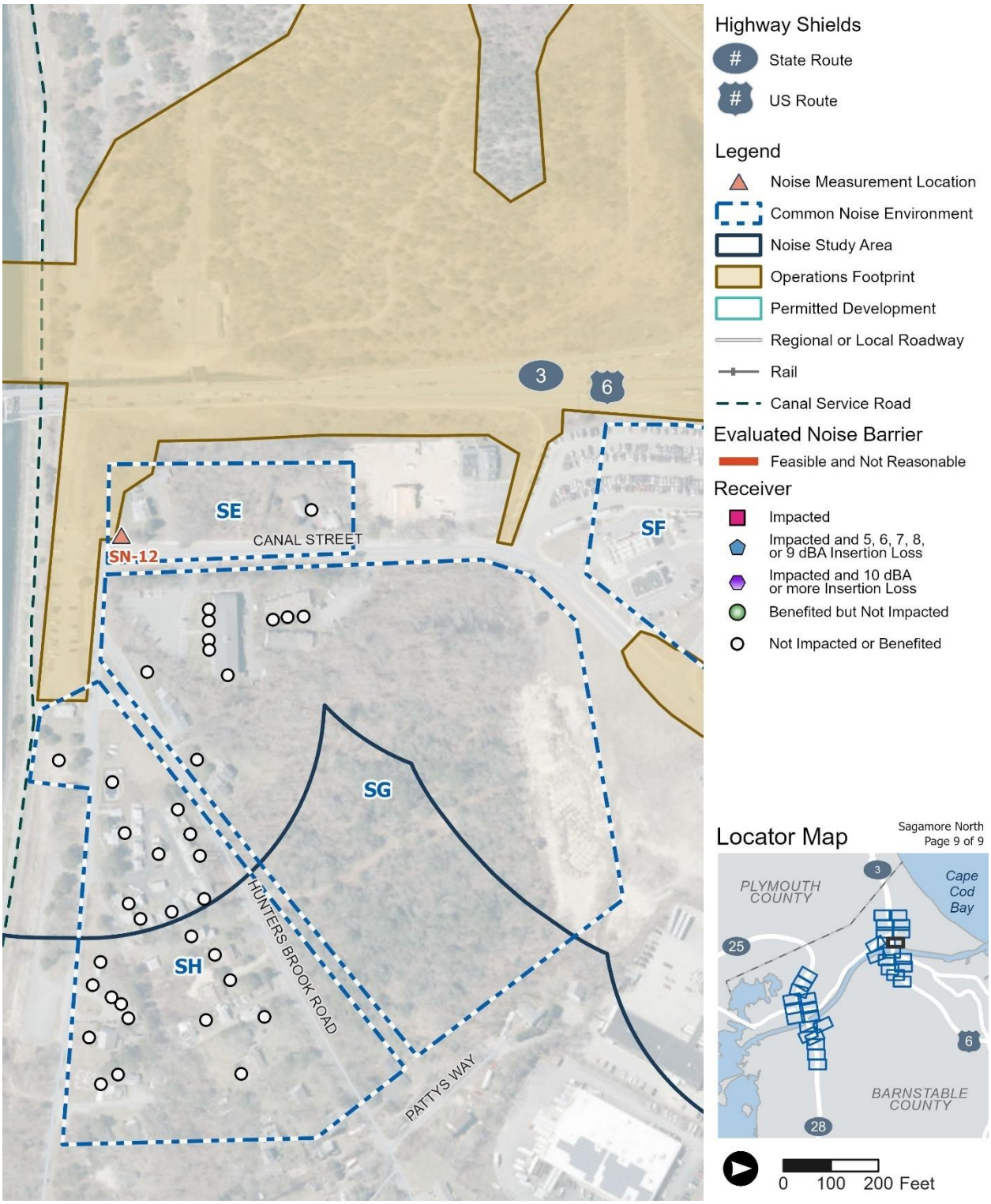
Source: Massachusetts Department of Transportation, 2024

Figure 6-1. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore North Quadrant) (8 of 9)



Source: Massachusetts Department of Transportation, 2024

Figure 6-1. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore North Quadrant) (9 of 9)



Source: Massachusetts Department of Transportation, 2024

6.2.2 Build Alternative Operational Traffic Noise Impacts (Sagamore South Quadrant)

Table 6-6 summarizes the predicted ranges in 2019 existing condition and 2050 Build Alternative noise levels as well as the number of impacted equivalent dwelling units within each CNE in Sagamore South. The 2019 existing condition noise levels are presented for comparison to 2050 Build Alternative noise levels to evaluate the substantial increase impact criterion. No permitted future developments were identified within the Sagamore South quadrant. **Figure 6-2** provides location maps for the CNEs, noise-sensitive receptors and barriers evaluated within the Sagamore South quadrant.

In the Sagamore South quadrant, the 2050 Build Alternative would acquire 10 residential properties within CNE SP along Eleanor Avenue and two homes in CNE SK along the U.S. Route 6 northbound off-ramp to Cranberry Highway.

Table 6-6 shows that, relative to the 2019 existing condition, noise levels are predicted to increase in some CNEs and decrease in others. Within CNE SP, noise levels are generally predicted to increase relative to the 2019 existing condition due to 1) a shift in the bridge alignment farther west, approximately 250 feet closer to homes on the west side of Eleanor Avenue, and 2) additional traffic volume on the Mid-Cape Connector/Cranberry Highway Extension. The horizontal alignment shift away from some noise-sensitive land use as well as an increase in bridge and approach roadway elevations in some areas would also contribute to decreases in predicted 2050 Build Alternative noise levels. Along Sandwich Road and Adams Street, noise levels are generally predicted to decrease due to reductions in overall traffic volumes on these roadways. The Cranberry Highway Extension would allow motorists to access Mid-Cape Connector and U.S. Route 6 southbound more easily, without needing to use Ben Abbey Road and Sandwich Road. In addition, motorists traveling southbound on U.S. Route 6 would have direct access to Cranberry Highway via the proposed Cranberry Highway Extension to Mid-Cape Connector.

There are 45 residential dwelling units that would approach or exceed the FHWA Category B NAC within CNEs SJ, SK, SL, SM, SN, and SQ. No Activity Category C, D, or E land uses would approach or exceed the respective NAC thresholds for the 2050 Build Alternative in the Sagamore South quadrant. In addition, no substantial noise increases are predicted within the Sagamore South quadrant.

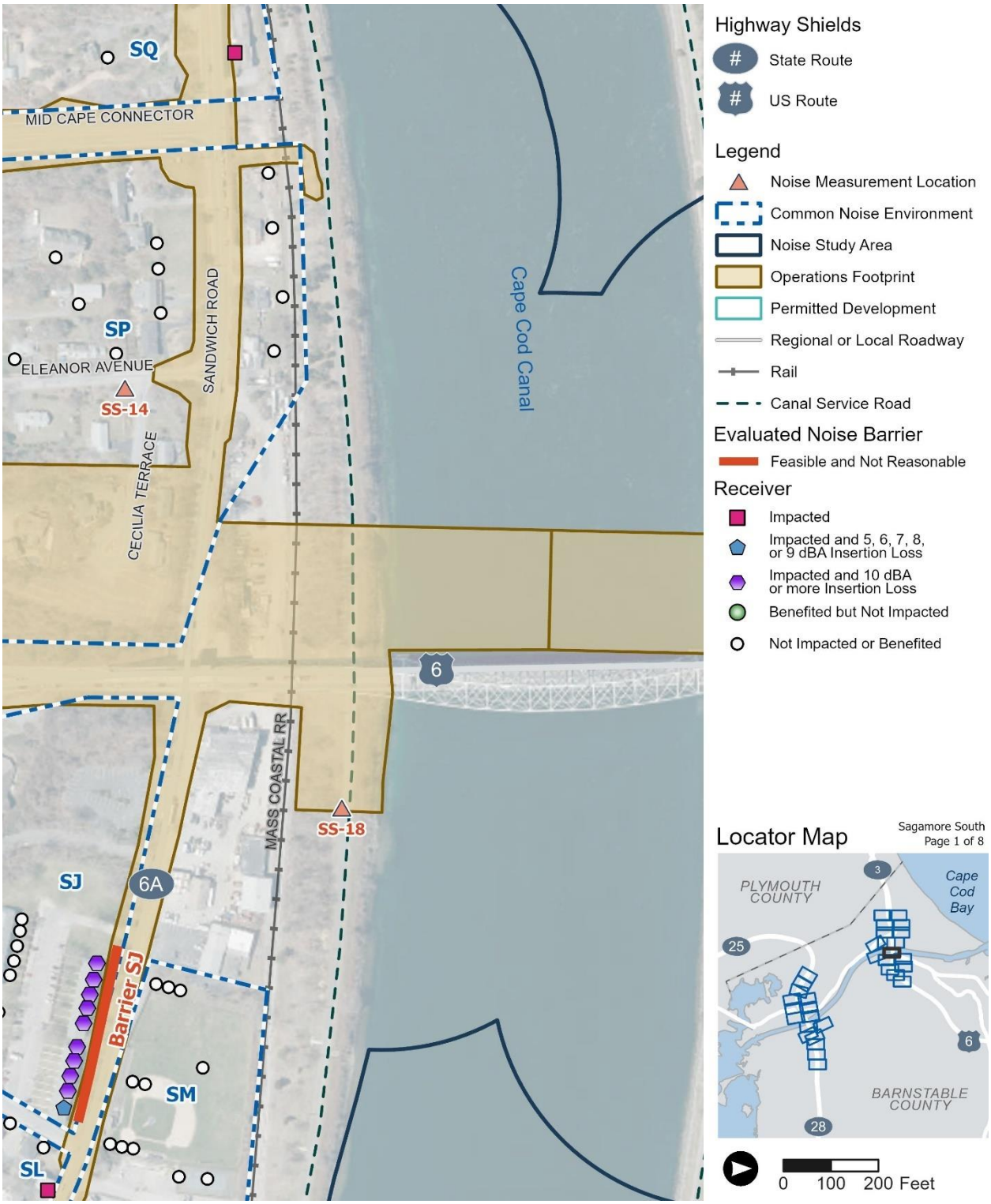
Table 6-6. 2050 Build Alternative: Loudest Traffic Hour Noise Levels (Sagamore South Quadrant)

Common Noise Environment	Adjacent Roadways	2019 Existing Condition Noise Level Ranges Leq	2050 Build Alternative Noise Level Ranges Leq	Federal Highway Administration Activity Category	2050 Build Alternative Approach or Exceed Noise Abatement Criteria
SJ	Sandwich Road	54–68	56–67	B	20
SK	U.S. Route 6 Northbound	53–71	56–69	B	5
	Sandwich Road			C	0

Common Noise Environment	Adjacent Roadways	2019 Existing Condition Noise Level Ranges Leq	2050 Build Alternative Noise Level Ranges Leq	Federal Highway Administration Activity Category	2050 Build Alternative Approach or Exceed Noise Abatement Criteria
SL	Sandwich Road	51–67	54–67	B	5
	Cranberry Highway			E	0
SM	Sandwich Road	48–67	50–66	B	7
				C	0
SN	Sandwich Road	49–65	52–66	B	1
	Cranberry Highway			C	0
				E	0
SO	Cranberry Highway	50–64	53–69	B	1
SP	U.S. Route 6 Southbound	53–61	61–64	B	0
	Mid-Cape Connector				
	Sandwich Road				
SQ	Mid-Cape Connector	49–69	52–71	B	6
	Sandwich Road				

Note: Refer to **Figure 6-2** for Common Noise Environment locations.

Figure 6-2. Build Alternative Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore South Quadrant) (1 of 8)

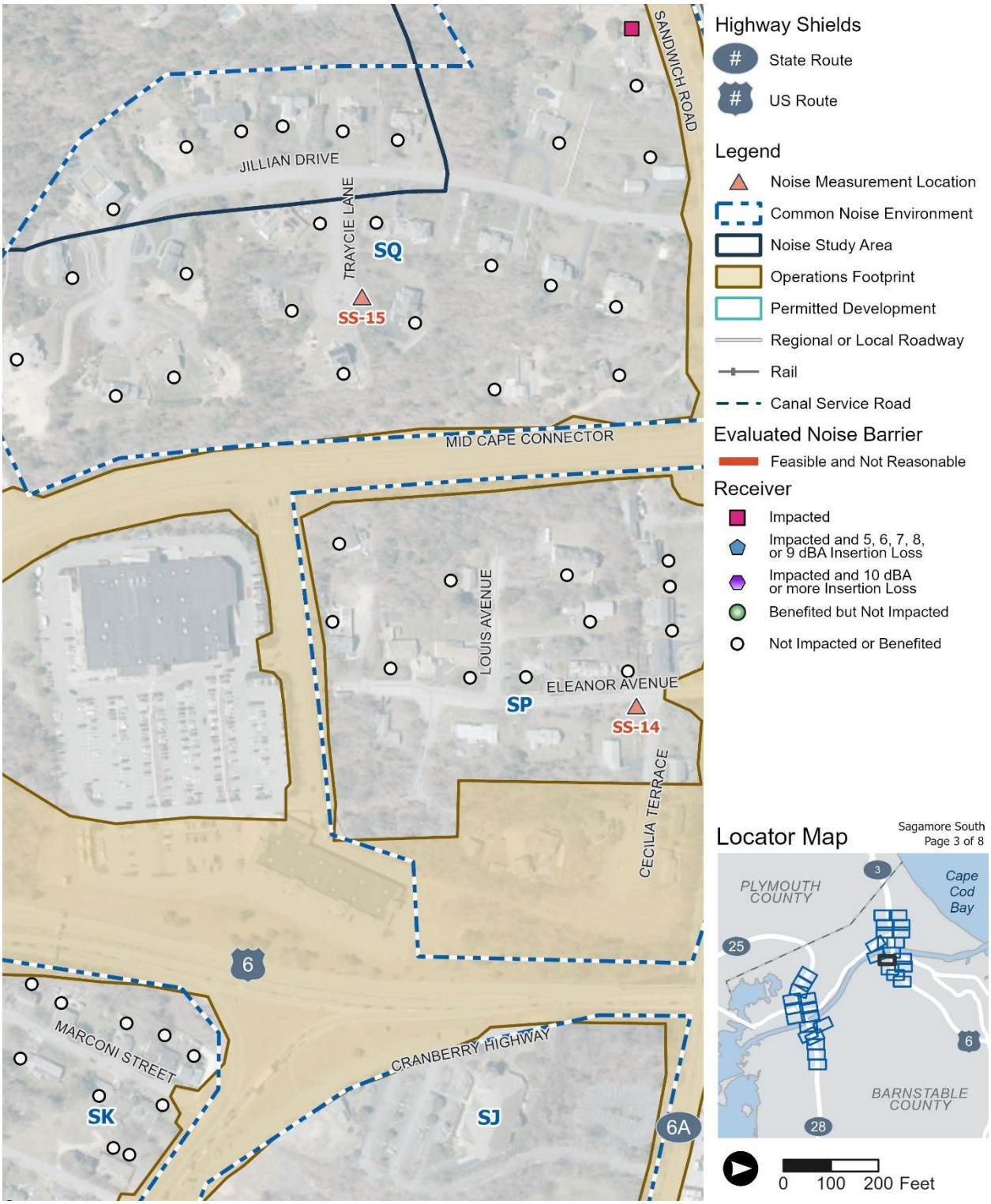


Source: Massachusetts Department of Transportation, 2024

Figure 6-2. Build Alternative Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore South) (2 of 8)

