Chapter 5 – Sustainable Design and Climate Change Adaptation

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5. SUSTAINABLE DESIGN AND CLIMATE CHANGE ADAPTATION

The overarching goal of the SSX project's sustainable design and climate change adaptation approach is to ensure that sustainability considerations are addressed throughout the project planning and design process, with attention to construction and operation stages, including on-going maintenance and subsequent renovations – in short, throughout the project life cycle. At the same time, adaptation must be considered now and incorporated into both near-term and long-term facility plans. To achieve the project's sustainable design and adaptation goals and meet requirements of MassDOT, the Commonwealth, the federal government, and the City of Boston, close coordination across all planning and design disciplines, including maintenance and operations considerations, is essential. Section 5.1 discusses various standards, guidelines, and approaches MassDOT will consider during the design and construction of the SSX project; Section 5.2 discusses how the SSX project will be consistent with MassDOT GreenDOT and Complete Streets goals; and the climate conditions for which the project would be designed are detailed in Section 5.3.

5.1. Standards and Guidelines

5.1.1. Overview of GreenDOT

On June 2, 2010, the Patrick Administration introduced the *GreenDOT Policy Directive*,[1] a sustainability initiative aimed at continuing the Commonwealth's commitment to the environment by "greening" the state transportation system. Through the *GreenDOT Policy*, MassDOT will promote sustainable economic development; protect the natural environment; and enhance the quality of life of all of the Commonwealth's residents and visitors. The objective was not just to make MassDOT itself "greener", but also to achieve outcomes that would encourage sustainable growth and practices in Massachusetts.

MassDOT's GreenDOT program was developed in response to numerous sustainability platforms, including: the Global Warming Solutions Act of 2008, the Healthy Transportation Compact that grew out of the Patrick Administration's 2009 Transportation Reform Law, and MassDOT's Complete Streets design approach. This initiative has three primary objectives:

- Reduce greenhouse gas emissions.
- Promote healthy transportation options of walking, bicycling, and public transit.
- Support smart growth development.

MassDOT has committed to infuse these objectives throughout its entire organization, facilities, infrastructure, and the contractors that work with the agency. This commitment is reinforced through the specificity and detail at which MassDOT plans to make the Commonwealth's transportation system sustainable. At the end of 2012, MassDOT released the *GreenDOT Implementation Plan*[2] that expanded on the original initiative using industry innovations, best practices, and public feedback to include seven broad themes:

- Air
- Energy
- Land
- Materials

[1] Massachusetts Department of Transportation. *GreenDOT Policy Directive*. June 2, 2010. https://www.massdot.state.ma.us/portals/0/docs/P-10-002.pdf.
[2] Massachusetts Department of Transportation. *GreenDOT Implementation Plan*. December 12, 2010. Accessed August 5, 2014. http://www.massdot.state.ma.us/Portals/0/docs/GreenDOT/finalImplementation/FinalGreenDOTImplementationPlan12.12.12.pdf.

- Policy, planning, and design
- Waste
- Water

Each of these themes contains multiple sustainability goals that can be achieved through measurable tasks and performance indicators which are further measured by time frame of accomplishment. The *GreenDOT Implementation Plan* is an innovative example of a public transportation agency mandating specific tasks toward achieving sustainable transportation goals and calculating results. MassDOT is committed to ensuring that the SSX project would be planned, designed, constructed, maintained, and operated in accordance with these guidelines.

5.1.2. Overview of Complete Streets Initiative

The conventional way to design roadways was historically from the inside out, with the focus primarily on vehicular travel. Since 2006, *MassDOT's Project Development and Design Guide* has promoted designing roadways from outside in; a multimodal, context sensitive, and more complete approach to roadway design that increases the role of non-motorized and transit options. Since its inception, MassDOT has employed its Complete Streets program on state roadways throughout the Commonwealth and over the past five years has offered workshops to educate municipal officials about the framework to deliver Complete Streets on local roadways. During that time, the City of Boston began developing a similar urban-focused set of guidelines for designing Boston's municipal roadway network.

Boston Complete Streets was inaugurated in 2009 as a collaboration to develop new street design guidelines and implement projects informed with a new Complete Streets approach to build road networks that are safer, more livable, and welcoming to everyone. Boston Complete Streets strives to improve the quality of life in the City of Boston by creating streets that are great public spaces and part of a sustainable transportation network. The Complete Streets approach places pedestrians, bicyclists, and transit users on equal footing with motor vehicle users. The objective of this initiative is to ensure that Boston's streets are: multimodal, green and smart. These three overriding themes frame the principles of the *Boston Complete Streets Design Guidelines* [3] (referred to hereafter as *The Guidelines*).

The Guidelines identify numerous different street types that balance operational capacity and mobility with the context and character of the street and surrounding neighborhood. Taking into consideration the type of street would help ensure that land use contexts are reflected in the design and use of Boston's streets. *The Guidelines* identify nine street types:

- Downtown Commercial
- Downtown Mixed-Use
- Neighborhood Main
- Neighborhood Connector
- Neighborhood Residential
- Industrial
- Shared Street
- Parkway
- Boulevard

The existing roadway network in and around South Station is primarily Downtown Commercial which defines Boston's dense commercial core. As defined in *The Guidelines,* these streets typically contain a mix of mid- and high-rise office buildings; serve as international cultural destinations; and connect with

[3] City of Boston. *Complete Streets Guideline*. bostoncompletestreets.org.

highways and transit hubs that serve the Greater Boston region. The newly designed section of Dorchester Avenue, with the proposal to provide a mix of retail, residential, office, and entertainment uses, would become a Downtown Mixed-Use street type as defined by *The Guidelines*. Downtown Mixed-Use streets serve a more diverse set of land uses than Downtown Commercial streets, creating many of the City's most dynamic public spaces such as Newbury Street in the Back Bay and Tremont Street in the South End. These street types support high levels of walking, bicycling, and transit, as well as support frequent parking turnover to foster economic vitality. These streets create a lively and visually stimulating public realm and are supported by greenscape, street furniture, outdoor cafés, street vendors, plazas, and public art. Boston's Downtown Mixed-Use Streets are where people work, play, shop, eat, and gather to enjoy city life.

5.1.3. Overview of Sustainable Design Guidelines

The alternatives under consideration contain both public agency actions and private developer actions. The public agency and joint/private development actions as part of SSX are subject to different sustainability guidelines and standards as described in this section. In general, public agency led actions are related to building and transportation improvements in support of public transportation service components of the SSX project found in all South Station site Build Alternatives (which includes demolition of the USPS building, new platforms and tracks, new passenger waiting areas, Dorchester Avenue redesign, and site work directly related to station construction) and proposed improvements at three layover yard sites: Widett Circle, Beacon Park Yard, and Readville-Yard 2. Joint/Private development led actions relate to the potential for additional joint development projects under Alternative 2 – Joint/Private Development Minimum Build (approximately 660,000 sf) and Alternative 3 – Joint/Private Development Maximum Build (approximately 2.1 million sf.) The next step in the design process for MassDOT would be to select a preferred alternative for the various project elements. Once a preferred alternative is selected, MassDOT would refine the sustainable design elements that would be incorporated in the SSX project through final design into construction and operations and maintenance.

The following industry benchmarking standards would be used for SSX project planning and design to guide and assess sustainability strategies and achievement:

- **SSX Public Buildings** – Would utilize U.S. Green Building Council (USGBC) Leadership in Energy & Environmental Design (LEED) Green Building Design + Construction Rating System, as adapted by the Commonwealth of Massachusetts, Executive Office for Administration and Finance, A&F Bulletin 12, "*Establishment of Minimum Standards for Sustainable Design and Construction of New Buildings and Major Renovations by Executive Agencies*" (Massachusetts LEED Plus). SSX public buildings include the new headhouse at the South Station site and any buildings constructed at the layover facilities.
- **SSX Public Infrastructure** – Would consider various sustainable infrastructure guidelines such as: FHWA INVEST, Complete Streets, the Institute for Sustainable Infrastructure (ISI) Envision™ Sustainable Infrastructure Rating System, and the Greenroads Rating System. SSX public infrastructure includes all proposed terminal track and platform work, Dorchester Avenue redesign, and pedestrian/bicycle infrastructure improvements at the South Station site and all rail yard and site access roadway improvements at the layover facilities.
- **SSX Joint/Private Development** – Would conform to the requirements of the Authority Having Jurisdiction (AHJ) over development review, approvals, and permitting. The primary standard to be used is the LEED Green Building Design + Construction Rating System certification by the Green Building Certification Institute (GBCI) at certification levels specified by the City of Boston and the Boston Redevelopment Authority (BRA). The BRA development review process includes the processing of a Green Building Report that serves as a LEED checklist; the use of a Climate Change checklist to ensure preparedness and resiliency for new construction; and

application of an energy model that is required to comply with the Commonwealth's Stretch Energy Code. It is expected that the private developer will work with MassDOT to ensure consistent sustainable design for development around the South Station headhouse and infrastructure. The private developer will also work with the MassDOT Public/Private Development Unit (PPDU) to ensure that the project is consistent with MassDOT policies, including GreenDOT.

The next section describes the applicability of these benchmarking standards to be used for public buildings and infrastructure components of the SSX project that are to be undertaken by MassDOT. It is assumed that undertakings by private interests shall conform to the requirements of the AHJ over development review, approvals, and permitting.

SSX Public Buildings

Massachusetts LEED Plus

One of the goals of GreenDOT is to "Build green facilities for MassDOT" and one of the indicators of that goal is "New facilities funded or built by MassDOT over 20,000 sq. ft. designed to MA LEED Plus." The Massachusetts LEED Plus standard is based on the LEED New Construction (NC) Version 2.2 rating system and is the required standard to be employed for public building components of the SSX project.

