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massDOT
Massachusetts Department of Transportation

DESIGN DIRECTIVE

To: Distribution

From: Erik Stoothoff, P.E.
Chief Engineer

Date: November 18, 2019

RE: MBTA Flood Resiliency Design Directive

This design directive is intended to provide guidance on the MBTA's design approach, preference, and requirements for protecting its assets and operations from the impacts of flooding.

OBJECTIVE

Design for all new construction, repair, or replacement projects shall include a flood resiliency design approach that is consistent with MBTA's priorities to:

- Minimize risk to MBTA assets from flooding events;
- Maximize resiliency[1] of the systems;
- Minimize downtime and prevent disruptions to the traveling public;
- Protect the safety of system users, workers, and the surrounding environment from risks associated with flood hazards.

Designing for flood protection is critical to the functionality and longevity of MBTA systems, including station platforms, parking areas, tracks, maintenance facilities, utilities, and all other supporting infrastructure. As such, design shall prioritize function and ease of maintenance over time. Flood resiliency should be a coordinated effort with MBTA departments as well as regulatory and representative agencies and municipalities.

REGULATORY CONTEXT

Design will conform to the standards of MBTA and MassDOT regulations and criteria. The MBTA is not required to comply with local zoning or local bylaws and regulations in accordance with Massachusetts General Law (M.G.L.) Chapter 161A Section 3(i), the MBTA. However, the designer shall review the local requirements for comparison to MBTA standards. Projects shall be designed in a way to satisfy the regulatory context of

[1] Resiliency is generally defined, for the purposes of this Directive, as the ability of a system or asset to withstand or recover from an extreme weather event.

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the proposed work, while focusing on the Design Principles and Criteria noted herein. Designs shall incorporate the MBTA's current policies and directives regarding drainage design and sea level rise and resiliency as described herein.

DESIGN HIERARCHY

Design shall adhere to the following hierarchy:

1. Protect system users and employees from flood hazards
2. Protect the MBTA's critical infrastructure from flood hazards (both coastal and inland)
3. Protect the environment and downstream resources[2]
4. Maximize the simplicity of designed systems, emphasizing ease of use and ease of maintenance
5. Create a resilient and sustainable design that withstands decades of use and maintenance

For new facilities or the redevelopment of project elements, preference shall be given for sites and solutions that avoid flood risk. If avoidance is not feasible, the project should be designed to protect assets from flooding. See recommendations on pages 6 and 7. Waivers may be requested when a designer cannot reasonably meet these conditions. Design waivers shall require the designers to demonstrate an operational recovery within a necessary number of hours based on the criticality of the asset to system operations.

CODES, STANDARDS, REFERENCES, AND GUIDELINES

The latest edition, including revisions, amendment and supplements, of the following publications:

- MBTA Book of Standard Trackwork Plans
- MBTA Book of Standard Plans – Track and Roadway
- MBTA Railroad Operations Commuter Rail Design Standards Manual for Track and Roadway
- MBTA Manual of Guidelines and Standards
- MBTA Light Rail and Heavy Rail Standards
- MBTA Drainage Design Directive
- MBTA Strategic Plan
- American Society of Civil Engineers (ASCE), *Flood Resistant Design and Construction*, ASCE 24
- Resilient MA - Climate Change Clearinghouse for the Commonwealth, http://resilientma.org
- Executive Order No. 569 – *Establishing an Integrated Climate Change Strategy for the Commonwealth*
- Massachusetts State Hazard Mitigation and Climate Adaptation Plan
- Massachusetts Bay Transportation Authority (MBTA) Vulnerability Assessment Report

[2] Including, but not limited to protection from hazardous waste, stormwater sewage overflow, hydrocarbons (gasoline/fuel/oil), and other toxic substances

DESIGN PRINCIPLES

The following guidelines establish the preferred approach to meet the Design Hierarchy outlined above. As noted in the Design Hierarchy, the first priority shall be to avoid flood risks wherever possible through siting decisions. When siting within an area of potential flood cannot be avoided, the project shall elevate assets above the potential flood elevation (i.e., Design Flood Elevation as described in pages 4 and 5). When neither avoidance nor elevation change measures are feasible, the asset shall be protected from flood risk through dry or wet floodproofing and/or appropriate material selection. Finally, if an asset cannot be protected through any of these means, the project shall be designed for operational recovery within a set number of hours commensurate with the criticality of that asset to system operation and/or human safety.

To design for flood resiliency within this hierarchy, the designer shall complete the following steps and include for MBTA review no later than the conceptual design phase of project development:

- Assess historic trends and current weather conditions at the site to determine if there is a history of flooding or storm damage.
- Identify exposure to and sensitivity to flood risks, including coastal flooding, inland flooding, or both, based on location, based on the coastal and inland assessment guidance that follows.

Prior to beginning the preliminary engineering phase of design development, the designer shall complete the following steps:

- Assess the criticality of project assets and operational components, including the acceptable level of operational downtime. This should be determined in cooperation with MBTA operations staff.
- Identify resiliency measures and industry best practices to minimize vulnerabilities and operational downtime, including provision of recovery procedures for potential operational failures.
- Determine the intended lifespan of the project and its components – the intended lifespan should be used to determine the climate projection time horizon (2030, 2050, 2070, 2100).