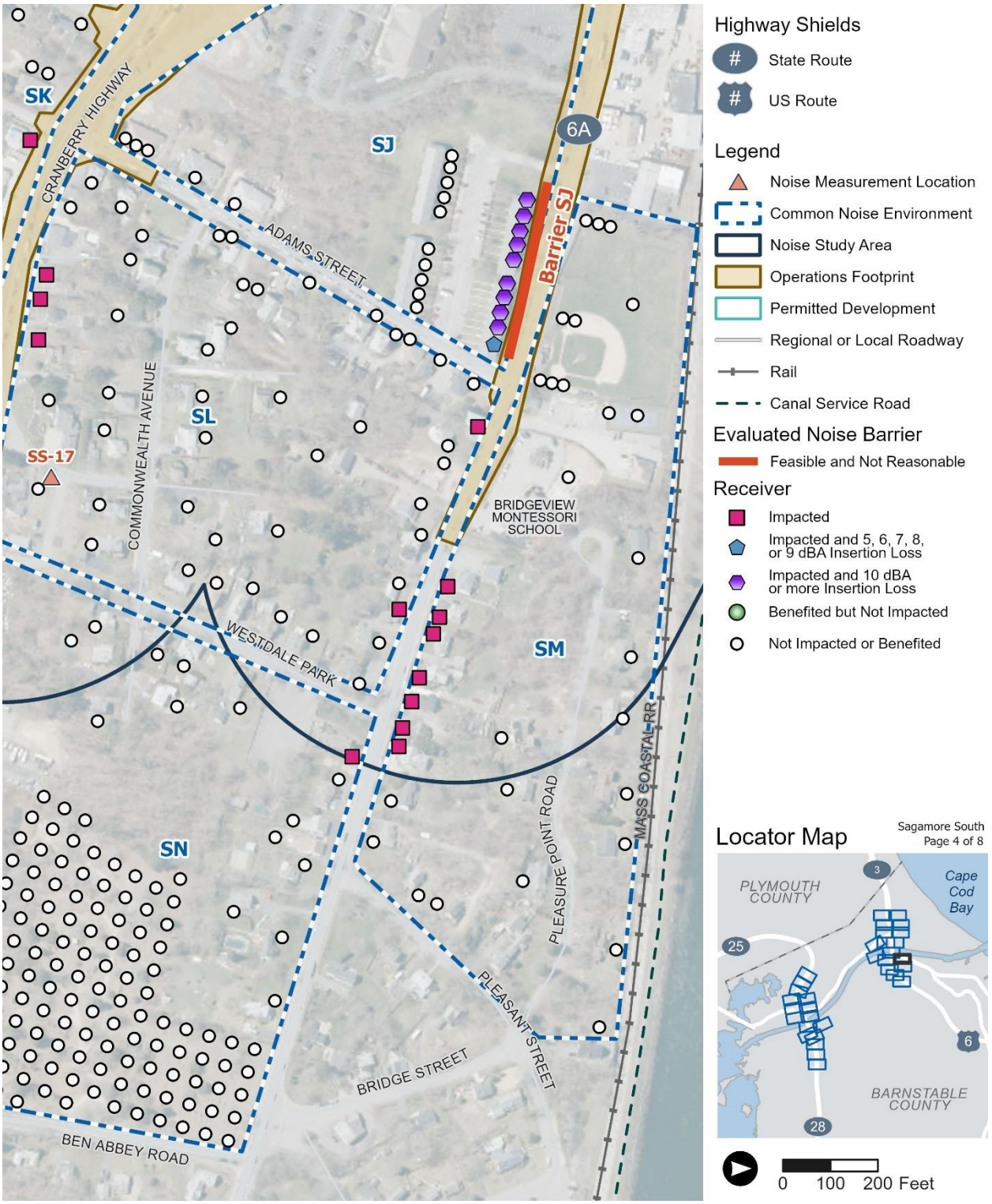
Source: Massachusetts Department of Transportation, 2024

Figure 6-2. Build Alternative Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore South) (3 of 8)



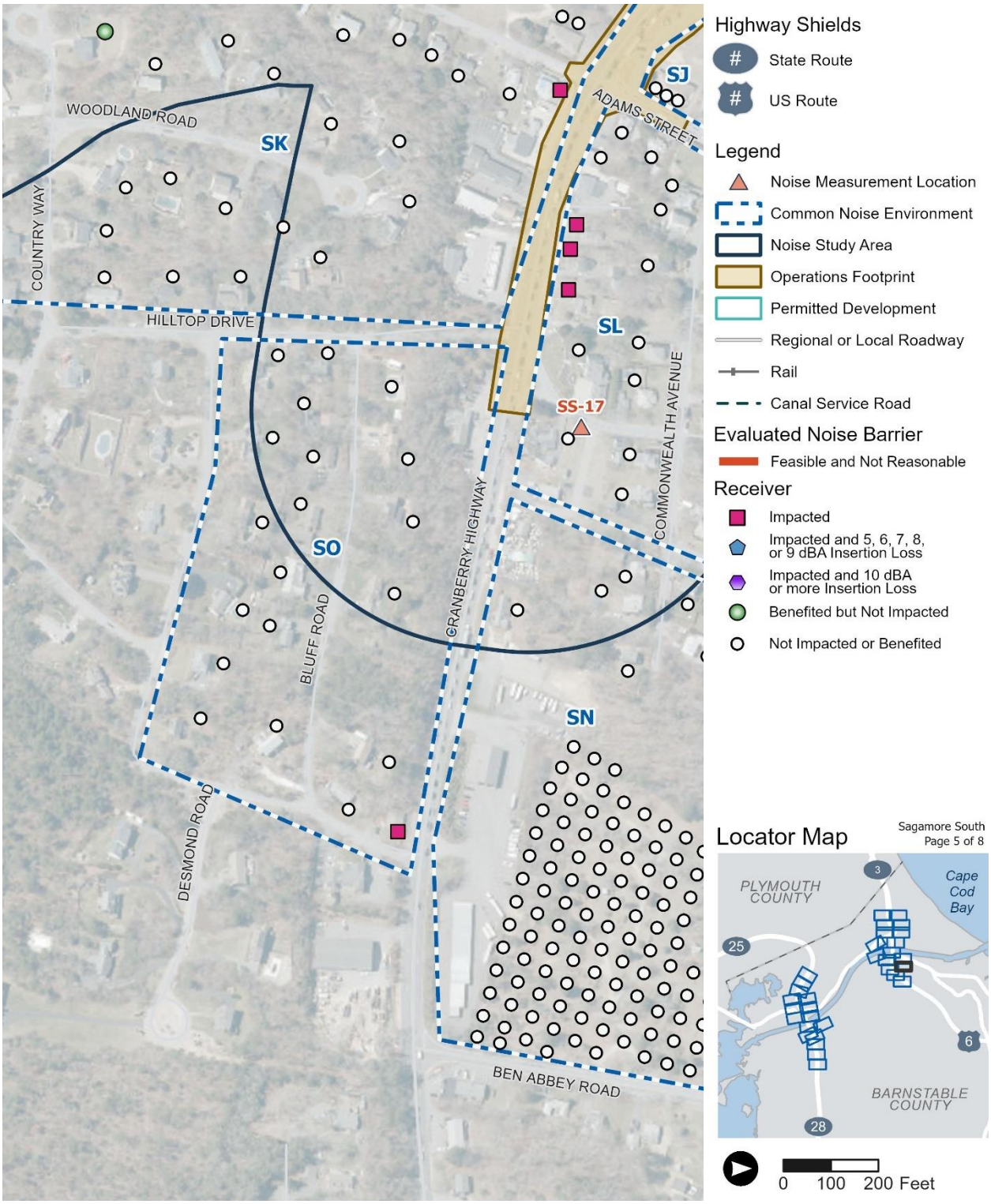
Source: Massachusetts Department of Transportation, 2024

Figure 6-2. Build Alternative Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore South) (4 of 8)



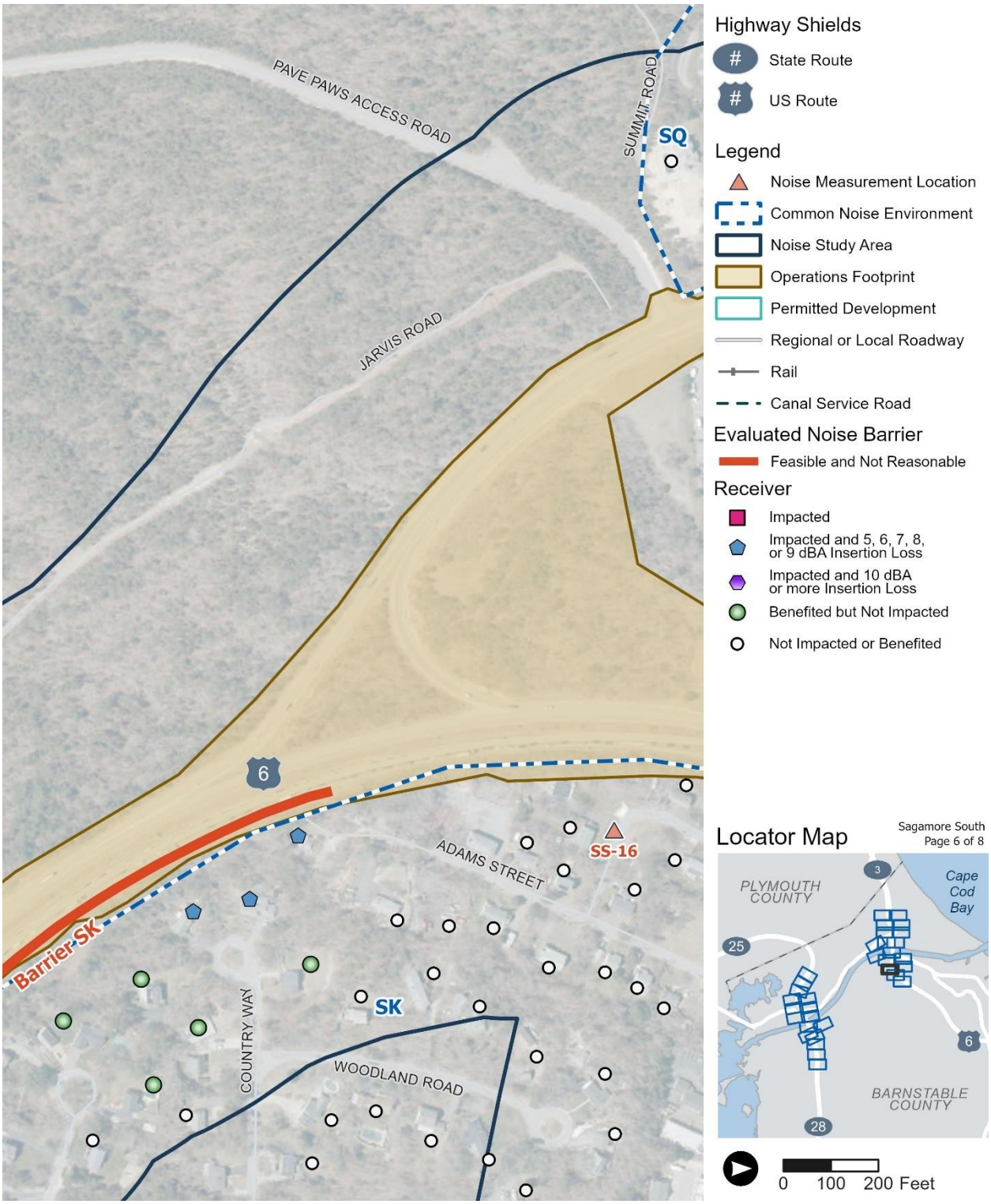
Source: Massachusetts Department of Transportation, 2024

Figure 6-2. Build Alternative Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore South) (5 of 8)



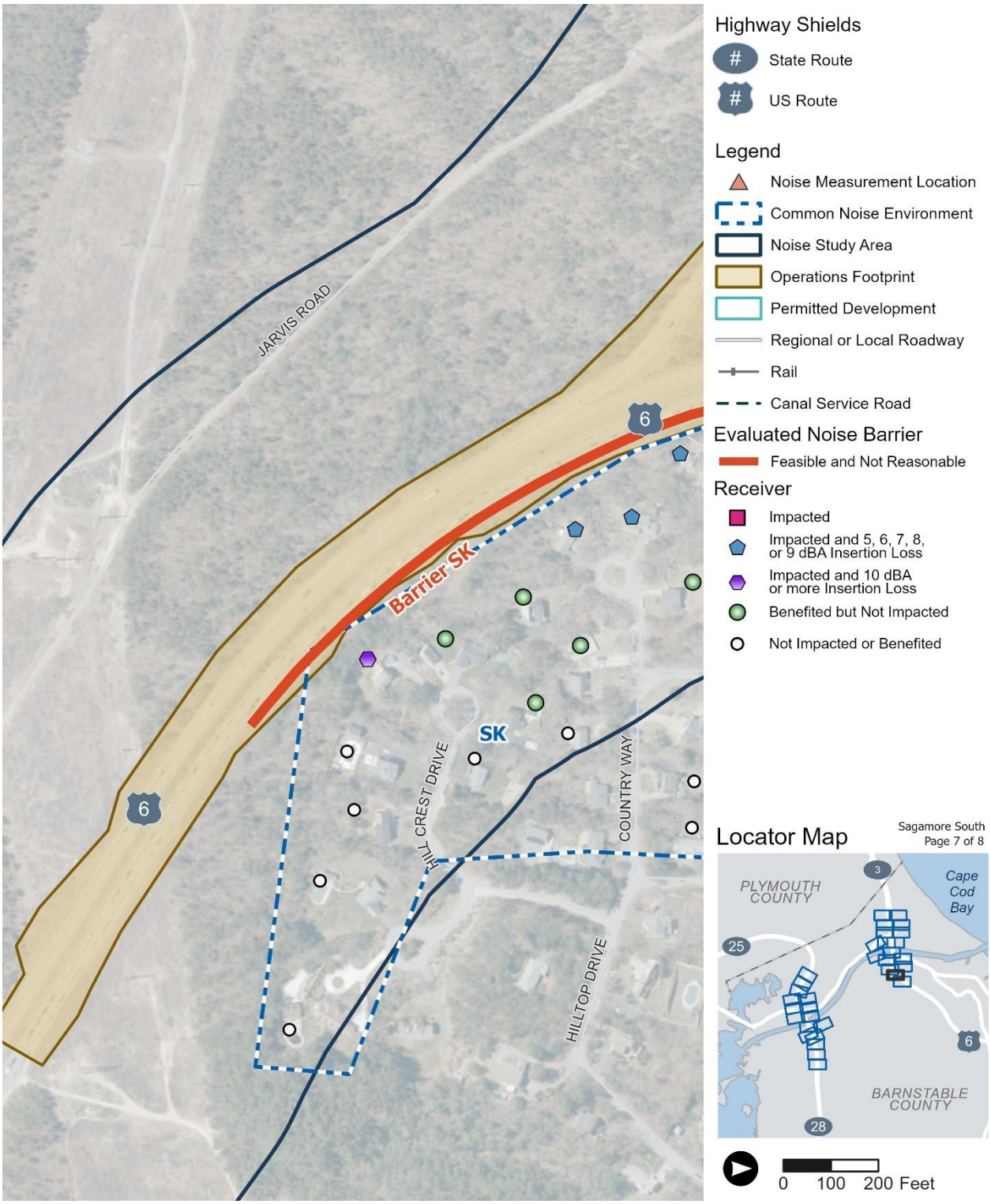
Source: Massachusetts Department of Transportation, 2024

Figure 6-2. Build Alternative Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore South) (6 of 8)



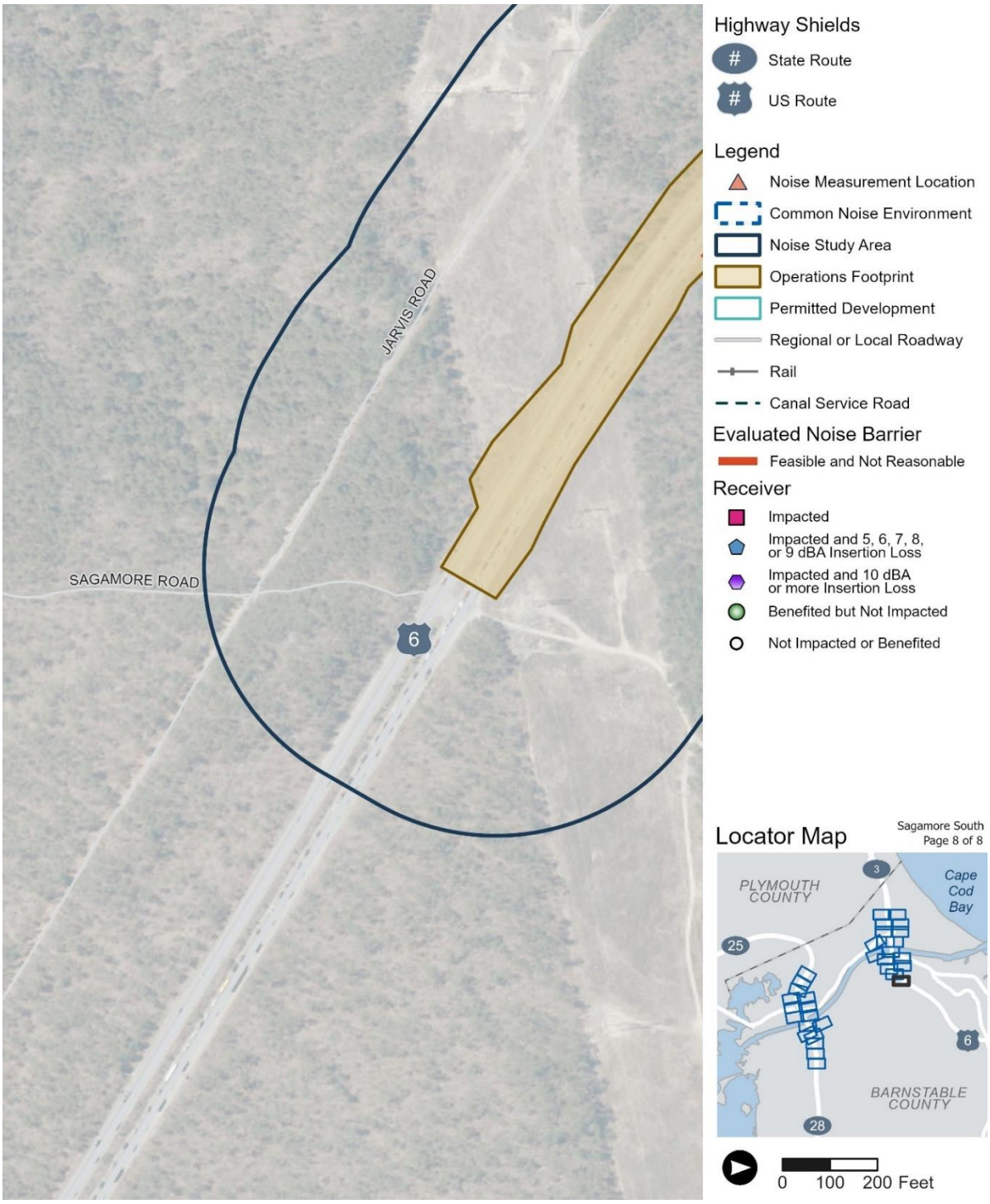
Source: Massachusetts Department of Transportation, 2024

Figure 6-2. Build Alternative Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore South) (7 of 8)



Source: Massachusetts Department of Transportation, 2024

Figure 6-2. Build Alternative Location Map for Barriers, Common Noise Environments, and Receptors (Sagamore South) (8 of 8)



Source: Massachusetts Department of Transportation, 2024

Note: Due to the large Operations Footprint, maps are provided in segments. This segment contains no common noise environments, barriers, or receptors, but is included for completeness.