The Basic Requirements (per Massachusetts LEED Plus Standard, LEED-NC Version 2.2) are:

- Energy Reduction (LEED Credit EAc1) – Reduce energy consumption cost by at least 20% over industry benchmarks (as developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (AHSRAE) 90.1-2004 standard for comparable building(s). Cost savings shall be demonstrated through use of an energy model bench marking the proposed design case against a typical standard comparable building baseline case. (Note: Building envelope, orientation, lighting, daylighting, glazing, and mechanical system approaches, plus opportunities for on-site renewables need to be discussed during project schematic design phase. City of Boston Environment Department Guidelines for High Performance Buildings and Sustainable Development would be used as a guidance document.)
- Building Commissioning (LEED Credit EAc3) – Use an independent third party commissioning authority (CxA) to conduct both design phase reviews of plans and specifications to confirm intended energy reduction strategies would meet energy use and cost reduction goals upon construction. An important requirement of this credit is also to validate modeled mechanical system performance results are being met during major mechanical systems testing and balancing prior to building occupancy. (Note: Engaging a CxA during the design development phase of the project is a requirement to achieve this credit.)
- Public Transportation Access (LEED Credit SSc4.1) – Construct or renovate on a site with public transportation, a given for this project.
- Reduce Use of Potable Water for Irrigation (LEED Credit WEc1) – Limit use of potable water for irrigation by 50% over conventional base lines, do not use potable water for irrigation, or do not install irrigation of landscape planting areas except for establishment periods.
- Reduce Building Water Use (LEED Credit WEc3.1) – Reduce potable water consumption in domestic building water use by 20% after meeting the fixture performance requirements of the Energy Policy Act of 1992.

Some additional considerations per Executive Order (EO) 484 that go beyond Massachusetts LEED Plus Standard:

- Document the project's potential contribution toward Commonwealth Agencies' goal of reduction of GHG emissions from state government operations by 40% by FY 2020 over FY 2002 baseline. Strategies could include the application of green construction practices, and quantification of the beneficial impacts the project has related to the corresponding reduction of GHG emissions from private vehicles based on number of additional transit trips served by the project expansion and/or replacement of transit vehicles with lower emitting vehicles.
- Document the project's potential contribution toward Commonwealth Agencies' goal of reduction of energy consumption at state owned facilities by 40% by FY 2020 over FY 2004 baseline and measured on a British Thermal Unit per Square Foot (BTU/SF) basis.
- Document the project's potential contribution toward Commonwealth Agencies' goal of procurement of 30% of electricity from renewable sources by FY 2020. (Note: strategies could include contribution from on-site renewable sources of power generation)
- Document the project's potential contribution toward Commonwealth Agencies' goal of reduction of potable water use by 15% by FY 2020 over FY 2006 baseline.

Approach for SSX Public Building Projects

Public building components of the SSX project include new building construction and potential renovation of some portions of existing buildings depending upon the alternative under consideration. Sustainability measures outlined in the following section represent strategies that would be considered where feasible to enable the overall project to meet the target mandates of the Massachusetts LEED Plus standard. These suggested approach strategies should be evaluated for both new construction and substantial renovation projects. These strategies would be explored for all occupied structures at the SSX public terminal site and layover yard sites.

- Reduce Energy Consumption by Increasing Building Envelope Energy Efficiencies: Reduction of heat/cold energy transference through use of high performing wall and roof insulation, air tight construction and reduced heat transference through window framing and glazing can be employed to reduce building energy use. These strategies can increase building energy efficiency, reduce energy consumption for space heating and cooling, reduce operations costs, reduce HVAC equipment sizing, and reduce carbon emissions associated with the burning of fossil fuels to heat and cool interior spaces.
- Reduce Energy Consumption by Use of High Efficient Heating Ventilating and Air Conditioning (HVAC) Equipment: Building mechanical systems, equipment, and operations control systems have a substantial impact on reducing energy consumption and operations costs, and carbon emissions associated with the burning of fossil fuels to heat and cool interior spaces. High efficiency equipment and systems and heat recovery strategies should be employed where practical to reduce energy usage while maintaining ventilation requirements for building occupant safety and comfort.
- Reduce Energy Consumption by Use of High Efficiency Lighting: High performing building illumination systems, equipment, use of daylighting strategies, and the installation of occupancy sensors can be employed to reduce overall energy consumption for illumination. Reducing wasted heat produced from lighting would also have the effect of reducing HVAC energy consumption. For the existing headhouse renovation, less-efficient and heat producing lighting systems can be replaced with more efficient cool lighting technologies (such as LED lighting) during scheduled repair, replacement, and maintenance projects.

- Reduce Potable Water Consumption and Wastewater: Use of low water consuming lavatory faucets and toilets can be employed to reduce consumption of potable water and production of wastewater. Treatment, storage, and distribution of potable water and wastewater consume significant amounts of electricity. Reduction of water use and wastewater production would reduce water and sewer costs to the facility, reduce use of fossil fuels to heat domestic hot water, and reduce potable water and wastewater energy consumption.
- Incorporate Renewable Energy Measures: There would be opportunities to consider installation of renewable energy production infrastructure, such as solar domestic hot water systems, photovoltaic solar power generation panels, and wind turbine power generation equipment with new buildings or major renovation projects. MassDOT would monitor these opportunities as design advances.

SSX Public Infrastructure

Sustainable Infrastructure Guidelines

MassDOT has not committed to one particular sustainable infrastructure rating system to guide the design of the SSX project public infrastructure, but for the purposes of demonstrating the opportunities for implementation on this project will use the Envision rating system as an example.

The Envision green infrastructure rating system is the product of a joint collaboration between the Zofnass Program for Sustainable Infrastructure and the Institute for Sustainable Infrastructure (ISI). Envision is designed to be a best practices tool to help engineers, planners, environmental professionals, and the community at-large plan, design, evaluate, and execute infrastructure projects with a deliberate intent on improving outcomes based on a number of critical sustainability metrics.

Envision provides a holistic framework for evaluating and rating the community, environmental and economic benefits of all types and sizes of infrastructure projects using a credit-based system similar to the LEED green building rating tool. It evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over a project's life cycle.

Credits are organized into five main categories which align well with sustainability measures and target areas for the infrastructure components of the SSX project. These are:

- Quality of Life Impacts – purpose, wellbeing, and community,
- Leadership Impacts – collaboration, management, and planning,
- Resource Allocation Impacts – materials, energy, water,
- Natural World Impacts – siting, land and water, and biodiversity, and
- Climate and Risk – GHG emissions and resilience/adaptation to climate change.

For each credit, project teams can plan for and obtain one of five levels of achievement based on the degree they are able to satisfy the intent of the credit. The five levels range from “Improved” meaning the project performs above minimum benchmarks, to “Restorative” meaning the project has a net positive benefit or restorative impact related to sustainability goals. This approach allows flexibility to establish achievement levels to meet overall project targets while considering project budget and scope. An overall project rating is determined based on the percentage of the total number of credits achieved compared to the total number of credits possible for the project.

Approach for Public Infrastructure Projects

The planning, design, and construction of new public infrastructure projects presents the opportunity to incorporate a number of sustainable design considerations that would help meet MassDOT's standards and targets. This section identifies some considerations for infrastructure projects, adapted from the Envision Sustainable Infrastructure Rating System. There are a number of specific examples where the 60 different credit areas could be applicable to the various roadway, track, platform, layover yard, and other proposed infrastructure components represented by the alternatives. The following section highlights some of the high-value targets that have the potential to contribute the most to meeting MassDOT's sustainability targets and standards.

- Extend the Useful Life of the Project: Design and construction methods should increase the useful life of the completed works. Strategies should include use of long-lasting materials that add durability and resilience to the design. Design and construction options that increase flexibility and adaptability can be employed to enable easy reconfiguration and refurbishment.
- Use Recycled Materials: Reduce the use of virgin materials in construction by specifying reused materials and material with recycled content when possible. As an example, steel rail components of infrastructure projects represent a significant opportunity to take advantage of the use of materials with a high percentage of recycled content.
- Commission and Monitor Energy Systems: Ensure efficient functioning and extend useful life of major energy using systems by commissioning and monitoring the performance of signals, traction, and power using components of rail transit infrastructure support projects.
- Prepare for Long-Term Climate Adaptability: Infrastructure improvements contemplated for the SSX project may have a design life of 50 years or more. Given the long-life of these systems and expected impacts of changes in climate, infrastructure systems must be resilient to the consequences of long-term climate change, perform adequately under altered climate conditions, or adapt to other long-term change scenarios. As discussed further in Section 5.4, climate change will likely lead to significant changes in the environmental conditions and the SSX project must consider designs to withstand or adapt to a range of conditions including changes in temperatures, humidity, precipitation, seasonal hydrology, flooding, and increased sea levels.
- Prepare for Short-Term Climate Event Hazards – Increase the resiliency of infrastructure systems and provide for quick recovery capabilities from natural and man-made short-term hazards such as flooding, severe storms, and temperature extremes.

5.2. Demonstration of Consistency

5.2.1. Consistency with GreenDOT

The following table demonstrates the areas where the four main SSX project elements- the headhouse expansion, the expanded terminal track facility, reopened Dorchester Avenue, and the layover facilities- are consistent with MassDOT's *GreenDOT Implementation Plan* tasks. The table breaks out *The Implementation Plan* into the seven main themes. Each of the themes are broken up into their respective goals, which are further broken down by the tasks. The four project elements are marked for their consistency with each of the tasks. There are a number of tasks that are not applicable to the SSX project and there are some tasks that cannot be marked for their consistency until the design advances further.