6.2.3 Build Alternative Operational Traffic Noise Impacts (Bourne North Quadrant)

Table 6-7 summarizes the predicted ranges in 2019 existing conditions and 2050 Build Alternative noise levels as well as number of impacted equivalent dwelling units within each CNE in Bourne North. The 2019 existing conditions noise levels are presented for comparison to 2050 Build Alternative noise levels to evaluate the substantial increase impact criterion. **Table 6-7** also includes predicted 2050 Build Alternative noise levels at one permitted proposed development identified within the Bourne North quadrant. **Figure 6-3** provides location maps for the CNEs, noise-sensitive receptors and barriers evaluated within the Bourne North quadrant.

In the Bourne North quadrant for the 2050 Build Alternative, one residential property on the corner of Nightingale Road and U.S. Route 6/Main Street within CNE BE would be acquired. Also, a portion of the Bourne Scenic Park would be acquired, just east of Bourne Bridge, to accommodate the eastward shift in the horizontal alignment of Bourne Bridge.

Table 6-7 shows that, relative to the 2019 existing condition, Build Alternative noise levels are predicted to increase in some CNEs and decrease in others. Sound level decreases would be attributed to changes in traffic volume and distribution throughout the Bourne North quadrant as well as a general eastward shift in horizontal alignment of Bourne Bridge and increase in vertical geometry (i.e., increased elevation of portions of the mainline). Specifically, traffic volumes would significantly decrease within the Bourne Rotary and on U.S. Route 6/Main Street within and east of the existing Bourne Rotary due to the proposed State Route 25 southbound flyover off-ramp to U.S. Route 6/Main Street. This new movement would allow motorists traveling from the north and seeking access to U.S. Route 6/Main Street east of Bourne Bridge to avoid the Bourne Rotary. This new movement would also reduce traffic on the State Route 25 southbound off-ramp to Belmont Circle for the AM peak traffic condition. In addition, the proposed State Route 25 northbound on-ramp from U.S. Route 6/Main Street would significantly reduce traffic volume in the Bourne Rotary as well as on the existing State Route 25 northbound on-ramp from Belmont Circle. The State Route 25 mainline alignment shift would also result in traffic noise being farther from some noise-sensitive land use, thereby resulting in a decrease in sound levels at some receptors. In addition, the mainline elevations would be higher, relative to the 2019 existing condition, which would also contribute to decreases in noise levels at some receptors.

For the 2050 Build Alternative in the Bourne North quadrant, there would be two residential dwelling units that would approach or exceed the FHWA Category B NAC CNE BC (one single-family residence along Head of the Bay Road) and CNE BF (one residence along U.S. Route 6/Main Street westbound). No impacts are predicted at the permitted proposed development (340 Main Street) for the 2050 Build Alternative. No Activity Category C, D, or E land uses would approach or exceed the respective NAC thresholds for the 2050 Build Alternative in the Bourne North quadrant. In addition, no substantial noise increases are predicted within the Bourne North quadrant.

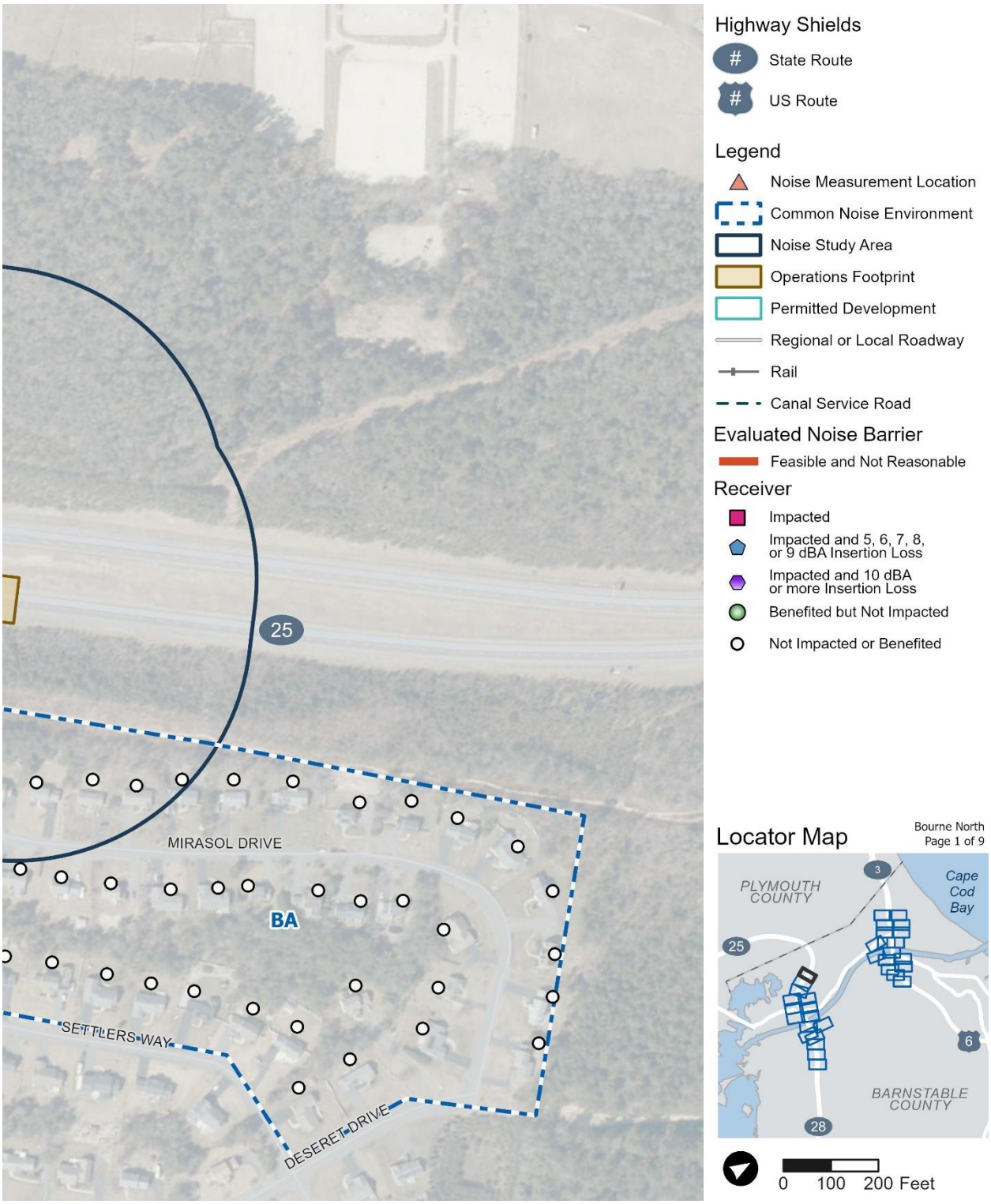
Table 6-7. 2050 Build Alternative: Loudest Traffic Hour Noise Levels (Bourne North Quadrant)

Common Noise Environment	Adjacent Roadways	2019 Existing Condition Noise Level Ranges Leq	2050 Build Alternative Noise Level Ranges Leq	Federal Highway Administration Activity Category	2050 Build Alternative Approach or Exceed Noise Abatement Criteria
BA	State Route 25 Northbound	45–63	46–64	B	0
BB	State Route 25 Northbound and northbound/ southbound on-ramps	52–55	52–56	B	0
BC	State Route 25 Southbound	48–65	48–66	B	1
				E	0
BD	State Route 25 Southbound	60–65	59–64	E	0
BE	State Route 28 Southbound	53–63	55–64	B	0
				C	0
				E	0
BF	State Route 28 Northbound	53–65	55–67	B	1
	U.S. Route 6/Main Street				
BG	State Route 28 Northbound	53–62	57–64	C	0
	U.S. Route 6/Main Street				
Permitted Development – 340 Main Street[a]	State Route 28 Northbound	N/A	58–65	B	0
	U.S. Route 6/Main Street				

[a] The permitted development at 340 Main Street is a part of a mixed-use development, where Phase I has been completed and includes six second-story apartment units above first floor commercial property. Phase II includes construction of 24 rental townhome-style units behind the commercial property. Phase II building permit was issued on March 5, 2022. Since the development does not exist for the 2019 existing condition, reported sound levels for the 2019 existing condition are not available.

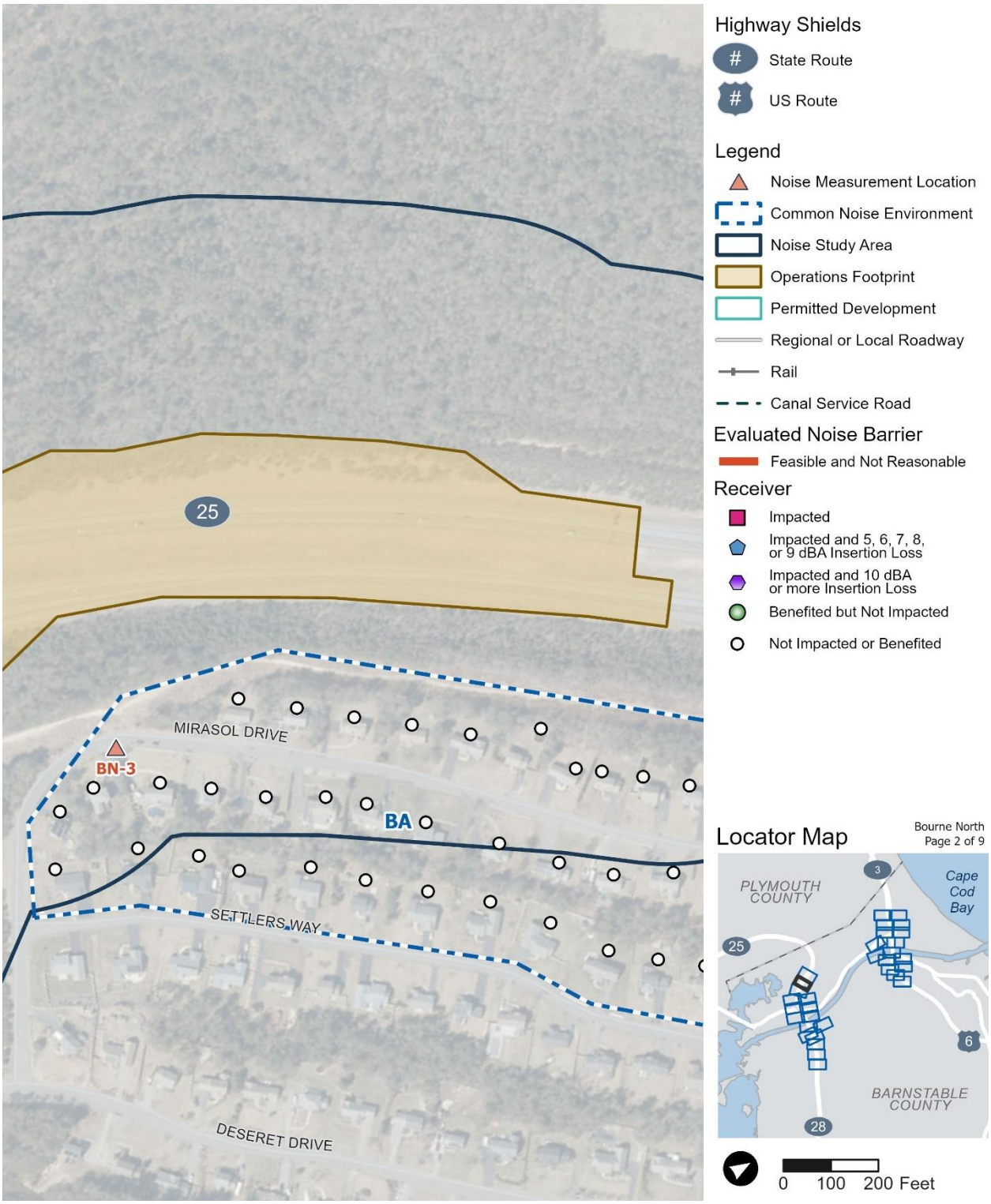
Note: Refer to **Figure 6-3** for Common Noise Environment locations.

Figure 6-3. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne North Quadrant) (1 of 9)



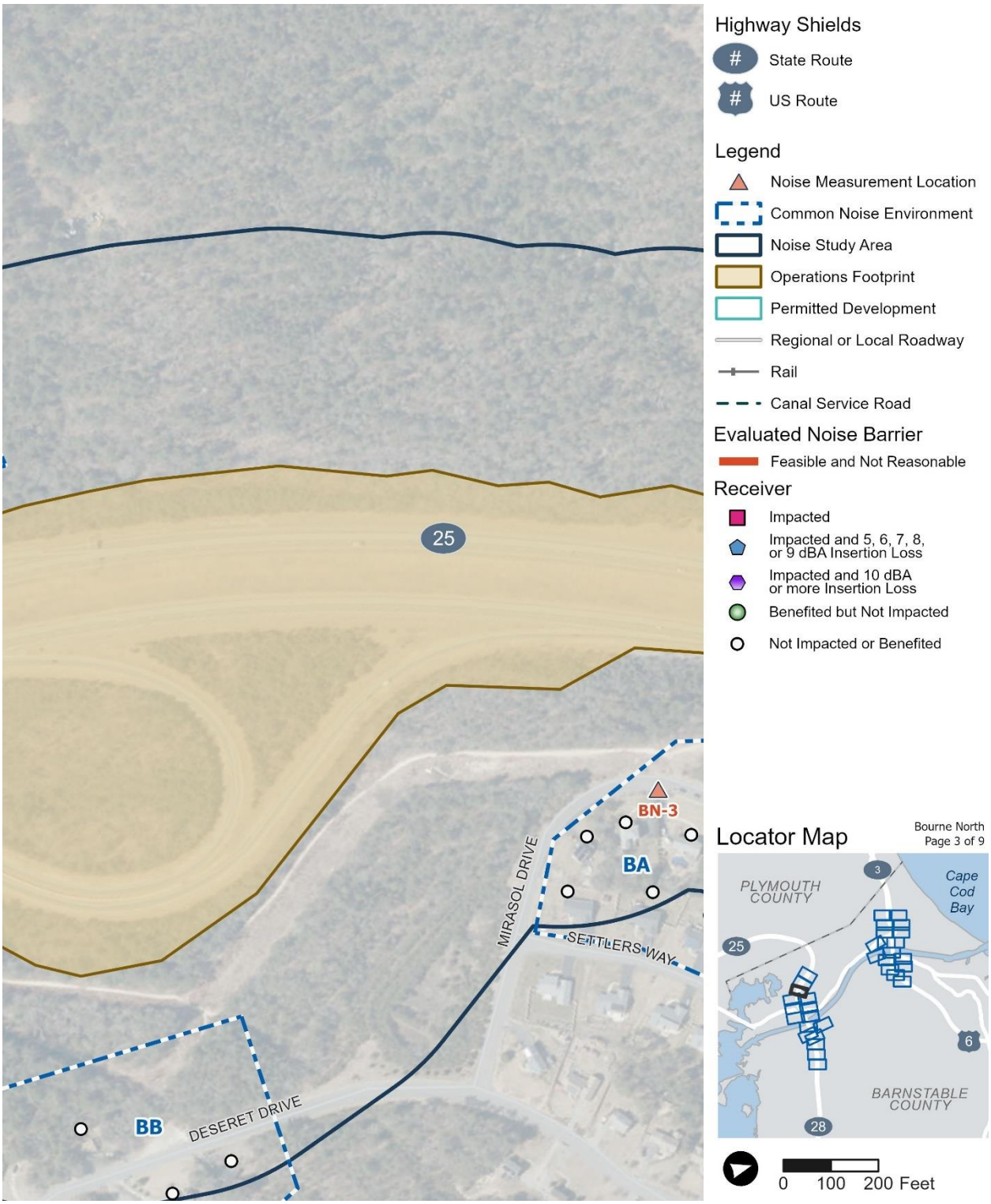
Source: Massachusetts Department of Transportation, 2024