Table 5-1—Consistency with MassDOT's GreenDOT Implementation Plan

GreenDOT Goals and Tasks		SSX Project Elements: Headhouse	Terminal Track Facility	Dorchester Avenue	Layover Facilities
Air					
Improve statewide air quality	Reduce emissions from maintenance & construction equipment	Yes	Yes	Yes	Yes
	Decrease total engine idling	N/A	Yes	Yes	Yes
	Decrease volatile organix compound discharge from facilities	N/A	N/A	N/A	TBD
	Increase fuel efficiency of operating transit fleet	N/A	N/A	N/A	N/A
	Increase efficiency of transportation systems operations	Yes	Yes	Yes	Yes
Reduce greenhouse gas emissions	Increase vehicle electrification facilities	Yes	Yes	TBD	Yes
	Increase use of alternative & renewable fuels	TBD	N/A	N/A	TBD
	Increase fuel efficiency of light duty vehicles	N/A	N/A	N/A	N/A
	Increase fuel efficiency of maintenance & construction equipment	Yes	Yes	Yes	Yes
	Increase telecommuting & meetings by web conference	N/A	N/A	N/A	N/A
	Track progress towards statewide GHG reduction and other sustainability goals	N/A	N/A	N/A	N/A
Energy					
Consume less energy	Reduce building electricity use	Yes	Yes	Yes	Yes
	Reduce electricity use by outdoor lighting	Yes	Yes	Yes	Yes
	Reduce fuel use for heating buildings & water	Yes	N/A	N/A	Yes
	Reduce electricity consumption by subways & trolleys	N/A	N/A	N/A	N/A
Increase reliance on renewable energy	Participate in MassDOT Energy Initiative	N/A	N/A	N/A	N/A
	Increase energy produced at MassDOT facilities	TBD	N/A	N/A	TBD
	Purchase more renewable energy	N/A	N/A	N/A	N/A
Land					
Minimize energy & chemical use in maintenance	Increase acreage of land planted with native/low maintenance vegetation	Yes	N/A	Yes	TBD
	Decrease area & frequency of land mowed	N/A	N/A	N/A	TBD
	Implement an integrated vegetation management approach for ROWs & facilities	N/A	N/A	Yes	Yes
	Require intelligent use herbicides & pesticides in construction & maintenance	N/A	N/A	Yes	Yes
	Protect, preserve & enhance woodland & urban tree coverage	N/A	N/A	Yes	Yes
Enhance ecological performance of MassDOT impacted land	Increase habitat preservation & enhancements	N/A	N/A	N/A	N/A
	Decrease outdoor light pollution	Yes	N/A	Yes	Yes
	Increase wildlife accommodation along ROWs & facilities	N/A	N/A	N/A	TBD
	Decrease quantity of invasive & noxious species	N/A	N/A	N/A	TBD
Materials					
Purchase environmentally preferred products	Implement an environmentally preferred materials purchasing program	Yes	Yes	Yes	Yes
	Purchase energy efficient equipment	Yes	Yes	TBD	Yes
	Use environmentally friendly cleaning products & procedures	Yes	N/A	N/A	Yes
	Reduce hazardous chemical use in operations & maintenance	Yes	Yes	TBD	Yes
	Increase opportunities for local vendors or locally sourced products at facilities	TBD	N/A	TBD	N/A
Improve life-cycle impacts of investments	Reduce energy input into paving operations	N/A	N/A	N/A	N/A
	Increase % of recycled materials in paving and concrete installations	TBD	TBD	TBD	TBD
	Increase total volume of materials sourced within 200 miles of construction site	TBD	TBD	TBD	TBD
	Increase albedo factor in hardscapes, rooftops, & paving	TBD	N/A	TBD	TBD
	Design for deconstruction & reuse	TBD	TBD	TBD	TBD
Build green facilities for MassDOT	Design all new facilities to green building standards	Yes	Yes	Yes	Yes
	Retrofit existing facilities to meet environmental design criteria	Yes	TBD	Yes	TBD
	Relocate offices & encourage healthy transportation options	N/A	N/A	N/A	N/A
	Consolidate office & maintenace facilities where feasible	N/A	N/A	N/A	N/A

Yes	SSX project consistent with this task
TBD	Consistency to be determined during final design
N/A	Not Applicable to the SSX project

GreenDOT Goals and Tasks		SSX Project Elements: Headhouse	Terminal Track Facility	Dorchester Avenue	Layover Facilities
Planning, Policy & Design					
Design a multimodal transportation system	Increase delivery of Complete Streets projects	Yes	N/A	Yes	TBD
	Increase bicycle parking & access to transit	Yes	N/A	Yes	N/A
	Increase total miles & connectivity of bicycle & pedestrian facilities	Yes	N/A	Yes	N/A
	Improve traffic controls to reduce vehicle emissions & to support walking & biking	N/A	N/A	Yes	N/A
	Improve transit system performance statewide	Yes	Yes	Yes	Yes
Promote healthy transportation & livable communities	Encourage walking, biking & transit as active transportation	Yes	N/A	Yes	N/A
	Promote eco-driving & programs to reduce reliance on single occupancy vehicles	N/A	N/A	N/A	N/A
	Utilize surplus land, parking lots & air rights for transit-oriented developments	Yes	N/A	Yes	N/A
Triple mode share of bicycling, walking & transit	Connect land use planning with transportation planning & investments	Yes	Yes	Yes	Yes
	Stabilize travel demand growth on roadways from single occupancy vehicles	Yes	Yes	Yes	Yes
	Collect data regarding factors influencing mode choices & utilize better planning tools	Yes	N/A	Yes	N/A
	Increase training opportunities on GreenDOT and mode shift	N/A	N/A	N/A	N/A
Waste					
Achieve zero solid waste disposal	Increase the diversion rate of office waste	TBD	N/A	N/A	TBD
	Eliminate litter accumulation in ROWs & stations	Yes	N/A	Yes	Yes
	Provide full-stream recycling opportunities at all customer facilities	Yes	N/A	Yes	N/A
	Decrease amount of waste generation during construction & maintenance	Yes	Yes	Yes	Yes
	Decrease paper use	Yes	N/A	N/A	Yes
Reduce all exposure to hazardous waste	Implement Environmental Management System	TBD	TBD	TBD	TBD
	Comply with waste ban & eliminate on-site storage	N/A	N/A	N/A	TBD
	Increase recycling rate of hazardous materials	TBD	N/A	N/A	TBD
	Evaluate & remediate brownfield sites	N/A	N/A	N/A	N/A
Water					
Use less water	Decrease potable water use in buildings	Yes	N/A	N/A	Yes
	Decrease water use for irrigation	Yes	N/A	Yes	Yes
	Increase utilization of recycled water & rainwater	Yes	N/A	Yes	Yes
	Install innovative dual plumbing water systems in facilities	Yes	N/A	N/A	Yes
Improve ecological function of water systems	Minimize impacts & enhance wetlands & impaired waters	N/A	N/A	N/A	Yes
	Adapt facilities for climate change resilience	Yes	Yes	Yes	Yes
	Minimize impacts of ROWs & bridges on fluvial processes	N/A	N/A	N/A	N/A
	Reduce stormwater volumes & increase permeable surface areas	Yes	Yes	Yes	Yes
	Decrease non-point source pollutant discharges	Yes	Yes	Yes	Yes

Yes	SSX project consistent with this task
TBD	Consistency to be determined during final design
N/A	Not Applicable to the SSX project

5.2.2. Next Steps

The SSX sustainable design approach is consistent with MassDOT's *GreenDOT Implementation Plan*. It is of paramount importance that the guidance laid out as part of the approach is agreed upon and implemented early on in the process. As the owner of the SSX project, MassDOT would have the opportunity for implementation at every phase including design, construction, and maintenance. In addition to ensuring the consistency with GreenDOT, MassDOT would also ensure that the SSX project fulfills the Healthy Transportation Compact (HTC) Directive. This inter-agency initiative is designed to facilitate transportation decisions that balance the needs of all transportation users, expand mobility, improve public health, support a cleaner environment, and create stronger communities. As the project progresses, there will be increased opportunities to implement the sustainable design approach and influence the project through construction. MassDOT will provide more specific sustainable design and climate change adaptation details at the next stage of the design process.

5.2.3. Consistency with Complete Streets Initiative

Existing Street Network Surrounding South Station

The existing South Station transportation facility is located at the corner of Atlantic Avenue and Summer Street, extending along Atlantic Avenue from Kneeland Street, then along Summer Street to Dorchester Avenue. The primary access to the commuter rail platforms is at the corner of Atlantic Avenue and Summer Street, through the headhouse. The primary access to the Bus Terminal is on Atlantic Avenue across from Beach Street, which connects to the Chinatown neighborhood.

Dorchester Avenue

Figure 5-1—Dorchester Avenue between Summer and Foundry Streets

Dorchester Avenue runs north-south from Congress Street in downtown to the Dorchester neighborhood. Dorchester Avenue has one travel lane in each direction carrying low traffic demands within the secure USPS area. The road is owned by the USPS adjacent to its general mail facility between Summer Street and Foundry Street. This section of Dorchester Avenue, adjacent to the Fort Point Channel, is currently closed to the public with the exception of access to the USPS retail facility and service access for 245 Summer Street on the corner of Summer Street and Dorchester Avenue. (See Figure 5-1 for photo of existing conditions on Dorchester Avenue between Summer Street and Foundry Street).

Atlantic Avenue and Summer Street

Due to the location of the station entrances, Atlantic Avenue must accommodate the majority of the arrival traffic to the station. The station creates very congested curb-side activity including taxi stands, pick-up and drop-off areas and 2-hour metered parking, in addition to residential and commercial parking located on the opposite side of the street. The streetscape on Atlantic Avenue adjacent to the station consists of a sidewalk of varying widths from Kneeland Street to Summer Street. A double row of trees defines the pedestrian walking zone with the exception of the area in front of the main Bus Terminal entrance as well as adjacent to the existing headhouse which are both void of any planting (as shown on Figure 5-2). Located between the existing headhouse and the main entrance to the Bus Terminal, benches occupy the space beneath the row of trees furthest from the street curb. Heavy planting separates these benches from the station, essentially creating a barrier between the station and the street. A Hubway bike share station is located on Atlantic Avenue adjacent to the headhouse from April to November.

Figure 5-2—Atlantic Avenue adjacent to South Station

Figure 5-3—Summer Street adjacent to South Station

The sidewalk on Summer Street adjacent to the South Station headhouse is void of any street trees or other vegetation. There is a bus shelter located near the station entrance adjacent to 245 Summer Street, (as shown on Figure 5-3). There are street trees in front of 245 Summer Street as well as heavily planted areas on the inside edge of the sidewalk associated with this private property. South Station does not have continuous frontage on Summer Street from Atlantic Avenue to Dorchester Avenue due to the 245 Summer Street building that occupies the corner of Summer Street and Dorchester Avenue.

Demonstration of Consistency

Roadway and streetscape design must respond to varied local conditions and site constraints. Therefore, not all of the recommendations outlined in *The Guidelines* may apply or be feasible for the SSX project. This section highlights those Complete Streets concepts that the SSX project is incorporating into the design of the roadway network as part of the preliminary design phase. There are many specific individual design treatments recommended in *The Guidelines* that may be applicable to the SSX project site but would not be fully developed or detailed during preliminary design. This section will focus on the broader Complete Streets design concepts but will list more specific individual design treatments that should be considered and investigated further during the final design phase as they relate to specific site conditions and context.