Figure 6-3. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne North Quadrant) (2 of 9)



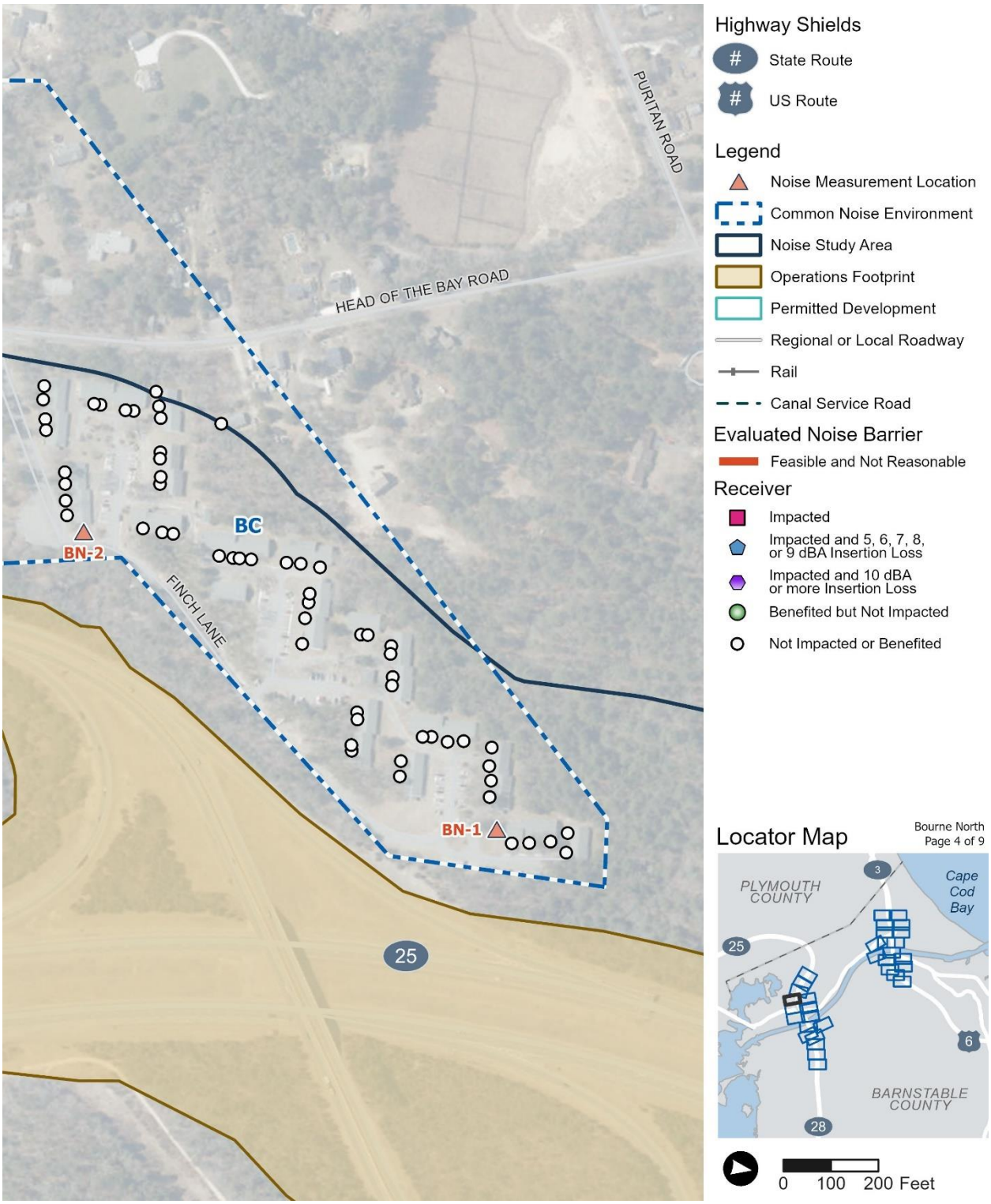
Source: Massachusetts Department of Transportation, 2024

Figure 6-3. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne North Quadrant) (3 of 9)



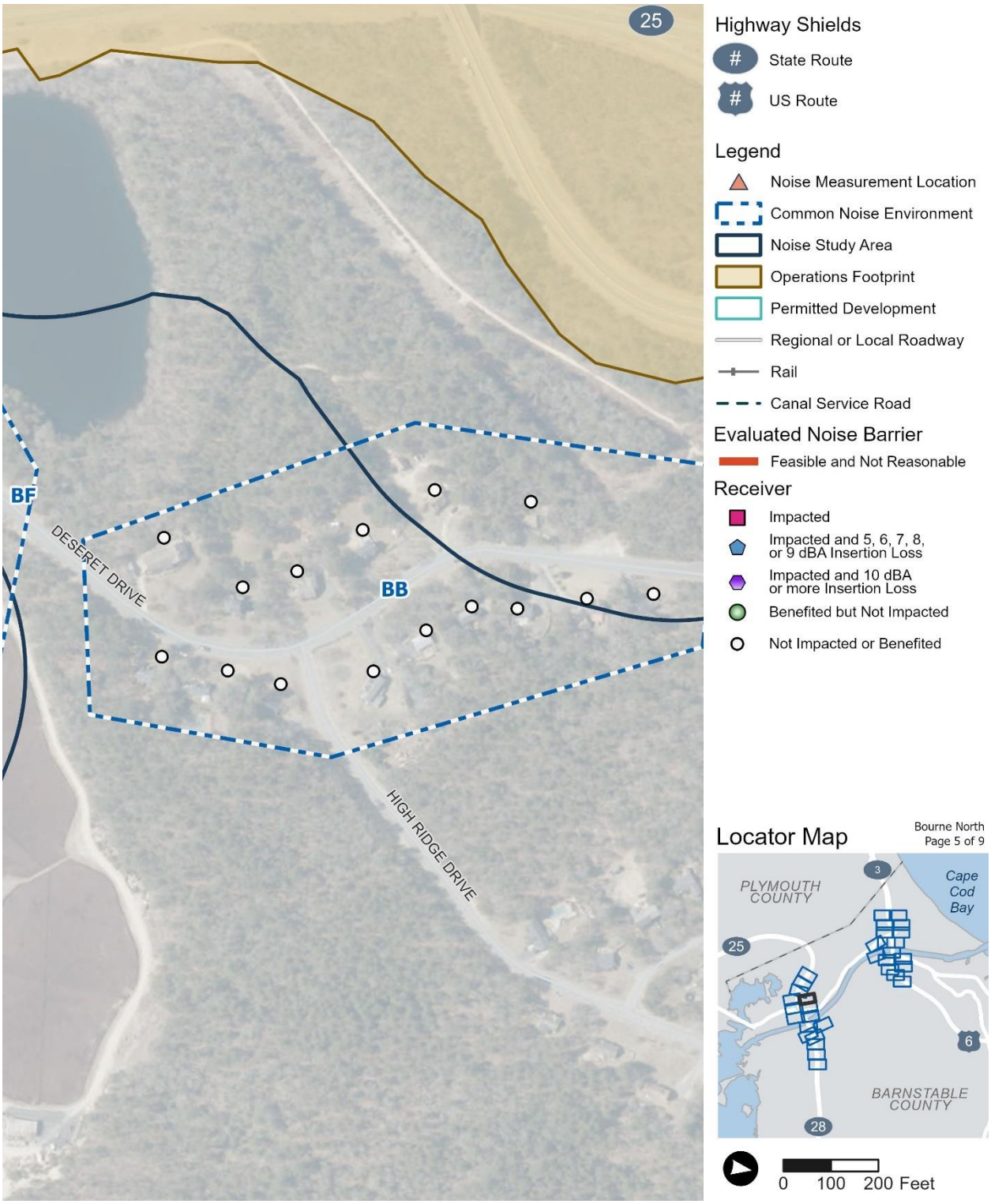
Source: Massachusetts Department of Transportation, 2024

Figure 6-3. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne North Quadrant) (4 of 9)



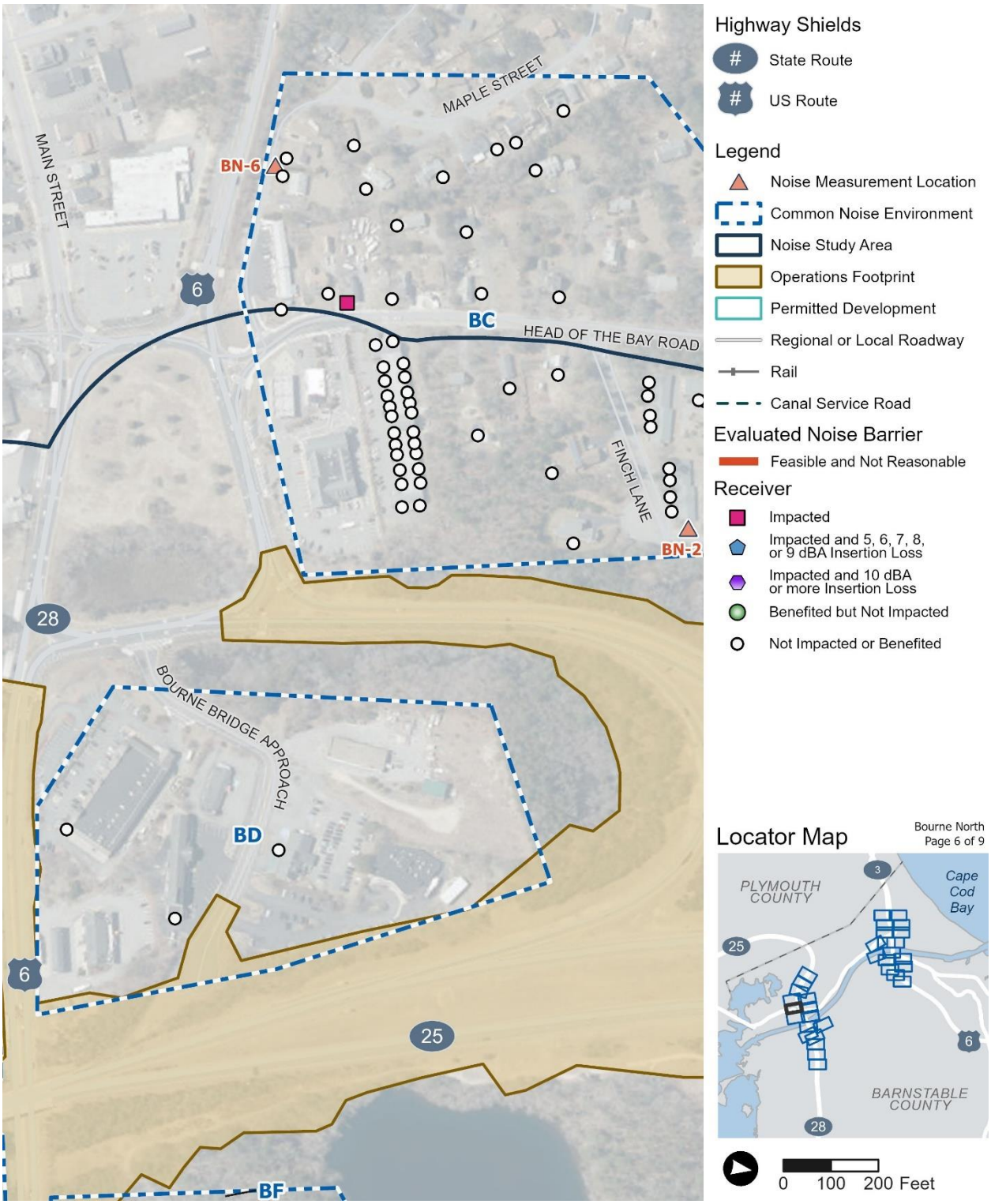
Source: Massachusetts Department of Transportation, 2024

Figure 6-3. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne North Quadrant) (5 of 9)



Source: Massachusetts Department of Transportation, 2024

Figure 6-3. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne North Quadrant) (6 of 9)

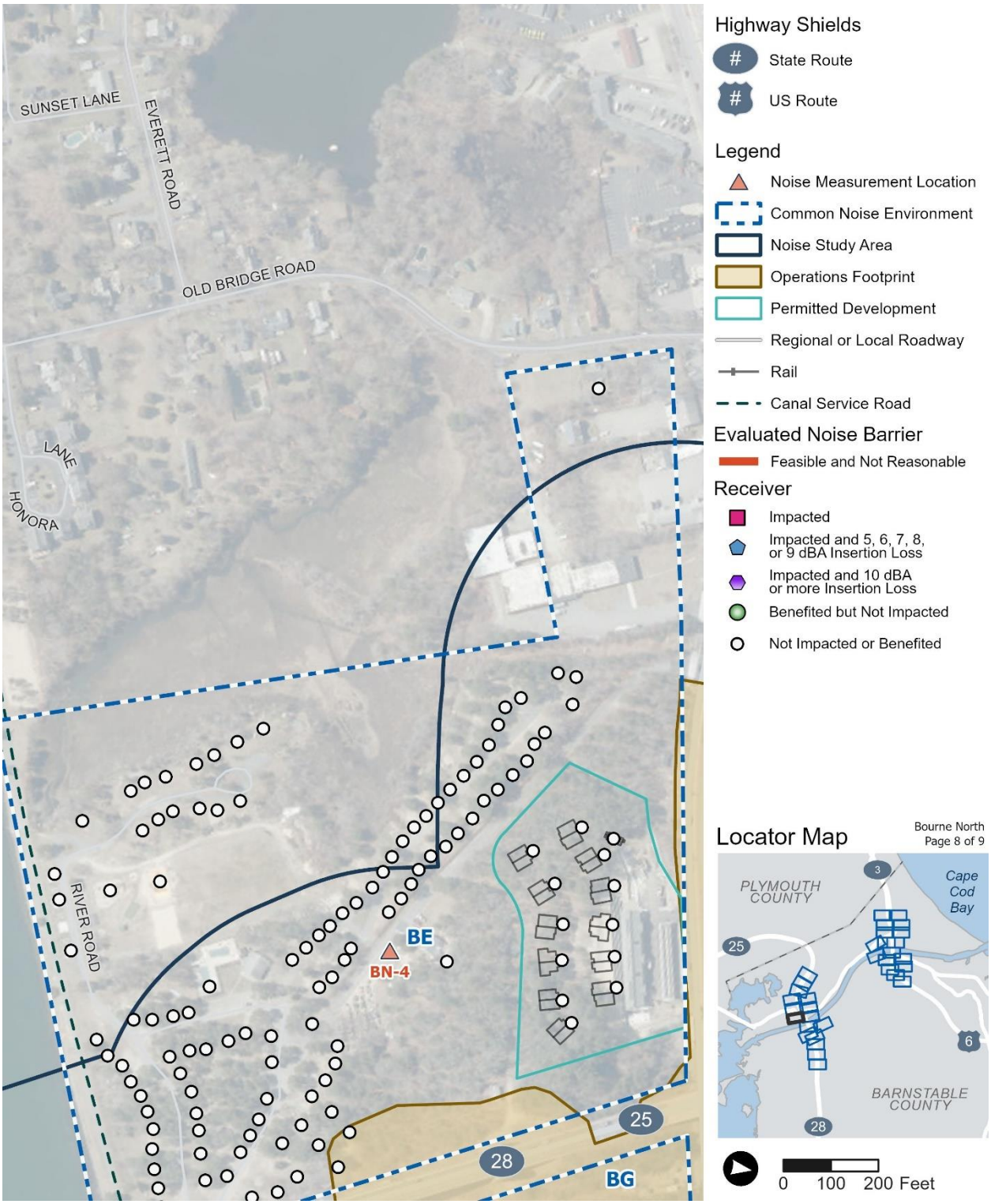


Source: Massachusetts Department of Transportation, 2024

Figure 6-3. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne North Quadrant) (7 of 9)

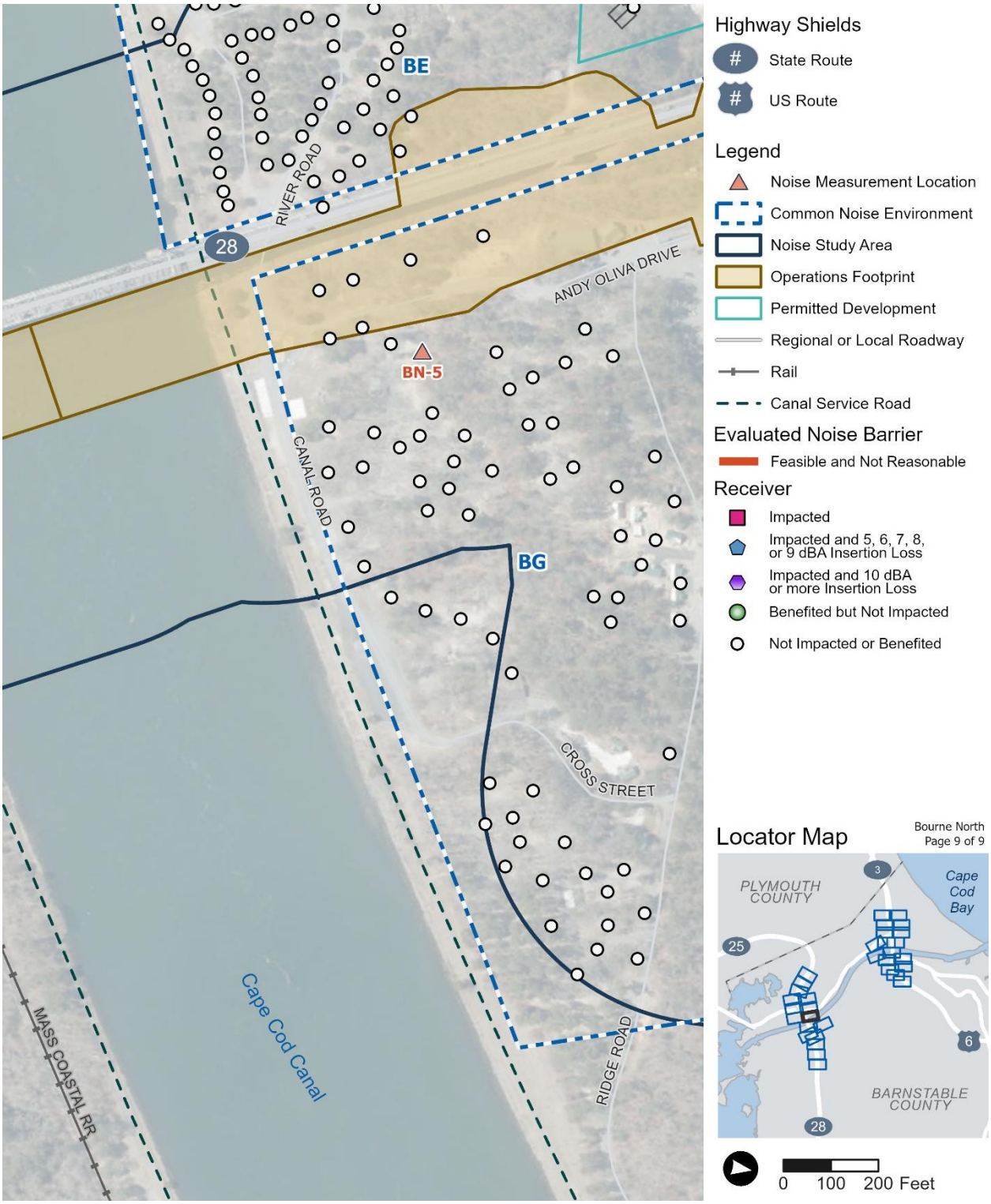
Source: Massachusetts Department of Transportation, 2024

Figure 6-3. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne North Quadrant) (8 of 9)



Source: Massachusetts Department of Transportation, 2024

Figure 6-3. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne North Quadrant) (9 of 9)



Source: Massachusetts Department of Transportation, 2024

6.2.4 Build Alternative: Operational Traffic Noise Impacts (Bourne South Quadrant)

Table 6-8 summarizes the predicted ranges in 2019 existing conditions and 2050 Build Alternative noise levels as well as number of impacted equivalent dwelling units within each CNE in the Bourne South quadrant. The 2019 existing conditions noise levels are presented for comparison to 2050 Build Alternative noise levels to evaluate the potential for substantial increase impact. No permitted future developments were identified within the Bourne South quadrant. **Figure 6-4** provides location maps for the CNEs, noise-sensitive receptors and barriers evaluated within the Bourne South quadrant.

In the Bourne South quadrant for the 2050 Build Alternative, there would be no property acquisitions with noise-sensitive land use other than the Bourne Recreation Area. The USACE is determining an appropriate relocation site for the Bourne Recreation Area; therefore, 2050 Build Alternative noise levels will be presented for the relocation site in the Final Environmental Impact Statement.

Table 6-8 shows that, relative to the 2019 existing conditions, Build Alternative noise levels are predicted to increase in some CNEs and decrease in others for the Build Alternative. The greatest sound level decreases are predicted to occur within CNE BJ and CNE BM. Relative to CNE BJ, the proposed horizontal alignment of Sandwich Road would shift farther away from a single-family residence at 201 Sandwich Road by approximately 250 feet. The vertical alignment of Sandwich Road adjacent to CNE J would increase by approximately 10 feet. In addition, with the proposed Sandwich Road roundabout near the Upper Cape Cod Regional Technical High School, traffic that currently passes 201 Sandwich Road would be shifted south through the roundabout and would continue on Sandwich Road through the proposed stretched “dog-bone” roundabout to access Bourne Bridge, State Route 28, or Trowbridge Road. Traffic speeds would also decrease with the proposed rotary. Therefore, less volume (especially truck traffic) and slower speeds past 201 Sandwich Road would also contribute to significant noise level decreases at this residence for the 2050 Build Alternative.

Predicted 2050 Build Alternative sound levels in other CNEs are expected to decrease due to the westward alignment shift away from most noise-sensitive receptors as well as an increase in mainline elevations (i.e., vertical geometry change). In some areas, noise levels are predicted to increase due to assumed posted speed increases based on roadway design speeds.

In the Bourne South quadrant for the 2050 Build Alternative, no residential dwelling units would approach or exceed the FHWA Category B NAC. Two benches on the north side of the Bourne Manor Extended Care facility would approach or exceed the FHWA Activity Category C NAC for the 2050 Build Alternative. No FHWA Activity Category D or E land uses would approach or exceed the respective NAC thresholds for the 2050 Build Alternative in the Bourne South quadrant. In addition, no substantial noise increases are predicted within the Bourne South quadrant.

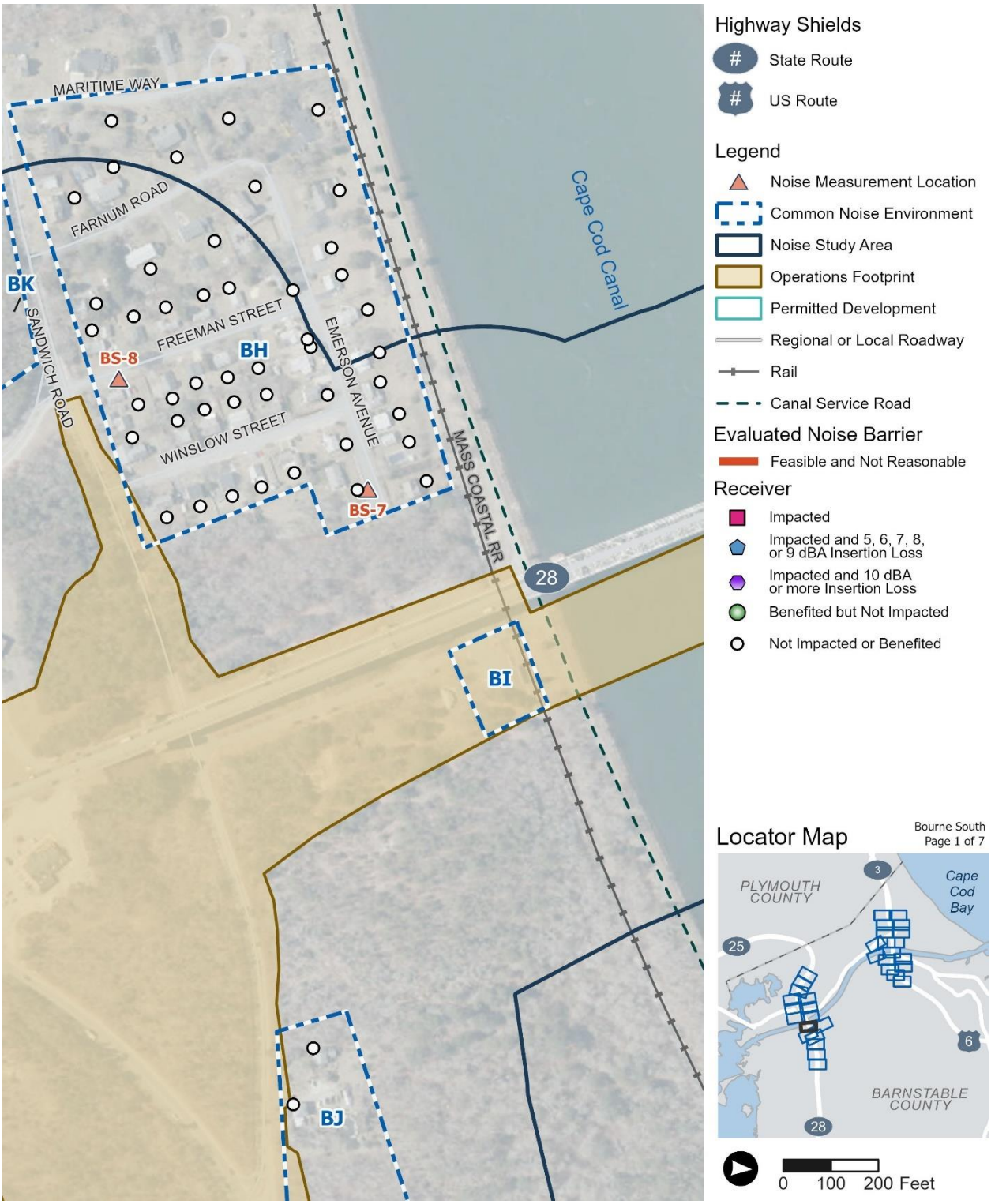
Table 6-8. 2050 Build Alternative: Loudest Traffic Hour Noise Levels (Bourne South Quadrant)

Common Noise Environment	Adjacent Roadways	2019 Existing Condition Noise Level Ranges Leq	2050 Build Alternative Noise Level Ranges Leq	Federal Highway Administration Activity Category	2050 Build Alternative Approach or Exceed Noise Abatement Criteria
BH	State Route 28 Southbound	52–60	53–60	B	0
BI	State Route 28 Northbound	57–58	*	C	*
BJ	Sandwich Road	59–64	57–59	B	0
BK	Veterans Way	42–64	41–63	B	0
	Sandwich Road			C	0
	Trowbridge Road			E	0
BL	Sandwich Road	51–53	52–56	B	0
	Trowbridge Road				
BM	State Route 28 Southbound	52–64	53–61	E	0
	Trowbridge Road				
BN	State Route 28 Southbound	46–60	47–60	B	0
	Trowbridge Road			C	
BO	State Route 28 Southbound	54–67	56–67	C	2
BP	Sandwich Road	28–55	30–58	B	0
				C	0

*The Bourne Recreation Area would be relocated for the 2050 Build Alternative. The U.S. Army Corps of Engineers is still determining the relocation site. Therefore, Bourne Recreation Area noise levels for the 2050 Build Alternative will be presented in the Final Environmental Impact Statement.

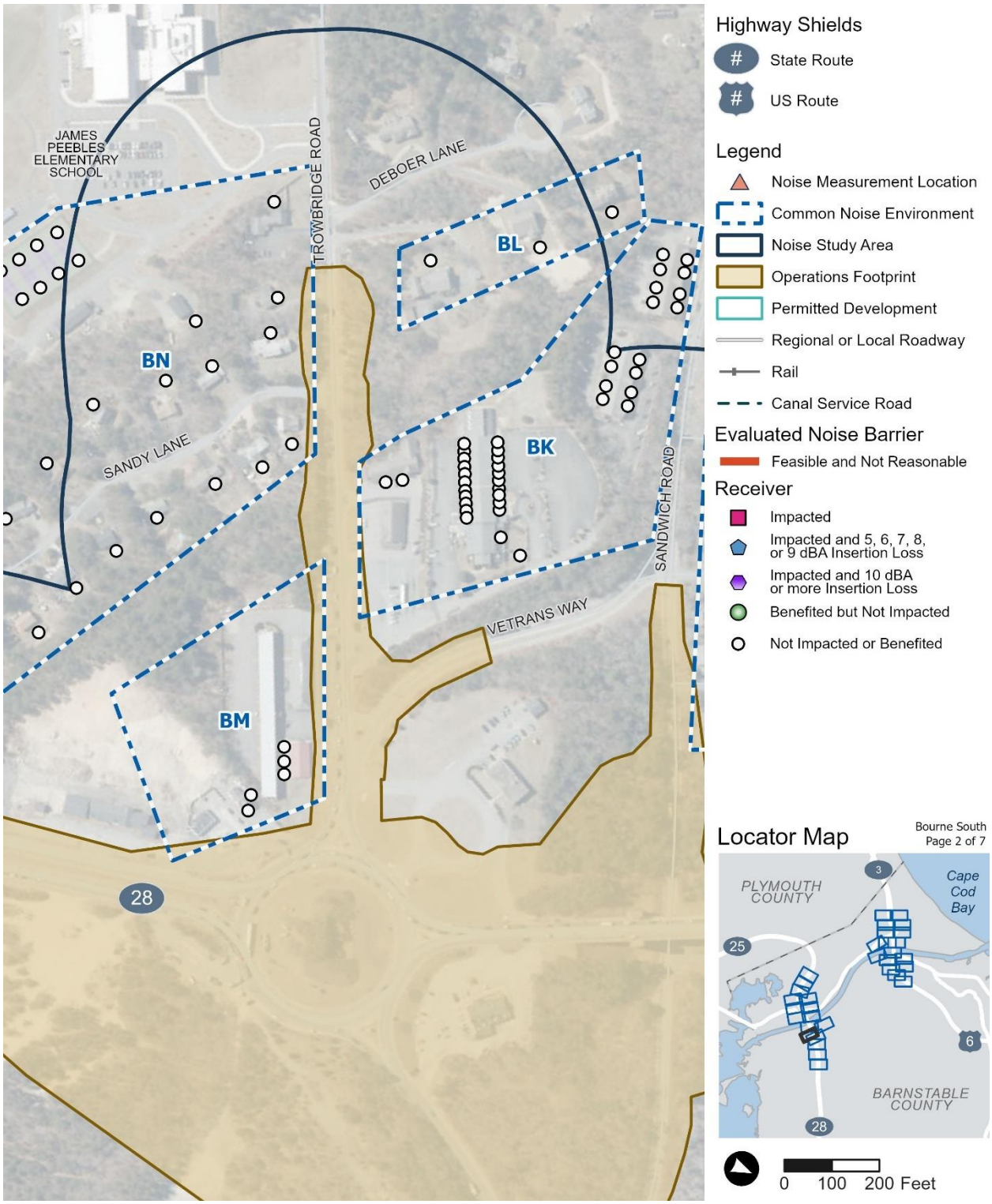
Note: Refer to **Figure 6-4** for Common Noise Environment locations.