It is imperative that the roadway network surrounding South Station be truly multimodal as it serves all modes of transportation: pedestrians, bicyclists, transit and bus users, and automobile drivers. The SSX project would improve the multimodal level of service with the design and reopening of Dorchester Avenue as a public right-of-way, as well as improvements to Atlantic Avenue and Summer Street, incorporating many of the design concepts outlined in *The Guidelines*. The SSX project would also investigate the use of the green and smart design concepts illustrated in *The Guidelines* and would incorporate those elements into the design that are deemed appropriate and feasible for the local site conditions and constraints.

Dorchester Avenue

With the acquisition of the USPS parcel and the subsequent expansion of South Station, this section of Dorchester Avenue is being transformed into a public throughway street that would be integrated into the existing fabric of the local and regional street and open space network. With its proximity to the Fort Point Channel and the Harborwalk; South Station; and an extensive network of parks and open space that connects to many local cultural and recreational resources, Dorchester Avenue at this location has the opportunity to become a major destination for residents, visitors, and workers to gather for outdoor recreation and enjoyment.

With the reopening of Dorchester Avenue to public access, some of the curb-side activity on Atlantic Avenue can be transferred to Dorchester Avenue, alleviating some of the congestion on Atlantic Avenue. This newly designed section of Dorchester Avenue would provide two-way vehicular traffic; a two-way cycle track that makes connections to existing bicycle networks; an extension of the Harborwalk along the Fort Point Channel; and streetscape design for sidewalks and open spaces adjacent to the new South

Station headhouse and joint development parcels (See Figure 5-4). *The Guidelines* would be incorporated into the design of this new roadway to respond to the context of the area and local conditions and site constraints.

The right-of-way (ROW) for Dorchester Avenue would extend from the Fort Point Channel seawall to the front building facades of the new South Station headhouse and any joint development that would define the public realm. The precise width of the roadway would be determined as the project progresses, but it would be between 80 and 100 feet. The public realm on Dorchester Avenue includes the Harborwalk at the seawall edge, the cycle track, two vehicular travel lanes, one parking lane for short term parking, curbside pick-up/drop-off, bus stops, and a wide sidewalk to accommodate the four sidewalk zones as defined in *The Guidelines* and described below.

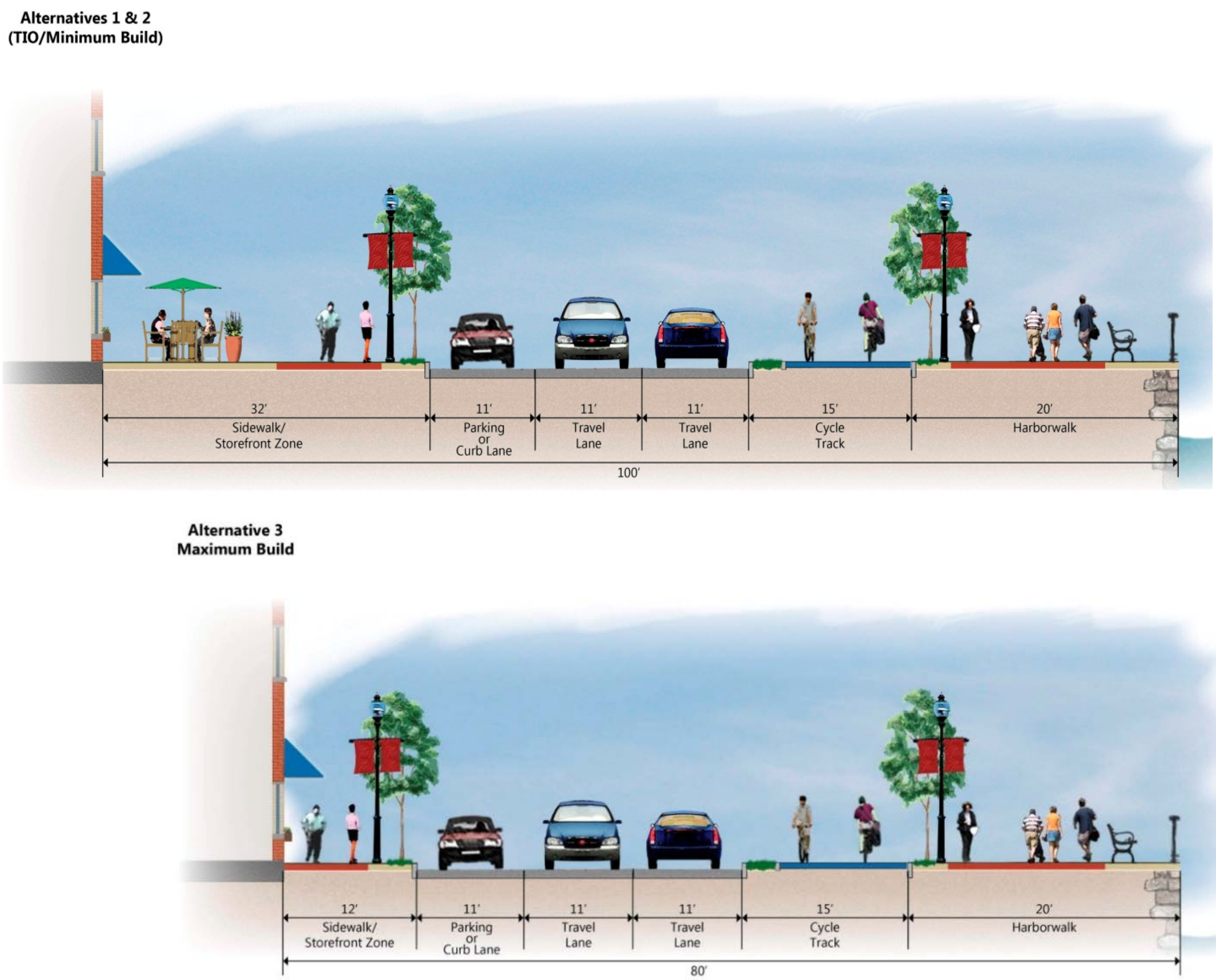

Figure 5-4—Proposed Dorchester Avenue Section from Seawall to Streetwall

The SSX project is taking a multimodal approach to the design of the roadway network at South Station, ensuring that surrounding streets are safe and shared comfortably by all users – pedestrians, bicyclists, transit users, and drivers. The following sections describe how the design of Dorchester Avenue is accommodating all modes.

Pedestrian Accommodations

The pedestrian realm on Dorchester Avenue includes the sidewalk adjacent to the new South Station headhouse as well as the Harborwalk, an extension of the larger Boston Harborwalk corridor that links the water's edge to the City's open space system, and the sidewalk adjacent to the new South Station headhouse and joint development parcels.

Sidewalk

Depending on the final width of the roadway, the sidewalk on Dorchester Avenue adjacent to the new South Station headhouse and joint development parcels would vary. With a 100-foot ROW as proposed in Alternative 2 - Joint/Private Development Minimum Build, the sidewalk width would vary between 32 and 43 feet; with an 80-foot ROW as proposed in Alternative 3 - Joint/Private Development Maximum Build, the sidewalk would vary between 12 and 23 feet. Under any of the alternatives, this sidewalk would accommodate the following four sidewalk zones, as shown on Figure 5-5.

Frontage Zone: This zone is the area between the Pedestrian Zone and the streetwall. In locations where buildings are adjacent to the sidewalk, the Frontage Zone provides a buffer for pedestrians from opening doors and architectural elements. This area is the space for sidewalk cafes, store entrances, retail displays, and landscaping. These elements should not infringe upon the Pedestrian Zone.

Pedestrian Zone: This zone is the sidewalk area specifically reserved for pedestrian travel where there should be no physical obstructions that inhibit pedestrian flow along the sidewalk corridor.

Greenscape/Furnishing Zone: This zone is the area between the curb and the Pedestrian Zone. It is within this zone where street trees, stormwater elements, street lights, signage, hydrants, benches, bicycle racks, public art, trash and recycling receptacles, parking meters, transit stops, signal and lighting control boxes, and utility hatch covers should be located. This zone not only provides a place for objects that may obstruct pedestrian flow, it provides a buffer for pedestrians from the adjacent roadway.

Curb Zone: The Curb Zone is the area between the edge of the roadway and the front edge of the Greenscape/Furnishing zone. In Boston, typically curbs are made of granite and rolled curbs are not recommended. Shared streets are curbless and flush with roadway. The existing street network around South Station employs granite curbs and it is assumed that this would be maintained throughout the SSX project.

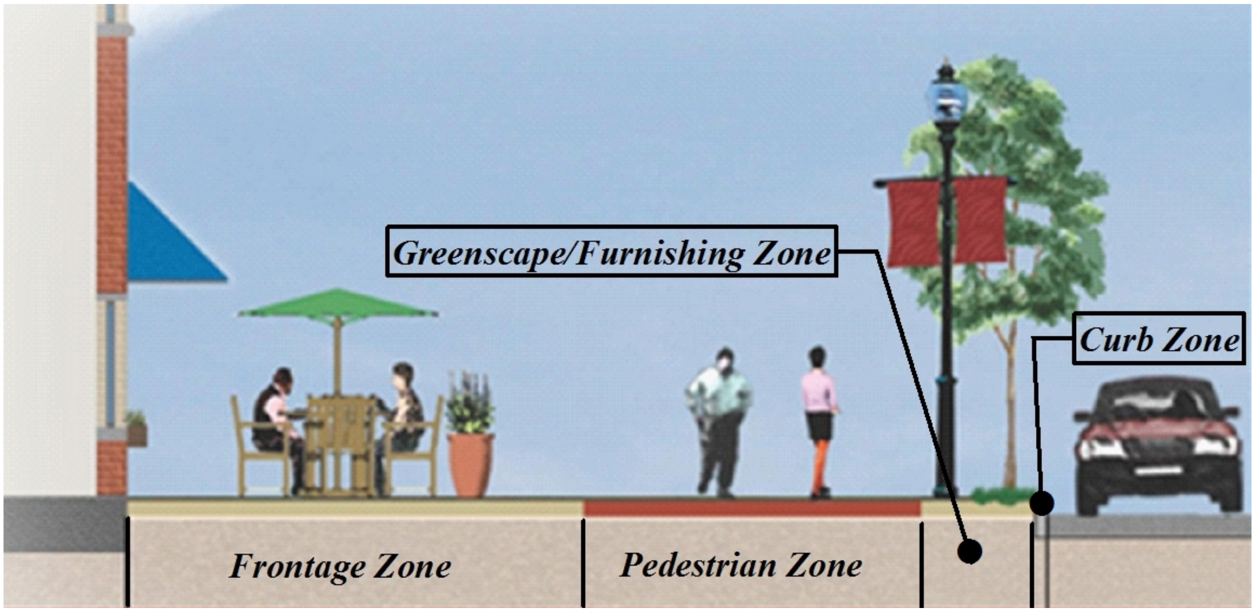

Figure 5-5—Proposed Dorchester Avenue concept, Illustrating the Four Sidewalk Zones

As part of the SSX project, open spaces would be created along the streetwall edge to provide a varied streetwall facade. These open spaces and joint development parcels would provide opportunities for activating the streetscape.