Figure 6-4. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne South Quadrant) (1 of 7)



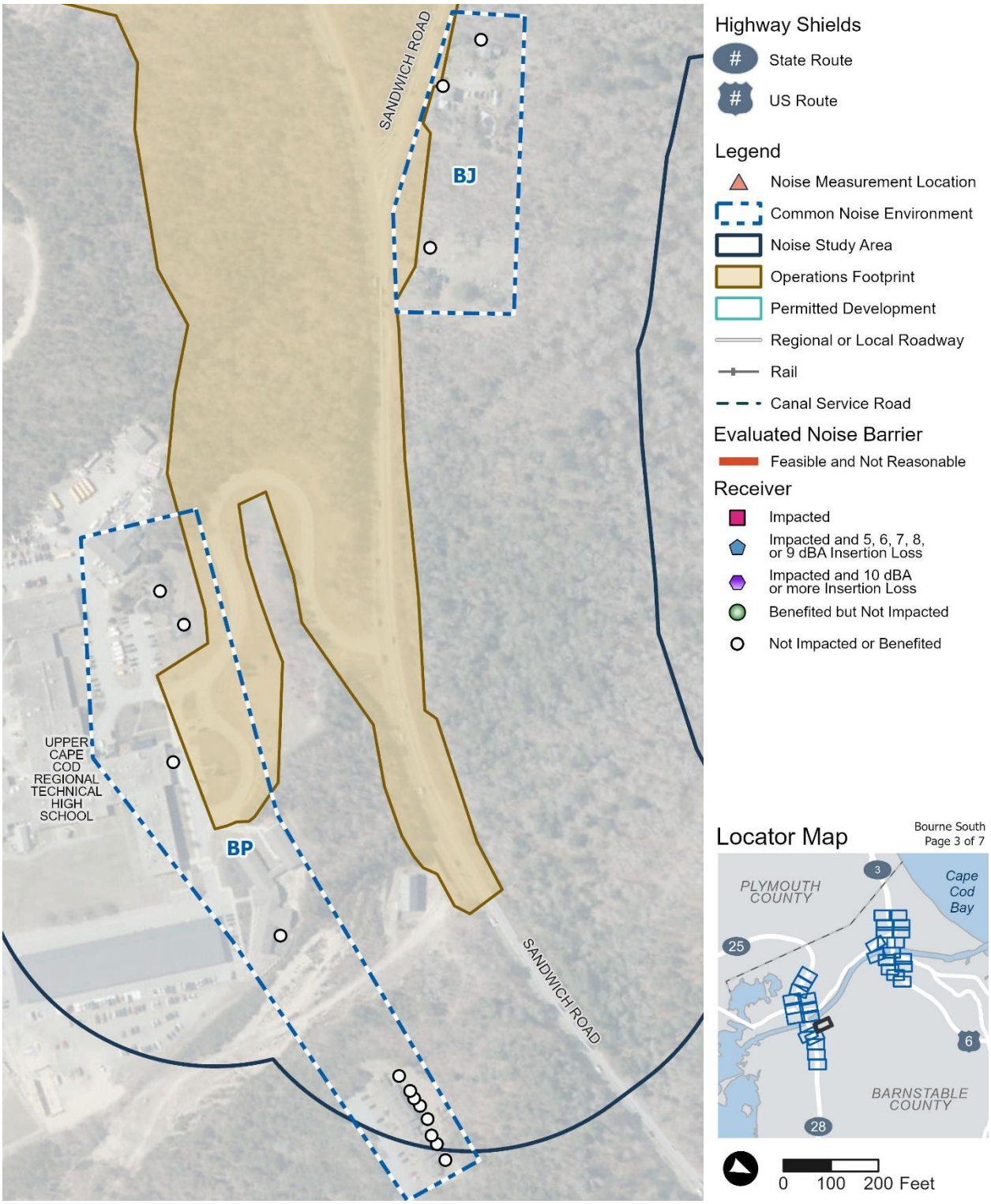
Source: Massachusetts Department of Transportation, 2024

Figure 6-4. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne South Quadrant) (2 of 7)



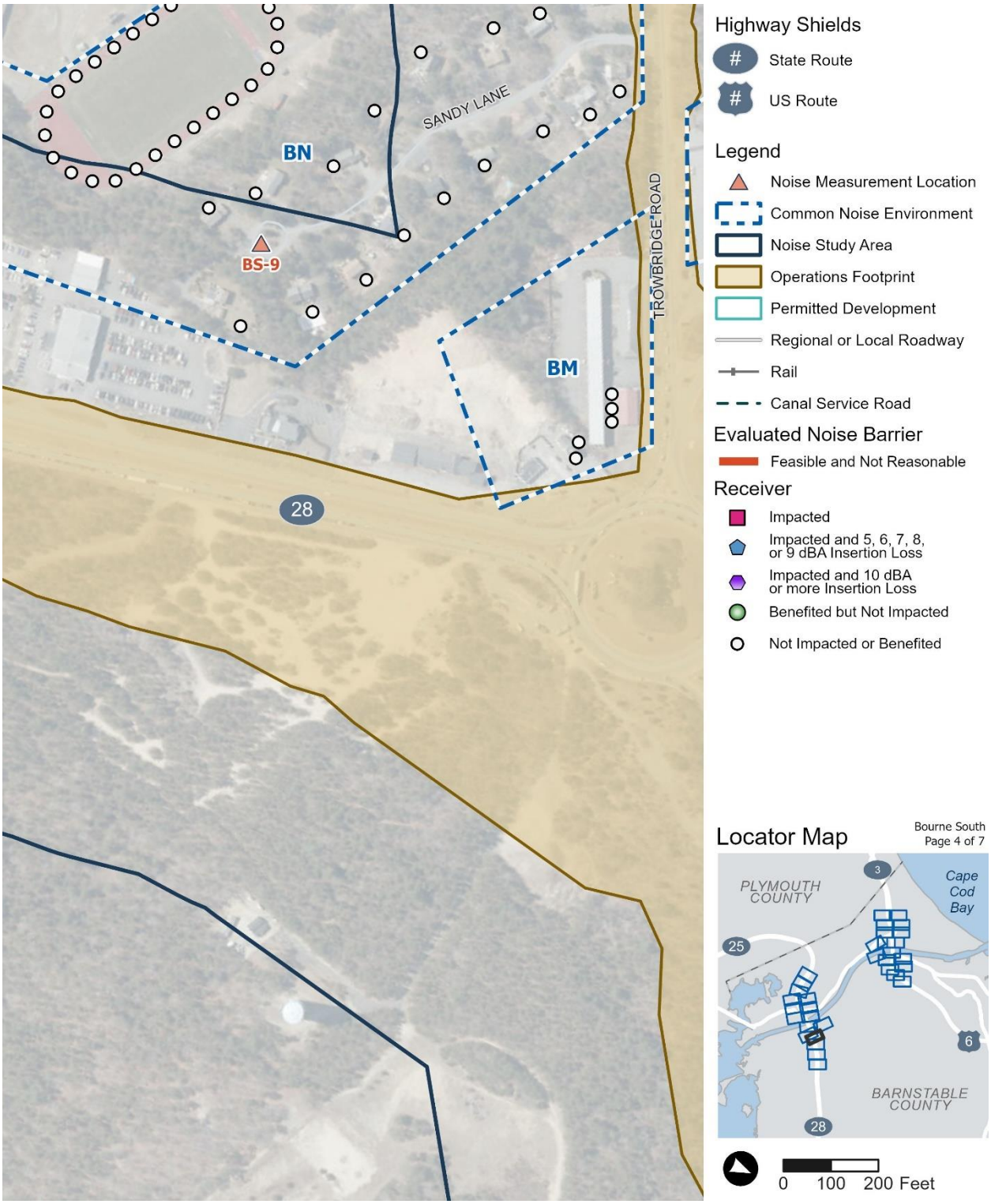
Source: Massachusetts Department of Transportation, 2024

Figure 6-4. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne South Quadrant) (3 of 7)



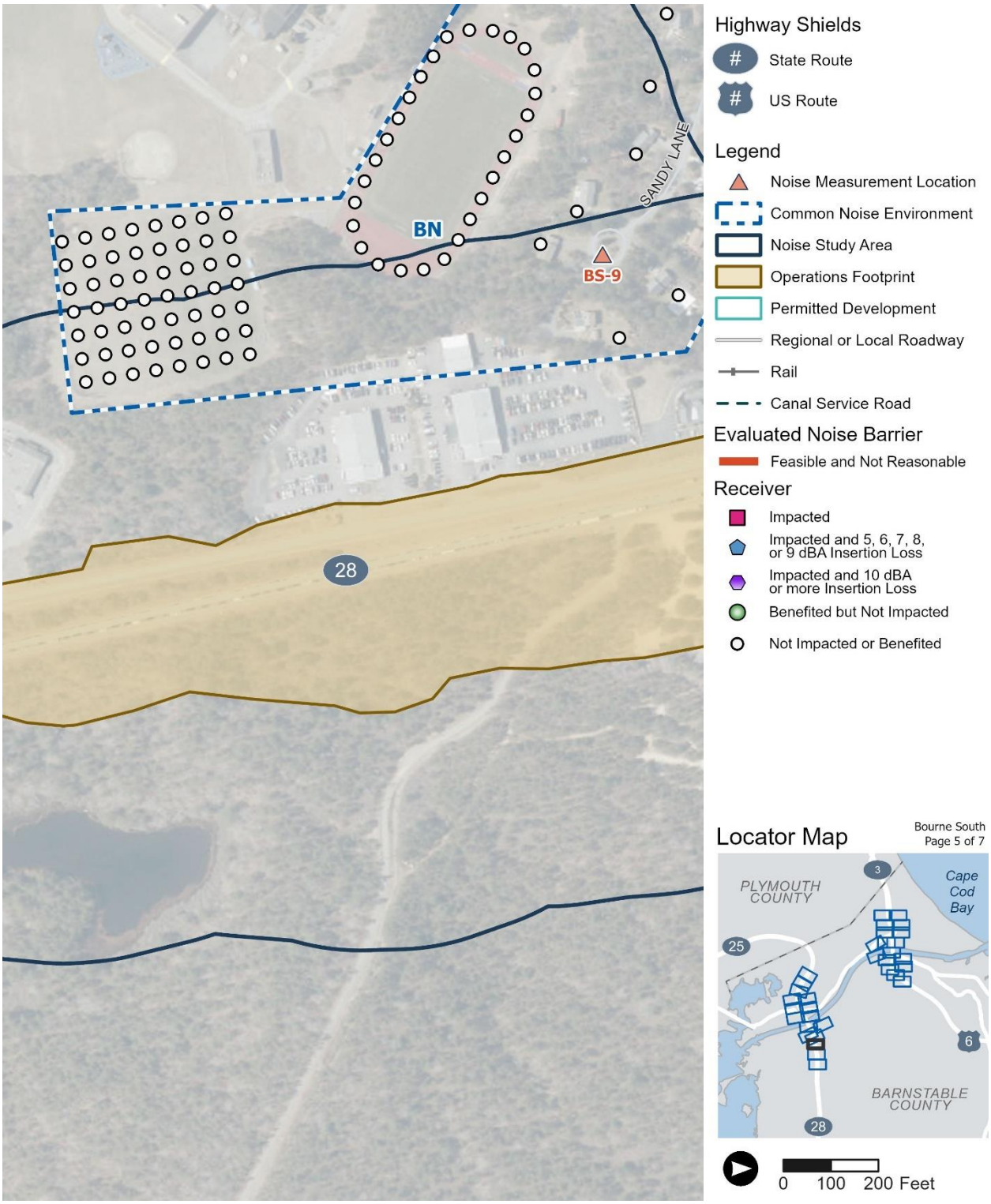
Source: Massachusetts Department of Transportation, 2024

Figure 6-4. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne South Quadrant) (4 of 7)



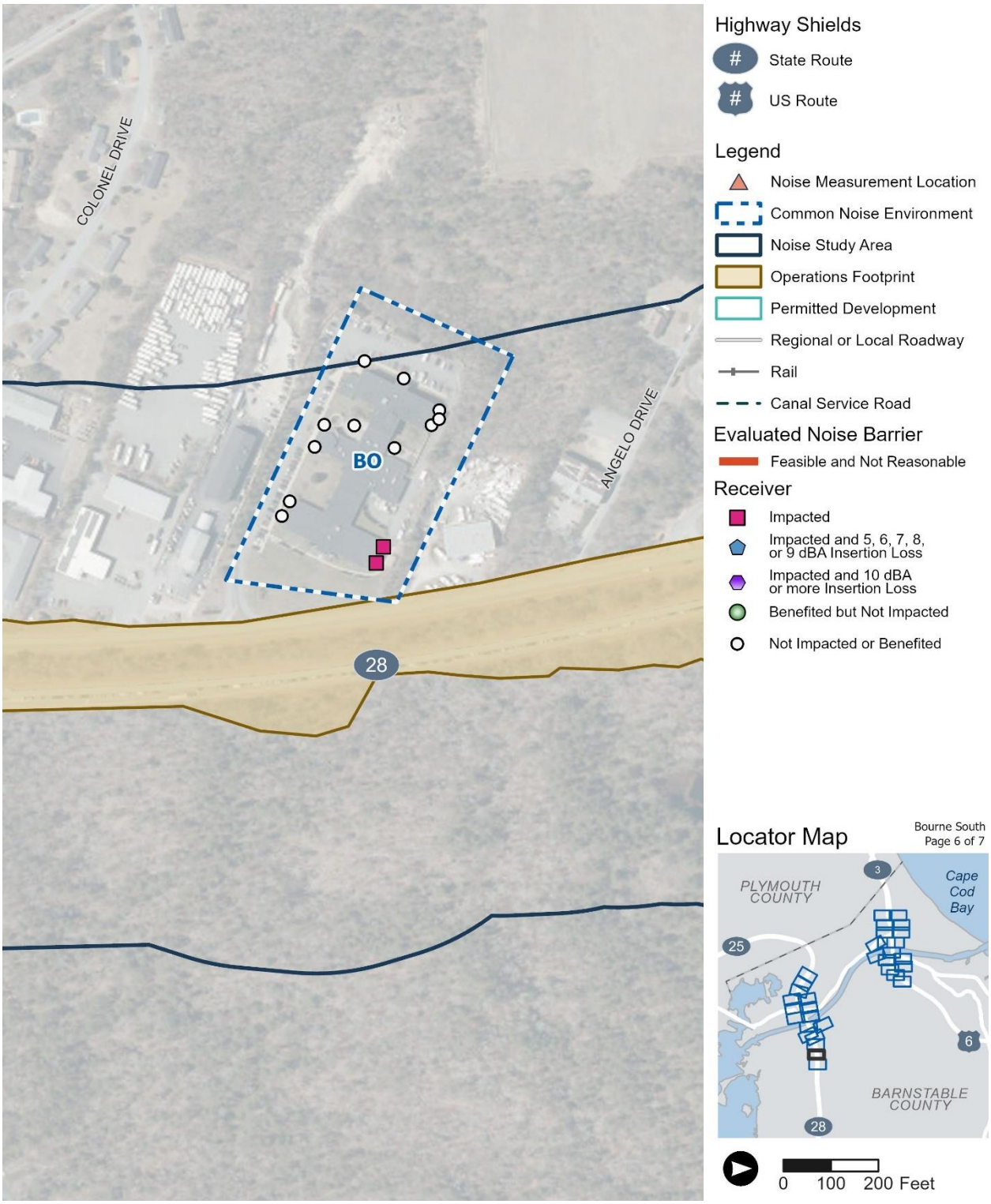
Source: Massachusetts Department of Transportation, 2024

Figure 6-4. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne South Quadrant) (5 of 7)



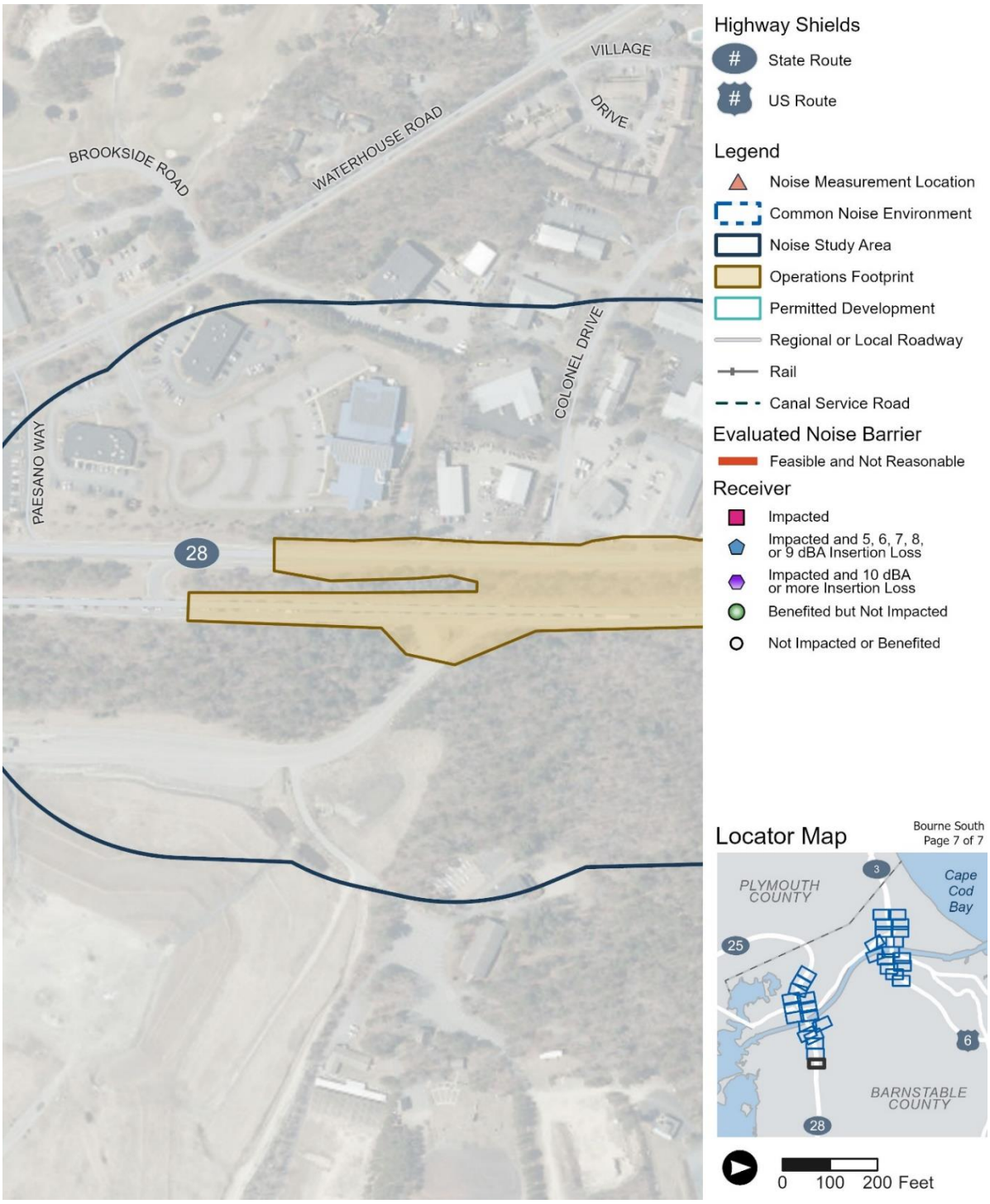
Source: Massachusetts Department of Transportation, 2024

Figure 6-4. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne South Quadrant) (6 of 7)



Source: Massachusetts Department of Transportation, 2024

Figure 6-4. Build Alternative: Location Map for Barriers, Common Noise Environments, and Receptors (Bourne South Quadrant) (7 of 7)



Source: Massachusetts Department of Transportation, 2024

Note: Due to the large Operations Footprint, maps are provided in segments. This segment contains no common noise environments, barriers, or receptors, but is included for completeness.

6.2.5 Structure-Reflected Noise and Expansion Joint Noise

All noise-sensitive areas adjacent to elevated structures where noise from at-grade roadways could potentially reflect off the undersides of elevated structures and affect nearby noise-sensitive areas were evaluated. Based on the relative positions and noise generated by the at-grade and structure roadways, it was determined that any structure-reflected noise would not add significantly to the sound emanating directly from the roadways in any of the Noise Study Areas.

Noise is sometimes generated when vehicles travel over older expansion joints that become mis-aligned over time or when vehicles travel over joints that do not provide continuous support to the vehicle's wheels. These types of expansion joints include single-gap joints and modular joints. Generally, the design of mat joints, flexible plug joints, and finger joints minimize the impacts and resultant vibrations caused by vehicle tires crossing these joints.[27] No expansion joint noise evaluation was conducted for this Program. However, if expansion joint noise is a community concern, various joint types are available that may reduce community complaints.

6.2.6 Construction Noise Impacts

Construction of the Build Alternative would result in intermittent fluctuations in noise levels due to construction vehicle operations and construction equipment performing earth disturbing work, bridge demolition and construction, and roadway reconstruction. Noise levels from construction would be dependent on the types and number of equipment used, condition of equipment, type of construction activity being performed, construction schedule, and the proximity of operating construction equipment to noise-sensitive receptors.

Table 6-9 provides a list of common construction equipment and their maximum noise levels at a reference distance of 50 feet. This equipment list is included in the FHWA's Roadway Construction Noise Model version 1.1 (RCNM 1.1) construction equipment database.[28]

As described within **Appendix 3.2, Construction Approach**, construction phases would generally consist of existing bridge demolition, new bridge construction, and construction of interchange approaches and roadways. The noisiest construction activities would generally be associated with existing bridge demolition and construction of new bridge piers, which may require saw cutting and/or hoe ramming to demolish the existing bridge and drilling and/or pile driving for pier construction. Saw cutting and hoe ramming could produce maximum noise levels of approximately 90 dBA at 50 feet, while drilling and/or pile driving of new bridge piers could produce maximum noise levels ranging between 84 and 101 dBA at 50 feet. Construction of interchange approaches and roadways would require site preparation and grading, potentially necessitating backhoes, excavators, dozers, graders, and dump trucks. Maximum noise levels associated with these pieces of equipment may range between 77 and 85 dBA at 50 feet. Roadway construction would also require pavers, rollers, dump trucks, with maximum noise levels generally ranging between 77 and 80 dBA.

[27] Noise-from-expansion-joints-NYCBC-2019-paper.pdf
[28] https://www.fhwa.dot.gov/environment/noise/construction_noise/rcnm/.

Table 6-9. Federal Highway Administration Roadway Construction Noise Model Equipment Noise Emissions Database

Equipment Description	Impact Device?	Acoustical Usage Factor (%)[a]	Spec. Lmax at 50 feet[b]	Measured Lmax at 50 feet[b]
All Other Equipment > 5 HP	No	50%	85	NA
Auger Drill Rig	No	20%	85	84
Backhoe	No	40%	80	78
Bar Bender	No	20%	80	NA
Blasting	Yes	NA	94	NA
Boring Jack Power Unit	No	50%	80	83
Chain Saw	No	20%	85	84
Clam Shovel (dropping)	Yes	20%	93	87
Compactor (ground)	No	20%	80	83
Compressor (air)	No	40%	80	78
Concrete Batch Plant	No	15%	83	NA
Concrete Mixer Truck	No	40%	85	79
Concrete Pump Truck	No	20%	82	81
Concrete Saw	No	20%	90	90
Crane	No	16%	85	81
Dozer	No	40%	85	82
Drill Rig Truck	No	20%	84	79
Drum Mixer	No	50%	80	80
Dump Truck	No	40%	84	76
Excavator	No	40%	85	81
Flat Bed Truck	No	40%	84	74
Front End Loader	No	40%	80	79
Generator	No	50%	82	81
Generator (<25KVA, VMS signs)	No	50%	70	73
Gradall	No	40%	85	83
Grader	No	40%	85	NA
Grapple (on backhoe)	No	40%	85	87
Horizontal Boring Hydr. Jack	No	25%	80	82
Hydra Break Ram	Yes	10%	90	NA
Impact Pile Driver	Yes	20%	95	101

Equipment Description	Impact Device?	Acoustical Usage Factor (%)[a]	Spec. Lmax at 50 feet[b]	Measured Lmax at 50 feet[b]
Jackhammer	Yes	20%	85	89
Man Lift	No	20%	85	75
Mounted Impact hammer (hoe ram)	Yes	20%	90	90
Pavement Scarafier	No	20%	85	90
Paver	No	50%	85	77
Pickup Truck	No	40%	55	75
Pneumatic Tools	No	50%	85	85
Pumps	No	50%	77	81
Refrigerator Unit	No	100%	82	73
Rivit Buster/chipping gun	Yes	20%	85	79
Rock Drill	No	20%	85	81
Roller	No	20%	85	80
Sand Blasting (Single Nozzle)	No	20%	85	96
Scraper	No	40%	85	84
Shears (on backhoe)	No	40%	85	96
Slurry Plant	No	100%	78	78
Slurry Trenching Machine	No	50%	82	80
Soil Mix Drill Rig	No	50%	80	NA
Tractor	No	40%	84	NA
Vacuum Excavator (Vac-truck)	No	40%	85	85
Vacuum Street Sweeper	No	10%	80	82
Ventilation Fan	No	100%	85	79
Vibrating Hopper	No	50%	85	87
Vibratory Concrete Mixer	No	20%	80	80
Vibratory Pile Driver	No	20%	95	101
Warning Horn	No	5%	85	83
Welder/Torch	No	40%	73	74

Source: FHWA Roadway Construction Noise Model Version 1.1 User's Guide, January 2006.

[a] The acoustical usage factor is the percentage of time a piece pf equipment is operating at full power during a construction operation.

[b] "Spec" refers to noise levels provided in manufacturer's specifications, while "measured" refers to noise levels measured at 50 feet from the equipment as part of the Central Artery Tunnel Project in Boston, Massachusetts.

6.2.7 Construction Vibration Impacts

During construction, the highest vibration levels would result from pile driving. Pile driving is typically required during bridge construction for the installation of bridge piers as well as for support of excavation. Assuming most buildings proximate to proposed construction activities are non-engineered timber and masonry buildings, structural damage has the potential to occur for these types of structures if they are within approximately 72 feet of impact pile driving and approximately 21 feet of vibratory pile driving. When pile driving occurs further than these distances, there would be no potential for structural damage to non-engineered timber and masonry buildings. The potential for structural damage to non-engineered timber and masonry structures from auger drilling, hoe ramming, and use of large bulldozers would occur within approximately 11 feet of these activities/pieces of equipment.

Construction-induced vibration is typically considered "infrequent" in nature. Therefore, the applicable annoyance threshold of 80 dBA for FTA Land Use Category 2 was used to evaluate potential vibration annoyance at nearby residences. The applicable annoyance threshold of 83 dBA for FTA Land Use Category 3 was used to evaluate potential vibration annoyance at nearby institutional land uses (e.g., schools). Based on the annoyance assessment prescribed within the FTA manual, should an impact pile driver be used, the annoyance threshold would be exceeded at any residential (FTA Land Use Category 2) structures within 157 feet and any institutional structures within 125 feet. Should a vibratory pile driver be used, the distance within which residences and institutional land uses would potentially experience vibration-induced annoyance would be reduced to 67 feet and 53 feet, respectively.

During construction activities that require auger drilling, hoe ramming, and use of large bulldozers, the annoyance threshold would be exceeded at any residential (FTA Land Use Category 2) structures within 42 feet and at any institutional structures within 33 feet. Loaded trucks would cause vibration-induced annoyance when driving within 39 feet of residences and 31 feet of institutional uses.

Preliminary "distance to impact" construction vibration assessment results are provided in **Attachment 4, Construction Vibration Impact Assessment Results**.

While these distances offer some guidance on vibration exposure based on receptor to source activity distances, ground-borne vibration effects are also influenced by other factors, including subsurface conditions, vibration frequency, contractor means/methods etc. MassDOT's Contract Specification will include provisions for pre-construction surveys, vibration monitoring, adherence to vibration limit thresholds, and equipment restrictions, as necessary. **Section 7.3** provides additional information on construction vibration mitigation measures.

7 Mitigation Measures

7.1 Operational Traffic Noise Barrier Evaluation Results

As required by FHWA and MassDOT noise assessment policy, noise abatement was considered for the receptors that were predicted to be impacted by traffic noise for the 2050 Build Alternative. Using methodology detailed in **Section 4.2.1.7**, noise barriers were modeled in TNM version 2.5 for each of the impacted noise-sensitive areas. Noise barriers evaluated in the Sagamore North and Sagamore South quadrants are described in **Section 7.1.1** and **Section 7.1.2**, respectively. One noise barrier evaluated in the Bourne North quadrant is described in **Section 7.1.3**. **Table 7-1** summarizes the results of the noise barrier evaluations in each quadrant.

Table 7-1. Noise Barrier Evaluation Summary Table

Noise Barrier ID and Location	Barrier SB Sagamore North Quadrant	Barrier SJ Sagamore South Quadrant	Barrier SK Sagamore South Quadrant	Barrier BF Bourne North Quadrant
Average Noise Reduction (dBA)	7	11	7	10
Length (feet)	1,072	380	1,200	442
Height (feet)	25	15	25	15
Surface Area (square feet)	23,821	5,704	29,994	6,626
Total Cost[a]	$1,429,260	$342,240	$1,799,640	$397,560
Number of Impacted and Benefited Receptors[b]	3	20	4	1
Number of Not Impacted and Benefited Receptors	17	0	5	0
Total Benefited	20	20	9	1
Cost-Effectiveness Index[c]	$11,489	$1,596	$29,026	$41,848
Barrier Status	Feasible and Not Reasonable	Feasible and Not Reasonable[d]	Feasible and Not Reasonable	Feasible and Not Reasonable

[a] Total cost calculated based on a unit cost of $60 per square foot, in accordance with MassDOT's 2021 cost update, submitted to FHWA, pursuant to 23 CFR 772.13(d)(2)(ii).

[b] A benefited receptor is a receptor in the Noise Study Area that attains at least a 5 dB noise reduction or greater with a noise abatement measure. A benefited receptor does not have to be an impacted receptor.

[c] An index that is based on cost, the average noise level reduction provided by a noise barrier, and the number of receptors that achieve a 5 dB or more reduction in noise levels. The Cost-Effectiveness Index (CEI) is calculated by dividing the total barrier cost ($60 per square foot * barrier surface area in square feet) by the average weighted insertion loss and the total number of benefited receptors) one of several criteria used to determine the reasonableness of noise abatement.

[d] Barrier SJ was determined to be not reasonable based on the combination of environmental impacts this abatement measure would impose on the Canal View Apartments, which is eligible for listing on the National Register of Historic Places. Refer to **Section 7.1.2.1** for additional information.

7.1.1 Sagamore North Quadrant

One noise barrier was evaluated within the Sagamore North quadrant. Noise abatement was not evaluated at other areas of predicted impacts in the Sagamore North quadrant due to engineering constraints that would preclude the effectiveness of the noise barriers, which is explained further in **Section 7.1.1.2**.

7.1.1.1 Barrier SB

A noise barrier approximately 1,072 feet in length was analyzed within CNE SB for three impacted residential dwelling units (FHWA Activity Category B) within the Canalside Apartments. **Figure 6-1** illustrates the location of the noise barrier, which was modeled along the State Route 3 southbound off-ramp to Scenic Highway at various uniform heights ranging from a minimum height of 10 feet to a maximum height of 25 feet. At a height of 15 feet, the modeled noise barrier would provide a 5 dBA reduction (benefit) to all first-row residential dwelling units, thereby achieving MassDOT's acoustical feasibility goal; however, to achieve MassDOT's NRDG to at least one first-row residence, the noise barrier would need to be 25 feet high. All modeled barrier heights would exceed MassDOT's 2021 CEI of $10,080 per decibel of noise reduction (insertion loss) per residential dwelling unit benefited. Therefore, Barrier SB would be feasible but not reasonable.

Based on the studies conducted to date, MassDOT does not intend to install highway traffic noise abatement in the form of a noise barrier at the noise impacted locations identified in CNE SB, as illustrated in **Figure 6-1** and described in **Section 6.2.1** because the noise barrier is not cost reasonable. If it subsequently develops during final design that conditions have substantially changed, the noise barrier will be reevaluated. A final decision on the construction of the noise barrier will be made upon completion of the project's final design and the public involvement process.

7.1.1.2 Other Impacted Areas

Other areas of impact within the Sagamore North quadrant would include four residences within CNE SC and CNE SD, and one residence within CNE SI. A noise barrier was not investigated for these CNEs because it would not be acoustically feasible along State Road (CNE SC and SCE SD) due to the various residential driveways that would maintain access to State Road, including those at the impacted residences. As described in **Section 4.2.1.7**, unlimited access roadways (such as State Road) that include a large number of openings required for driveways frequently prevent noise barriers from being feasible, because sufficient noise reduction cannot be achieved with such gaps. In addition, there

would be only one impacted residence within CNE SI along Scenic Highway, and it is generally not possible to design a cost-effective noise barrier for one dwelling unit.

Based on the studies conducted to date, MassDOT does not intend to install highway traffic noise abatement in the form of a noise barrier at the noise impacted locations identified in CNEs SC, SD, and SI, as illustrated in **Figure 6-1** and described in **Section 6.2.1** because numerous gaps necessary to maintain access to properties would preclude construction of an acoustically effective noise barrier. If it subsequently develops during final design that conditions have substantially changed, noise barriers will be reconsidered. A final decision on the construction of noise barriers will be made upon completion of the project's final design and the public involvement process.