The sidewalk would be designed with *The Guidelines* in mind but it should be noted that many of the Complete Streets elements discussed in *The Guidelines* to activate the sidewalk require specific programming dictated by the tenants of the ground floor of the joint development parcels (e.g.: cafés in the frontage zone of the sidewalk would require an eating establishment within the adjacent building). Food carts and other vendors not associated with the adjacent buildings could occupy a portion of the sidewalk to create a vibrant and active street environment although this activity would also require specific programming. The design of the sidewalk would provide accommodations for such programming and activity to occur.

Harborwalk

The Harborwalk along Dorchester Avenue within the SSX project area would provide additional pedestrian access to the Fort Point Channel waterfront and create a pedestrian link from downtown Boston to South Boston. Moreover, the expansion of South Station onto Dorchester Avenue would provide a direct link to the Harborwalk open space network from the new South Station headhouse. This new section of the Harborwalk, with its proximity to South Station, public transportation, and connections to open space corridors and parks from all corners of the City, has the opportunity to become a destination to experience Boston's rich history along the waterfront with its many nearby cultural and recreational resources.

The new section of the Harborwalk would be approximately 20 feet wide and can be divided into similar sidewalk zones as described above although they would need to be modified to accommodate the waterfront edge. The Harborwalk design does not anticipate a Frontage Zone, rather there would be a Pedestrian Zone flanked on either side by a Greenscape/Furnishing zone, as shown on Figure 5-6. Both zones would likely include landscaping but the area adjacent to the seawall may have more accommodations for individuals and groups to congregate such as benches whereas the zone adjacent to the roadway may accommodate such elements as utilities, signage or bike parking.

Figure 5-6—Existing Harborwalk on Dorchester Avenue between Summer St and Congress St

Bicycle Accommodations

A two-way cycle track would be provided adjacent to the Harborwalk connecting to proposed bike lanes on Summer Street and on Dorchester Avenue between Summer Street and Congress Street. The bike lanes on Summer Street would connect with bike lanes on Atlantic Avenue, providing connections to the Rose Kennedy Greenway, and downtown Boston. The City is proposing a two-way bike lane on the north side of Summer Street east of Dorchester Avenue to South Boston that would connect downtown Boston with South Boston. The proposed Dorchester Avenue cycle track would connect to this bicycle network.

At the south end of the Fort Point Channel, just beyond the MassDOT Vent Building #1, the cycle track within the SSX project site transitions to on-road bicycle lanes on Dorchester Avenue in South Boston. The bike lanes on Dorchester Avenue in South Boston are proposed as part of the South Bay Harbor Trail plan which is part of the Bay State Greenway.

Bus and Automobile Accommodations

Two-way vehicular traffic would be accommodated on Dorchester Avenue between Summer Street and Foundry Street, providing automobile and bus connections from downtown Boston to South Boston. There would be a number of mid-block crossings to provide safe access to the Harborwalk from the new headhouse and joint development parcels that are proposed adjacent to and over the expanded South Station Transportation facility.

The roadway, adjacent cycle track, Harborwalk, and sidewalk would all be designed to provide safe and efficient movement of modes along the length of and across the roadway from the new South Station headhouse and the potential joint development parcels to the seawall at the edge of the Fort Point Channel using methods recommended in *The Guidelines*.

Atlantic Avenue and Summer Street

Improvements would also be made to Atlantic Avenue and Summer Street as part of the SSX project. Existing sidewalks on both of these streets adjacent to South Station are wide and provide sufficient space for the four sidewalk zones described in *The Guidelines*.

5.2.4. Next Steps

As the design for the South Station expansion progresses to preliminary and final design and construction, the following individual design treatments and operational policies recommended for complete streets would be considered and integrated into the design as appropriate for the street type and neighborhood context, given the local conditions and site constraints.

5.3. Climate Change

South Station and the proposed expansion project occupy a unique coastal setting abutting the Fort Point Channel and Boston Harbor. The functionality, aesthetics, and historic richness of this location are confronted with sobering challenges of a key transportation facility sited within the near reach of the Atlantic Ocean. Planning for present and future vulnerabilities warrants consideration of methods to adapt to the wide range of threats that could exist. Given the considerable importance and investment in the station and the time and complexity to implement protective measures, adaptation must be considered now and incorporated into both near-term and long-term facility and site elements as appropriate.

Predicting the future changes to weather is challenging and beyond the scope of this study. However, recognizing the potential for such future changes now during planning stages and in subsequent design phases is important in order to not preclude the ability to make modifications in the future. It is too early to analyze costs and practicability of designs for all mitigation measures to address these risks. Some elements can be planned for use now, such as elevating power, heating, ventilation, and air conditioning systems above the reach of water during storm surges, but other elements have much greater challenges to face and require substantial analyses to determine if and when implementation is warranted.

5.3.1. Storm Intensity and Frequency

New England is expected to experience changes in the amount, frequency, and timing of precipitation due to climate change. According to the Massachusetts Climate Change Adaptation Report[4] annual precipitation is predicted to increase in Massachusetts by 5% to 8% by 2050, and 7% to 14% by the end of the century, with more winter precipitation falling as rain. More frequent precipitation events have the potential to negatively impact the built environment. Most notably these types of changes can manifest through the reduced function and performance of storm drainage systems and infrastructure supported by those systems. Similarly, changes to the characteristics of winter storms could lead to more snowfall; longer periods of snow cover; and more snow removal challenges.

Due to topography and proximity, the South Station site does and would continue to drain to the tidally influenced Fort Point Channel. Under the various build scenarios, portions of the existing storm drain infrastructure would be utilized. Much of the existing site storm drain infrastructure was installed as part of the Northeast Corridor Improvement Project (NECIP) and the South Station Bus Terminal Project (SSTC), both designed in the 1980s. Those drainage systems were designed using historic precipitation records and predictive models and may not be reflective of currently changing weather patterns.

[4] Massachusetts Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee. *Massachusetts Climate Change Adaptation Report*, September 2011.

The portions of the existing drainage system proposed to be retained would have to be analyzed to confirm acceptability for use with evolving precipitation intensity and frequency data, and rising sea levels. It may be determined that the existing system is inadequate under a new set of design inputs, such as elevated tailwater due to sea level rise or possibly storms with greater precipitation intensities. However, it is unlikely that the functionality of the entire existing storm drainage system would be compromised: For example, the upgrade/upstream portions of the existing piping would be less impacted by the effects of sea level rise.

5.3.2. Excessive Heat

Climate change forecasts suggest that global temperatures are increasing and in the United States, the majority of the country has shown an increasing temperature trend when using data from 1901 to 2012. US EPA notes that new extremes for daily temperatures are natural variation of the weather, but as the climate warms "heat waves are expected to become more frequent, longer, and more intense." According to the Massachusetts Climate Change Adaptation Report, by 2050, the average summer temperature in the state could increase by four to five degrees, from today's average of 68 degrees Fahrenheit to 72/73 degrees. By 2100, it could increase by four to 10 degrees, to 72/78 degrees. Days with temperatures over 90 degrees could increase from current conditions of five to 20 days per year to between 30 and 60 days per year by the end of the century. Projected increases in temperature could result not only in impacts to human health, but to the built environment as well.

With respect to infrastructure, high temperatures strain the electrical grid though higher demand for electricity used for cooling and can lead to warming of transmission lines and sagging of overhead wires. That can cause safety risks and power failures. Increased heat can also affect tracks by the expansion of steel rail causing buckling, or possibly causing electrical component failures for devices operating outside of normal temperature conditions. These failures have the potential to cause severe public safety risks or service disruptions. Innovative methods of track manufacturing and installation designed to minimize the buckling effect are being developed and MassDOT would consider these when developing engineering plans for the SSX project. Section 5.1.3 describes some of the sustainable design guidelines MassDOT would consider during design of public buildings to mitigate extreme heat.

5.3.3. Sea Level Rise, Storm Surge, and Floodplains

Sea levels are rising in Boston Harbor and across the globe, as evidenced through empirical data. In order to assess future risk and planning for rising seas, Massachusetts Office of Coastal Zone Management (CZM) recommends selecting specific scenarios. As directed by the Secretary of EEA, the SSX project DEIR assesses the impacts of a two-foot sea level rise upon the SSX project, which is consistent with planning for a project with a design life of 50 years.

Sea level rise will increase the height of storm surges and associated coastal flooding frequencies and permanently inundate low-lying coastal areas. Extensive development and infrastructure, both public and private, would be affected in these expanding areas of vulnerability. Threats to coastal Boston also occur from inundation caused by hurricanes. Hurricanes causing extreme storm surges, such as occurred with Hurricane Sandy in New Jersey and New York in late October 2012, are plausible in Boston, and need to be considered when analyzing a project site's vulnerability.

To assess the project's vulnerability to flooding, floodplains in the study areas were identified using both the effective 2009 and preliminary 2015 Federal Emergency Management Agency (FEMA) Flood

Insurance Rate Maps (FIRM) and Flood Insurance Study (FIS).[5] Figure 5-7 shows existing floodplain conditions at the South Station and Widett Circle sites relative to Fort Point Channel.

FEMA's current floodplain maps are based upon existing sea levels and historical data and do not account for sea level rise.[6] Since flood elevations are directly related to sea levels, which are projected to increase, a correlating increase in flood elevations would occur. This correlation is applicable in coastal settings where ocean waters supply virtually unlimited water to spread over land areas; whereas in inland settings or watercourse based flooding, the water contributing to floods is limited to the watershed. To estimate the potential reach of future coastal flood zones due to sea level rise, existing ground elevations were determined from site survey information from city-wide mapping, and the projected two-foot sea level rise was added to the existing FEMA flood elevations. This is a simple analysis that doesn't take into account changes in bathymetry effecting flooding characteristics.