7.1.2 Sagamore South Quadrant

Four noise barriers were evaluated within the Sagamore South quadrant. Noise abatement was not evaluated at other areas of predicted impacts in the Sagamore South quadrant due to engineering constraints that would preclude the effectiveness of the noise barriers, which is explained further in **Section 7.1.2.3**.

7.1.2.1 Barrier SJ

A noise barrier approximately 380 feet in length was analyzed for 20 impacted residential dwelling units (FHWA Activity Category B) within CNE SJ at the Canal View Apartments (South Sagamore Area), which is eligible for listing on the National Register of Historic Places. **Figure 6-2** illustrates the location of the noise barrier, which was modeled along the eastbound edge of pavement on Sandwich Road at various uniform heights ranging from a minimum height of 10 feet to a maximum height of 25 feet. At a height of 15 feet, the modeled noise barrier would provide a 5 dBA reduction (benefit) to all 20 impacted first-row residential dwelling units and reduce noise levels by 10 dB at 18 first-row residential dwelling units, thereby achieving MassDOT's acoustical feasibility goal and NRDG, respectively. The barrier would also achieve a weighted average insertion loss of approximately 11 dBA and benefit 20 residential dwelling units. Using MassDOT's 2021 unit cost of $60 per square foot, the total barrier cost would be $342,240, yielding a CEI of $1,596, which is below MassDOT's CEI of $10,080 per decibel of noise reduction (insertion loss) per residential dwelling unit benefited.

23 CFR 772.5 defines reasonableness, specific to noise abatement, as "The combination of social, economic, and environmental factors considered in the evaluation of a noise abatement measure." Given the Canal View Apartments (South Sagamore Area) eligibility for listing on the National Register of Historic Places, the installation of a noise barrier at location CNE SJ would likely result in an Adverse Effect under Section 106 of the National Historic Preservation Act, necessitating Individual evaluation under Section 4(f) of the US DOT Act for the "use" of a historic resource. The installation of a noise barrier at this location would also require the removal of 10 or more mature shade trees currently providing the only buffer between the apartments and Sandwich Road. MassDOT recognizes the environmental and aesthetic benefits provided by these shade trees. Further, a noise barrier would be a visual obstruction for some residents of the Canal View Apartments and impede views of the Cape Cod Canal which is a defining attribute of the property. In consideration of this location's existing noise level range (54–68 dBA) and the 2050 build condition noise level range (56–67 dBA), the likely adverse

effect to and use of a historic property under Section 106 and Section 4(f), and the environmental conditions described above, MassDOT has determined construction of noise Barrier SJ is not reasonable due to environmental impacts.

7.1.2.2 Barrier SK

A noise barrier approximately 1,200 feet in length was analyzed for four impacted residential dwelling units (FHWA Activity Category B) within CNE SK. **Figure 6-2** illustrates the noise barrier location, which was modeled along the proposed U.S. Route 6 northbound off-ramp to Cranberry Highway at various uniform heights ranging from a minimum height of 10 feet to a maximum height of 25 feet. At a height of 25 feet, the modeled noise barrier would provide a 5 dBA reduction (benefit) to all impacted first-row residential dwelling units and reduce noise levels by 10 dB at one first-row residence, thereby achieving MassDOT's acoustical feasibility goal and NRDG, respectively. The barrier would also achieve a weighted average insertion loss of approximately 7 dBA and benefit 9 residential dwelling units. Using MassDOT's 2021 unit cost of $60 per square foot, the total barrier cost would be $1,799,640, yielding a CEI of $29,026, which exceeds MassDOT's 2021 CEI of $10,080 per decibel of noise reduction (insertion loss) per residential dwelling unit benefited. Therefore, Barrier SK would be feasible but not reasonable.

Based on the studies conducted to date, MassDOT does not intend to install highway traffic noise abatement in the form of a noise barrier at the noise impacted locations identified in CNE SK, as illustrated in **Figure 6-2** and described in **Section 6.2.2** because the noise barrier is not cost reasonable. If it subsequently develops during final design that conditions have substantially changed, the noise barrier will be reevaluated. A final decision on the construction of the noise barrier will be made upon completion of the project's final design and the public involvement process.

7.1.2.3 Other Impacted Areas

As discussed in **Section 6.2.2**, the 2050 Build Alternative impacts are predicted within CNEs SL, SM, SN, SO, and SQ. Impacts predicted within these CNEs would be all along Sandwich Road and Cranberry Highway, which are unlimited access roadways with numerous residential and commercial driveways. All of the impacted single-family residences have driveways connected to Sandwich Road or Cranberry Highway, which would preclude construction of an effective noise barrier due to the numerous gaps necessary to maintain residential access (as described in **Section 4.2.1.7**).

Based on the studies conducted to date, MassDOT does not intend to install highway traffic noise abatement in the form of a noise barrier at the noise-impacted locations identified in CNEs SL, SM, SN, SO, and SQ, as illustrated in **Figure 6-2** and described in **Section 6.2.2** because numerous gaps necessary to maintain residential access to properties would preclude construction of an acoustically effective noise barrier. If it subsequently develops during final design that conditions have substantially changed, noise barriers will be reconsidered. A final decision on the construction of noise barriers will be made upon completion of the project's final design and the public involvement process.

7.1.3 Bourne North Quadrant

One noise barrier was evaluated within the Bourne North quadrant. Noise abatement was not evaluated at other areas of predicted impacts in the Bourne North quadrant due to engineering constraints that would preclude the effectiveness of the noise barriers, which is explained further in .

7.1.3.1 Barrier BF

A noise barrier approximately 442 feet in length was analyzed within CNE BF for one impacted single-family residence (FHWA Activity Category B). **Figure 6-3** illustrates the noise barrier modeled along U.S. Route 6/Main Street westbound at various uniform heights ranging from a minimum height of 10 feet to a maximum height of 25 feet. At a height of 15 feet, the modeled noise barrier would provide a 5 dBA reduction (benefit) to the impacted residence, thereby achieving MassDOT's acoustical feasibility goal. This noise barrier would also reduce traffic noise levels by 10 dBA, thereby achieving MassDOT's NRDG. However, with a total barrier cost of $397,560 and insertion loss of 10 dBA, the CEI would be $41,848, which would exceed MassDOT's 2021 CEI of $10,080 per decibel of noise reduction (insertion loss) per residential dwelling unit benefited. Therefore, Barrier BF would be feasible but not reasonable.

Based on the studies conducted to date, MassDOT does not intend to install highway traffic noise abatement in the form of a noise barrier at the noise-impacted locations identified in CNE BF, as illustrated in **Figure 6-3** and described in **Section 6.2.3** because the noise barrier is feasible but not cost reasonable. If it subsequently develops during final design that conditions have substantially changed, the noise barrier will be reevaluated. A final decision on the construction of the noise barrier will be made upon completion of the project's final design and the public involvement process.

7.1.3.2 Other Impacted Areas

One additional noise impact was predicted within CNE BC at a single-family residence on Head of the Bay Road in the Bourne North quadrant. A noise barrier was not investigated for this predicted impact because residential driveways with access to Head of the Bay Road as well as limited available right-of-way would preclude an effective noise barrier. As described in **Section 4.2.1.7**, unlimited access roadways, which include a large number of openings required for driveways, frequently prevent noise barriers from being feasible, because sufficient noise reduction cannot be achieved with such gaps.

Based on the studies conducted to date, MassDOT does not intend to install highway traffic noise abatement in the form of a noise barrier at the noise-impacted location identified in CNE BC, as illustrated in **Figure 6-3** and described in **Section 6.2.3** because numerous gaps necessary to maintain residential access to properties and limited available right-of-way would preclude construction of an acoustically effective noise barrier. If it subsequently develops during final design that conditions have substantially changed, a noise barrier will be reconsidered. A final decision on the construction of a noise barrier will be made upon completion of the project's final design and the public involvement process.

7.1.4 Bourne South Quadrant

One area of impact (CNE BO) was identified at two benches on the north side of the Bourne Manor Extended Care facility adjacent to the State Route 28 northbound travel lanes. A noise wall was not investigated to mitigate these predicted impacts since it would need to terminate prematurely for the access driveway to the facility as well as for the access driveway to a commercial property (Cape Marine) to the north. A noise barrier that is too short in length degrades its effectiveness for receptors close to the barrier termini because those receptors receive too much sound around the barrier ends. Therefore, a noise barrier could not be acoustically feasible for predicted impacts within CNE BO.

Based on the studies conducted to date, MassDOT does not intend to install highway traffic noise abatement in the form of a noise barrier at the noise impacted location identified in CNE BO, as illustrated in **Figure 6-4** and described in **Section 6.2.4** because the noise barrier would need to terminate prematurely to maintain access to a commercial property, thereby degrading the effectiveness. If it subsequently develops during final design that conditions have substantially changed, a noise barrier will be reconsidered. A final decision on the construction of a noise barrier will be made upon completion of the project's final design and the public involvement process.

7.2 Construction Noise Mitigation

MassDOT will include special provisions for noise control during construction. The special provision would require the contractor to submit a Noise Control Plan (NCP) for approval by MassDOT prior to commencement of construction. The NCP will describe the procedure for predicting construction noise levels prior to performing construction activities, including identification of noise reduction measures required to meet the noise level limitations and minimize nuisance noise conditions. The NCP will be developed by an acoustical engineer to be employed by the contractor.

The following additional measures will be implemented to minimize the impacts of construction noise on noise-sensitive receptors:

- Schedule the loudest construction activities during daytime hours near residential neighborhoods.
- Ensure that all construction equipment is in good working order and equipped with mufflers and other noise-reducing features.
- Limit the number and duration of equipment idling on the construction sites.
- Conduct noise monitoring to document compliance with recommended construction noise limits outlined in the NCP. Measured noise levels that exceed or approach construction noise limits in the NCP will implement corrective action, in coordination with local communities.
- Route construction-related truck traffic along roads that would cause the least disturbance to residents.
- Use noise control measures such as temporary noise barriers/curtain systems and portable enclosures for small equipment (i.e., jackhammers and concrete saws), where feasible.

- Implement an active and responsive public outreach program during construction to coordinate construction activities and schedules, and work with local communities to address concerns.

7.3 Construction Vibration Mitigation

MassDOT's contract specifications will include special provisions for vibration control during construction. The special provision will require the contractor to submit a Vibration Control and Mitigation Plan for approval by MassDOT prior to commencing construction. The Vibration Control and Mitigation Plan will describe the procedure for predicting vibration levels prior to performing construction activities, will provide results of a pre-construction buildings survey (identifying structures of concern), will identify vibration reduction measures required to meet established vibration limits set forth to preclude structural damage and minimize vibration-induced annoyance, and will provide a third-party compliance monitoring plan. The Vibration Control and Mitigation Plan will be developed by an acoustical engineer or vibration specialist to be employed by the contractor.

The following additional measures will be implemented to minimize the impacts of construction vibration:

- Establish construction vibration structural damage response action and stop-work levels.
- Sequence operations to reduce total vibration levels by separating significant vibration-inducing activities.
- Limit vibration-inducing activities to daytime hours, where feasible.
- Require selection of alternative means and methods, where conditions permit.

8 Information for Local Government Officials

FHWA and MassDOT policies require that MassDOT provides certain information to local officials within whose jurisdiction the highway project is located, to minimize future traffic noise impacts of Type I projects on currently undeveloped lands. (Type I projects involve highway improvements with noise analysis.) This information must include information on noise-compatible land use planning, noise impact zones in undeveloped land in the highway project corridor and federal participation in Type II projects (noise abatement only).

8.1 Noise-Compatible Land Use Planning

Section 9.0 of MassDOT's 2011 noise policy outlines MassDOT's approach to communication with local officials and provides information and resources on highway noise and noise-compatible land use planning. MassDOT's intention is to assist local officials in planning the uses of undeveloped land adjacent to highways to minimize the potential impacts of highway traffic noise.

The "Entering the Quiet Zone" brochure provides general information and examples to elected officials, planners, developers, and the general public about the problem of traffic noise and effective responses to it.[29]

A wide variety of administrative strategies may be used to minimize or eliminate potential highway noise impacts, thereby preventing the need or desire for costly noise abatement structures such as noise barriers in future years. There are five broad categories of such strategies:

- Zoning
- Other legal restrictions (subdivision control, building codes, health codes)
- Municipal ownership or control of the land
- Financial incentives for compatible development
- Educational and advisory services

The Audible Landscape: A Manual for Highway and Land Use is a well-written and comprehensive guide that addresses these noise-compatible land use planning strategies, with significant detailed information.[30]

8.2 Noise Impact Zones in Undeveloped Land Along the Study Corridor

Also required under the revised 2011 FHWA and MassDOT noise policies is information on the noise impact zones adjacent to project roadways in undeveloped lands. To determine these zones, noise levels are computed at various distances from the edge of the project roadways in the undeveloped areas of the Noise Study Areas. The distances from the edge of the roadway to the NAC sound levels are then determined through interpolation. Distances may vary in the project corridor due to changes in traffic volumes, or terrain features. Any noise-sensitive sites within these zones should be considered noise impacted if no barrier is present to reduce sound levels.

Highway traffic noise is considered a linear noise source and sound levels can drop considerably over distance. The degree that sound levels decrease can vary based on a number of different factors including objects that shield the roadway noise, terrain features and ground cover type (e.g., grass, pavement or water). Through conscious planning efforts and the information provided herein, municipal officials may restrict future development within specified distances from the edges of the improved roadway travel lanes for NAC Activity Categories B and C (residential and recreational, respectively) and Category E (commercial) land uses. Distances are provided by Study Area quadrant in **Section 8.2.1**, **Section 8.2.2**, **Section 8.2.3**, and **Section 8.2.4**.

[29] http://www.fhwa.dot.gov/environment/noise/noise_compatible_planning/federal_approach/land_use/qz00.cfm
[30] http://www.fhwa.dot.gov/environment/noise/noise_compatible_planning/federal_approach/audible_landscape/al00.cfm

8.2.1 Sagamore North Quadrant

Three undeveloped parcels were identified within the Sagamore North quadrant. Two of the three parcels are at a sufficient distance from proposed roadway improvements; therefore, no development restrictions were identified for those parcels. These parcels include an area along Canal Street, southeast of the Sagamore Park and Ride and east of the U.S. Route 6 southbound travel lanes (21 Canal Street) as well as a parcel behind CNE SI, south of Scenic Highway (5 Brigantine Passage Drive). However, it is recommended that future noise-sensitive development is restricted within 35 feet of the edge of travel along westbound Scenic Highway, west of the intersection of Church Lane with Scenic Highway at 1 Frank Circle. A setback distance of 35 feet from the edge of travel would preclude impact to FHWA Activity Categories B and C land use. Distance to impact for Activity Category E land use does not fall within the bounds of the undeveloped parcel.

8.2.2 Sagamore South Quadrant

Within the Sagamore South quadrant, seven undeveloped parcels were identified; however, all undeveloped parcels are at sufficient distance from roadway improvements such that there would be no noise impact to future development on those parcels.

8.2.3 Bourne North Quadrant

There are several undeveloped parcels in the northern portion of the Bourne North quadrant along State Route 25 northbound. These parcels are conserved land or productive woodlands. No other undeveloped lands were identified within the Bourne North quadrant.

8.2.4 Bourne South Quadrant

Within the Bourne South quadrant, most undeveloped land is either conserved or undevelopable. However, two parcels of commercial developable land were identified along the relocated Sandwich Road between the proposed Sandwich Road roundabout and dog-bone roundabout. The address of these parcels is 0 Bourne Rotary according to MassGIS property tax records, and the parcels are located directly south and southwest of the Upper Cape Cod Vocational Technical School. A receptor grid was placed on both parcels to identify distance to impact; however, the highest predicted noise levels on both parcels would be below the FHWA Activity Categories B, C, and E NAC values.

8.3 Federal Participation

Local officials should understand the limits of federal-aid participation for a Type II project (noise abatement only, not part of a highway improvement project) as described in Section 772.15(b):

1. No funds made available out of the Highway Trust Fund may be used to construct Type II noise barriers, as defined by this regulation, if such noise barriers were not part of a project approved by the FHWA before November 28, 1995.
2. Federal funds are available for Type II noise barriers along lands that were developed or were under substantial construction before approval of the acquisition of the rights-of-ways for, or construction of, the existing highway.
3. FHWA will not approve noise abatement measures for locations where such measures were previously determined not to be feasible and reasonable for a Type I project.