South Station Site

Mean high water (MHW) in Boston Harbor is approximately 4.63 feet above mean sea level North American Vertical Datum of 1988 (NAVD 88). The project site's base flood elevations (BFEs), which are the modeled heights of the 1% annual chance flood, are 10 to 13 feet NAVD 88. The existing ground elevation at South Station varies from approximately 9 to 16 feet NAVD 88. This indicates that a portion of the South Station site is already vulnerable to flooding without any projected sea level rise.[7] Approximately 2.9 acres of the site are within the 1% annual chance floodplain (commonly referred to as the 100-year floodplain), and approximately 18.9 acres are within the 0.2% annual chance floodplain (commonly referred to as the 500-year floodplain.) Adding two feet to the flood elevations to reflect a future sea level rise scenario would amplify the risk at South Station and increase flood elevations to a range of 12 to 15 feet NAVD 88. Figure 5-8 shows the extent of potential flooding at the South Station site with a 100-year flood elevation of 14 feet NAVD 88, which would represent the mid-range of flood elevations in Fort Point Channel with a two-foot sea level rise. In the absence of mitigation, the 100-year floodplain would encompass approximately 38 acres of the SSX project footprint, representing nearly complete inundation of the site and infrastructure, during a 100-year flood event. Some of the mitigation methods that MassDOT would consider to minimize the vulnerability of South Station to these events include: elevating power/HVAC sources, designing infrastructure and critical equipment to accommodate seawater flooding, and installing pumping systems to accommodate stormwater drainage. For more mitigation strategies see Table 5-2 at the end of this Chapter.

Layover Facility Sites

MassDOT will consider mitigation strategies to adapt to vulnerabilities while designing the layover facilities. These include: locating critical systems to higher levels, using corrosion protection elements and materials for underground structures, and water-proofing rail equipment. See Table 5-2 at the end of the Chapter for a list of more mitigation strategies. The specific vulnerabilities at each site are described below.

Widett Circle

FEMA indicates that the existing 100-year flood elevation does not reach the Widett Circle layover facility site by an overland connection. However, based upon a review of mapped ground elevations at the

[5] Federal Emergency Management Agency. *Flood Insurance Study, Suffolk County Massachusetts*. September 25, 2009. Accessed October, 2012. https://msc.fema.gov/webapp/wcs/stores/servlet/FreeViewDigitalPOCmd?storeId=10001&catalogId=10001&langId=-1&catentry_id=10592947&af=0

[6] Federal Emergency Management Agency. *Preliminary Flood Insurance Study, Suffolk County Massachusetts*, November 15, 2013.

[7] Federal Emergency Management Agency. *Preliminary Flood Insurance Study, Suffolk County Massachusetts*, November 15, 2013.

site, the layover facility site is at or slightly below the 100-year flood elevation depicted at the southern end of Fort Point Channel. There could be risks of flooding through unknown underground connections, such as storm drainage pipes. Considering a future two-foot sea level rise, there would be a direct overland connection to Fort Point Channel, which would cause the site to be vulnerable to flooding. As shown in Figure 5-8, with a two-foot sea level rise, the 100-year flood would completely inundate the Widett Circle layover facility project footprint of approximately 30 acres. Under current conditions during a 500-year flood event (absent the two-foot sea level rise), FEMA indicates that the site is subject to potential flooding that would affect almost the entire site (29.7 acres).

Beacon Park Yard

The Beacon Park Yard layover facility site is located inland from Boston Harbor and is not within a coastal flood hazard area. A two-foot rise in sea level would raise the height of the 100-year coastal flood at the downstream Charles River Dam, which controls water levels near the Beacon Park Yard site. Because the dam isolates the tidal waters and coastal flood events from the Charles River, a two-foot sea level rise and expectant higher 100-year flood would not directly reach or alter the Charles River floodplain near Beacon Park Yard.

A rise in sea level and corresponding higher coastal floods could require managing Charles River water levels during flood events. The Charles River Dam was constructed to provide flood control in the river basin and tributaries and block tidally-driven sea water from flowing upstream. The dam height is 11.87 feet above MSL, (11.57 feet NAVD 88), and the proposed 100-year BFE at the dam is 10 feet NAVD 88.[8] A two-foot sea level rise would place the BFE very close to the dam height; as a result, there could be a need for additional water management practices to minimize upstream effects in the Charles River near the Beacon Park Yard site. Consistent with current practices, altering the available capacity of the Charles River basin to allow for an increase in water volume could be one method to protect against potential flooding due to a higher sea level.[9] Based upon the elevation of the Beacon Park Yard site and downstream surge control protection at the dam, it is unlikely that a two-foot sea level rise would result in any new flood impacts to the site.

Readville – Yard 2

The Readville – Yard 2 layover facility site is located approximately six miles inland from Boston Harbor and is not within a coastal flood hazard area. Two dams on the Neponset River downstream from the site, Tileston & Hollingsworth Dam (Between Milton and Hyde Park) and Baker Dam (Dorchester/Milton Lower Mills) isolate this reach of the river from tidal action and coastal 100-year flood zones. Based upon the distance of the site from the ocean, the site's elevation, and the presence of downstream dams, it is anticipated that no changes to the 100-year floodplain would occur due to a two-foot rise in sea level.

[8] Federal Emergency Management Agency. *Preliminary Flood Insurance Rate Map, Suffolk County Massachusetts*, November 15, 2013.
[9] Kruel, Stephanie. City of Boston Floodplain Manager. Boston, MA. Personal Communication February 28, 2014.

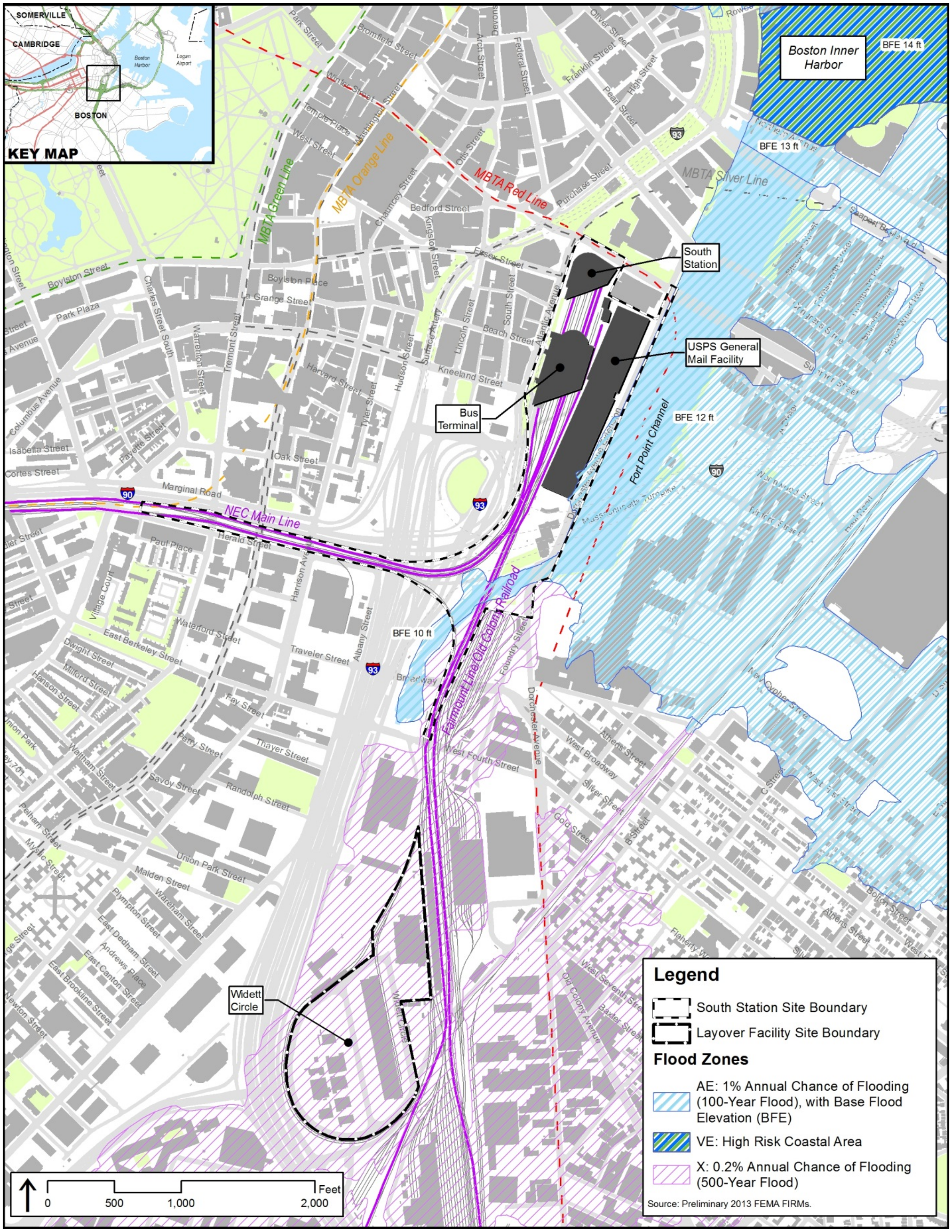

Figure 5-7—Floodplain Existing Conditions – South Station and Widett Circle

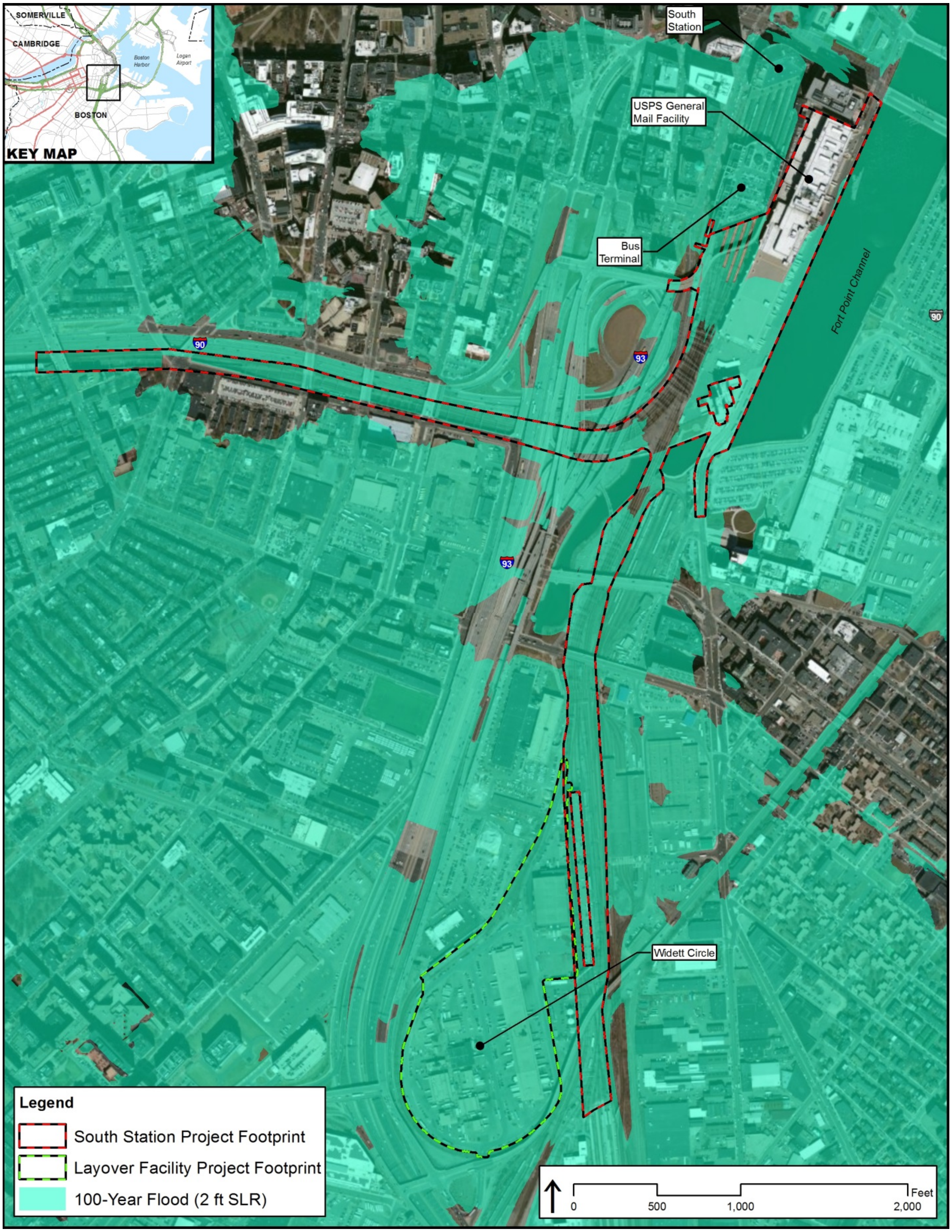

Figure 5-8—1% Annual Chance (100-Year) Flood Inundation with Two-Foot SLR – South Station Project and Widett Circle Footprint (Elevation 14 NAVD 88)

5.3.4. Hurricane Surge

The FEMA floodplains are based on a storm of a particular strength that currently has a 1% annual chance of occurrence. It is also useful to look at scenario-based storms, which can result in water levels that far exceed those anticipated during the 1% annual chance flood event. For this reason, the Hurricane Surge Inundation Maps that have been produced as part of a Massachusetts Hurricane Evacuation Study have also been evaluated.[10] These maps were produced by FEMA and the Army Corps of Engineers using the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model.

For the purpose of the South Station Expansion Project, city-wide maps and GIS data produced in the evacuation study were used. The maps show areas of coastal Massachusetts that would become inundated based upon different categories of hurricanes, ranging in strength from Category 1 (with winds ranging from 74 to 95 miles per hour [mph] and coastal flooding with some damage) to Category 4 (with winds of 130 to 156 mph and catastrophic damage requiring extensive evacuations).[11] Hurricane inundation modeling for the Boston area accounts for two potential scenarios: hurricanes with tracks from south or southwest to north or northeast are predicted to have lower surge levels than hurricane tracks that follow a path directly toward land from offshore (from southeast or east). Storms approaching Boston from the east or southeast have the ability to build higher waves, force water ahead of the storm, and "pile up" water in the harbor and against land masses. Storms approaching from this heading also may contribute more surge influence due to low barometric pressure and its effects on water levels. Storms approaching Boston from the west or southwest are crossing overland, which can dampen some of these surge effects. Progression speeds of approaching hurricanes are likely to be slower when generally heading from east to west compared with storms generally tracking from the south to north. The progression speed of storms typically changes the duration of the storm which in turn affects surge levels.

In partnership with FHWA, MassDOT is conducting a *Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options of the Central Artery*. Many MassDOT assets, including the Central Artery tunnels, are currently vulnerable to flooding from an extreme coastal storm. This vulnerability will increase in the future due to projected sea level rise due to climate change. The Central Artery is a critical link in regional transportation and a vitally important asset in the Boston metropolitan area. As one of the single most valuable components of Massachusetts infrastructure, its maintenance, protection and enhancement are a priority for the Commonwealth. The objectives of the pilot project are: assess vulnerability of Central Artery to sea level rise and extreme storm events for the present day, 2030, 2070, 2100; investigate options to reduce identified vulnerabilities; and establish an emergency response plan for tunnel protection and/or shut down in the event of a major storm. The project is composed of seven phases, including: inventory and survey of assets, hydrodynamic analysis, a vulnerability assessment, an adaptation strategy, and is anticipated to result in a final report by the end of 2014. The cornerstone of the project is the hydrodynamic model called Boston Harbor Flood Risk Model. Although the model is designed to target the Central Artery Tunnel's numerous assets, the model will be able to provide flood risk information throughout the Cities of Boston and Cambridge; the location of the South Station Expansion Project is included in the model domain. In contrast to the Hurricane Surge Inundation Maps referenced earlier, the Boston Harbor Flood Risk Model includes both hurricane and "nor'east" storms and is forward looking from the present day to 2100.

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[10] U. S. Army Corps of Engineers, Federal Emergency Management Agency, National Oceanic and Atmospheric Administration, MassGIS. *Massachusetts Hurricane Evacuation study Hurricane Surge Inundation Mapping*, March 2013.
[11] National Weather Service, National Hurricane Center. *Saffir/Simpson Hurricane Wind Scal*. http://www.nhc.noaa.gov/aboutsshws.php.

Existing Hurricane Surge Conditions

South Station Site

Figure 5-9 presents modeled hurricane inundation at the South Station site with existing conditions and with a storm tracking from the east or southeast. Portions of the South Station project footprint, including areas along Dorchester Avenue and some areas along the western site boundary, would become inundated by a Category 1 hurricane. A Category 2 hurricane would inundate the majority of the area within the project footprint, with the exception of northern portions of the site from the USPS facility extending west to portions of the South Station headhouse. A Category 3 hurricane would encompass the entire South Station project footprint and surrounding areas, and extend approximately 1,500 feet inland from Fort Point Channel. The area on the west side of the Fort Point Channel extending from MassDOT Vent Building #1 south to Broadway Bridge shows no surge information. Data for this area are unavailable because the base map used for the Massachusetts Hurricane Evacuation Study predates the development of that area and is representative of when this area was still a part of the channel and adjacent intertidal areas.

If the hurricane paths were from the south or southwest, the South Station footprint would not become inundated by Category 1 or 2 storms. Stronger hurricanes categorized as Category 3 and 4 would inundate much of the site, leaving only the northern portions of the USPS facility and headhouse above water. Figure 5-10 utilizes excerpts from the Hurricane Surge Inundation Map for Boston showing differences in storm surge based upon the direction of the hurricane paths. The image on the left shows a storm from a south or southwest direction The image on the right shows a storm from a southeast or east direction.

Layover Facility Sites

Widett Circle

Figure 5-9 presents modeled hurricane surge inundation at the Widett Circle layover facility site with existing conditions and with a storm tracking from the east or southeast. A Category 1 hurricane would completely flood the Widett Circle site project footprint, along with the majority of South Boston, Back Bay, and the Fort Point Channel area, thereby making it the most vulnerable to hurricane surges of all four SSX project sites. If the hurricane path were from the south or southwest, a Category 2 storm or stronger would completely inundate the site.

Beacon Park Yard

Figure 5-11 presents modeled hurricane inundation at the Beacon Park Yard layover facility site with existing conditions and with a storm tracking from the east or southeast. The Beacon Park Yard site is not at risk of flooding from a Category 1 or 2 hurricane, but is at risk of flooding from a Category 3 or 4 hurricane. A Category 3 hurricane would inundate the central third of the site boundary and a Category 4 hurricane would flood the entire site. A hurricane tracking from the south or southwest would not affect the Beacon Park layover facility site.

Readville - Yard 2

Hurricane surge inundation modeling indicates that the Readville – Yard 2 site is not at risk of surge damage resulting from any of the existing hurricane scenarios.

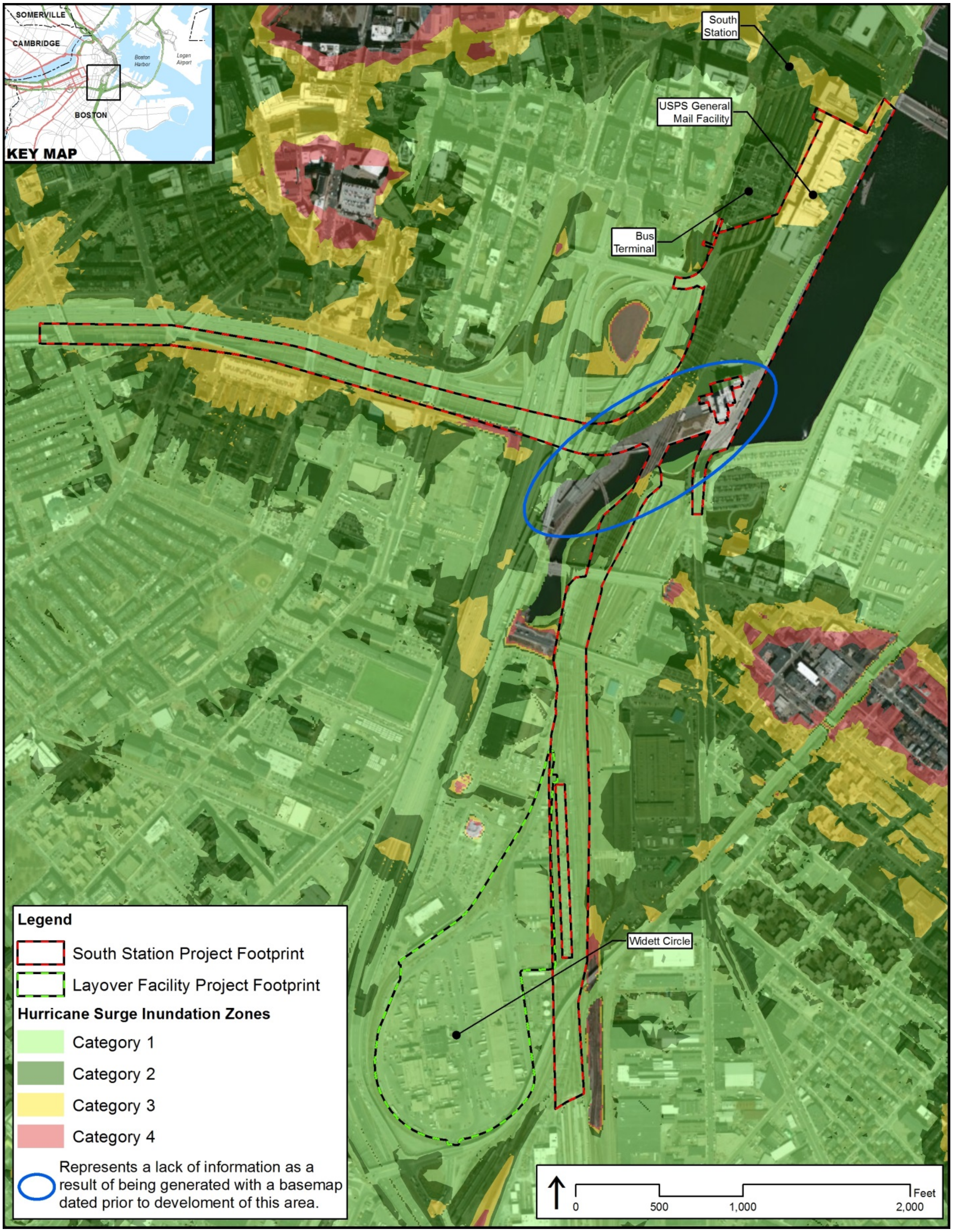
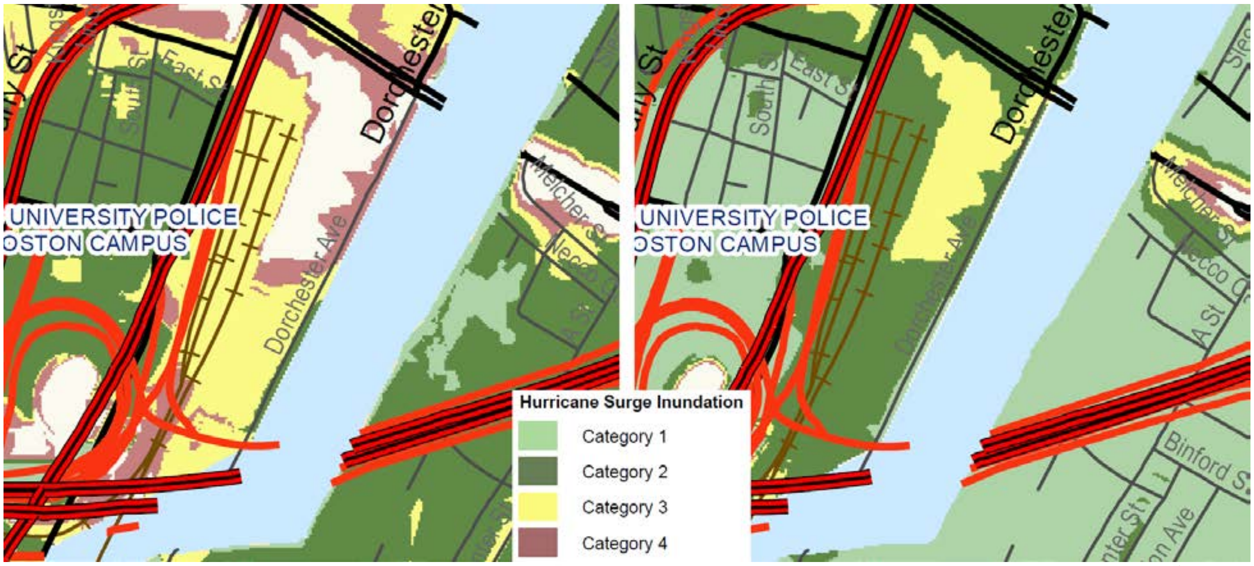


Figure 5-9—Hurricane Inundation Existing Conditions – South Station and Widett Circle Project Footprint (Storm path from E or SE)



Storm direction from South or Southwest Storm direction from Southeast or East

Figure 5-10—Existing Conditions of Hurricane Surge Inundation Based on Storm Intensity and Direction[12]

Future Hurricane Surge with Sea Level Rise

The Hurricane Surge Inundation Maps represent current sea level conditions only and do not account for future sea level rise. Hurricane surge elevations from the Massachusetts Hurricane Evacuation Study are not published, and as a result predicted future surge conditions due to sea level rise are qualitative in this DEIR study. Because elevations are not available for flooding associated with different hurricane intensities, effects due to a projected two-foot sea level rise are estimated. With a rise in sea level, hurricane surge inundation scenarios are expected to increase to some proportionate elevation and horizontal extent, similar to the anticipated effects of projected sea level rise upon 1% annual chance flood events. It is anticipated that with sea level rise, storms tracking from the south or southwest would have similar surge effects as current sea level conditions and hurricanes tracking from the southeast or east.

South Station Site

As sea level rises, hurricane surge inundation scenarios at South Station are anticipated to worsen. It is anticipated that under a worst case scenario, with a storm tracking from the east or southeast, the South Station site could be substantially inundated by a Category 1 hurricane surge, and the site could be completely inundated by a Category 2 hurricane surge. If a hurricane track were to be from the south or southwest, the South Station site might not be inundated until a Category 2 or stronger storm.

Layover Facility Sites

Widett Circle

In existing conditions, the Widett Circle layover facility site would be completely inundated by surge from a Category 1 hurricane with a storm tracking from the east or southeast. Adding a rise in sea level

[12] Massachusetts Emergency Management Agency. *Hurricane Inundation Maps*. http://www.mass.gov/eopss/agencies/mema/hurricane-inundation-maps.html.

would likely increase the depth of flooding at the site. If a hurricane track were to be from the south or southwest, in combination with the sea level rise, it is likely that the effects would be the same as existing sea level conditions and a Category 1 hurricane tracking from east.

Beacon Park Yard

As sea levels rise, hurricane surge inundation scenarios at the Beacon Park Yard layover facility site are anticipated to worsen. It is anticipated that in a scenario with a storm tracking from the east or southeast, in combination with the sea level rise, the site may be at risk of flooding from a Category 1 or 2 hurricane, compared to only Category 3 or stronger with existing sea level conditions. It is reasonable to assume that a Category 2 hurricane would inundate the central third of the site and a Category 3 or stronger hurricane would flood the entire site. It is difficult to predict whether a hurricane tracking from the south or southwest would affect the Beacon Park layover facility site in a Category 1 or 2 scenario in combination with the two-foot sea level rise condition. This is due to the potentially mitigating features such as the downstream Charles River Dam and the elevation of the terrain surrounding the site.

Readville - Yard 2

At current conditions, Readville – Yard 2 is not at risk of inundation due to surge from a hurricane of any intensity. Due to its elevation and series of downstream dams, the site is not anticipated to be affected by surge from hurricane conditions with a two-foot sea level rise.

Figure 5-11—Hurricane Inundation Existing Conditions – Beacon Park Yard Project Footprint (Storm path from E or SE)

Table 5-2—Risks and Mitigation Strategies Associated with Hurricane Surge and Sea Level Rise

		Mitigation Strategies													
Identified Risks	Severity ↓	Incorporate repair and maintenance procedures of underground systems in design and construction.	Elevating power/HVAC sources.	Relocating critical systems to higher levels.	Design infrastructure and critical systems to accommodate seawater flooding.	Water-proofing rail equipment.	Water-proofing subsurface site elements.	Pumping systems to support control gate/door areas.	Pumping systems to accommodate storm water drainage.	Use corrosion protection elements and materials for underground structures.	Floodwater control gates/doors for temporary flood isolation.	Upgrade substructure design for high groundwater and storm loading cases.	Underground structure soil erosion and piping protection materials and methods.	Floodwater control dike surrounding site.	Raising base level for the site.
		Cost →													
Tracks submersion causing restricted train access.			✓	✓	✓	✓	✓				✓			✓	✓
Site inundation caused by reduced flow capacity.		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Soil erosion and substructure undermining due to storm flooding.		✓			✓		✓	✓	✓		✓	✓	✓	✓	✓
Uplift forces on foundations due to rising groundwater.		✓					✓					✓	✓	✓	✓
Weakening of the subsurface soils and displacement of underground structures.		✓			✓		✓					✓	✓	✓	✓
Seawater intrusion causing concrete/steel corrosion.		✓			✓		✓			✓		✓	✓	✓	✓
Drainage becomes less efficient or dysfunctional.					✓	✓	✓	✓	✓		✓			✓	✓
Back flowing water through floor drains, conduits, other sources.		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Track immersion, switches, signals, communications.			✓	✓	✓	✓	✓	✓	✓		✓			✓	✓
Lateral pressure and hydro-dynamic forces on underground retaining walls due to rising groundwater.		✓					✓					✓	✓	✓	✓
Direct inundation by above ground connections to sea water.		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Flooding of below ground level infrastructure.		✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
Safety – electrical hazards, water depths, system failures.		✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓
Egress/access affected during evacuation.		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Inundation of structure and utilities through below-ground utility ducts, drainage systems etc.		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Subway system innundation through surface openings.		✓	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓
At-grade roadway and sidewalk flooding.			✓	✓	✓		✓	✓	✓		✓			✓	✓