For a ***Coastal Flooding Assessment***, designers shall:

- Coastal Flooding is defined as flood events whose behavior is affected by astronomical tides.
- Review of the most up-to-date FEMA Flood Insurance Rate Map (FIRM) panels to identify existing flood zones and current base flood elevation (BFE) at the location and adjacent to the asset. When completing this review the designer shall consider how the flood zones may change with Sea Level Rise (SLR), as an asset may not be currently in a flood zone but will be in the future.
- Based on the intended lifespan of the asset, review the most current regional SLR projections on http://resilientma.org; use the high scenario estimates given. Elevation level should be commensurate with the criticality of the asset to the transportation network.

Determine Design Flood Elevation: DFE = BFE + SLR + Freeboard

Freeboard: Non-critical = 1 foot
Critical = 2 feet

There are multiple regional SLR projections for the Greater Boston area. The Northeast Climate Adaptation Science Center (NECASC) at the University of Massachusetts projections are mean SLR scenarios relative to the Boston Tide Station based on projections for the National Climate Assessment global scenarios. This analysis consisted of the probabilistic assessment of future relative SLR given two future atmospheric greenhouse gas concentration pathways: medium regional concentration pathway ("RCP") 4.5 and RCP 8.5. RCP 8.5 is the highest emissions scenario, which is consistent with the continuation of fossil-fuel intensive economic growth that has characterized the past two centuries. The NECASC projections are based on the following four scenarios:

1. **Intermediate:** 17% probability of being exceeded given a high emissions pathway
2. **Intermediate – High**: 5% probability of being exceeded given a high emissions pathway
3. **High:** 0.5% probability of being exceeded given a high emissions pathway
4. **Extreme (Maximum Physically Possible):** 0.01% probability of being exceeded given a high emissions pathway.

Table 1 below shows projected SLR projections at the Boston Tide Station in the years 2030, 2050, 2070, and 2100 under the four scenarios described above for the RCP 8.5 emissions scenario.

Table 1: NECASC Relative SLR Projections for Boston, MA (feet above MSL 2018)

Scenario	**2030**	**2050**	**2070**	**2100**
Intermediate (17% probability of being exceeded)	0.7	1.4	2.3	4.0
Intermediate – High (5% probability of being exceeded)	0.8	1.7	2.9	5.0
High (0.5% probability of being exceeded)	1.2	2.4	4.2	7.6
Extreme (0.01% probability of being exceeded: maximum physically plausible)	1.4	3.1	5.4	10.2

These projections are the current and most up-to-date regional SLR projections for the Massachusetts coastline as of the date of this directive. The designer should also check http://resilientma.org to determine if revised projections are available.

For an ***<u>Inland Flooding Assessment</u>***, designers shall:

- Inland Flooding is defined as flood events whose behavior is not affected by astronomical tides.
- Review FEMA FIRM panels and FIS to identify existing flood zones and current flood elevations for the asset. Typically, the 10-, 50-, 100-, and 500-year elevations are available in populated areas.
- Based on the intended lifespan of the asset, review the most current regional precipitation projections on http://resilientma.org and determine the appropriate design storm frequency for the asset.
- Use future design storm precipitation depths to perform a local hydraulic model (*recommended*) or use the below table and estimate design flood frequency elevation (DFFE) from FIRM/FIS.

Table 2: Design Storm Frequency by Design Life

Current	< 25 years	25 - 50 years	> 50 Years
10-	10-	25-	25-
25-	50-	100-	200-
50-	100-	200-	500-
100-	200-	500-	1000-

Determine Design Flood Elevation: DFE = DFFE + Freeboard

Freeboard: Non-critical = 1 foot
Critical = 2 feet

FLOOD RESILIENCY DESIGN APPROACH

When avoidance of flood risk is not feasible, the preferred design approach is to elevate assets above the potential flood elevation. The project should be designed to elevate both critical and non-critical assets according to the coastal and inland flood design elevations described above. Critical assets should be designed for greater freeboard to further protect from flood risk.

For assets that cannot be elevated, design options include:

- Dry floodproofing, including permanent and temporary barrier deployment
- Wet floodproofing, including material selection that is resilient to flooding/wet conditions/salt water intrusion

Determination of which of the above approaches, or combination of approaches, to pursue should be made based on the criticality of the asset and feasibility of the design approach, as well as ability to recover from operational downtime.

Dry Floodproofing

Dry floodproofing uses design techniques that fully seal off a structure or equipment to any water intrusion. Such methods may include:

- Use of waterproof membranes
- Permanent sealants or coatings
- Use of flood-resistant doors or hatches
- Installation of backflow preventer valves
- Installation of interior drainage systems and sump pumps
- Sealing electrical conduits and other utilities
- Reinforcement of walls to resist hydrodynamic loads caused by flooding
- Flood protection measures on underground structures, such as vent grates (especially on street level), egresses, and air louvers.

Dry floodproofing may also utilize temporary or permanent barrier deployment, or watertight shields. If temporary barrier deployment is pursued, the project will need to consider maintenance requirements as well as ability to put in place operational procedures for sufficient warning time for deployment.

Wet Floodproofing

Floodproofing refers to design actions that reduce or eliminate flood damage to structures or equipment. More specifically, wet floodproofing uses design strategies, including selection of flood damage resistant materials, that will allow for flooding to occur, but with minimal or no operational downtime and without short- or long-term damage to the asset. Such methods may include:

- Using flood damage-resistant materials, including materials resistant to salt water intrusion/corrosion
- Elevating critical components of an asset while allowing non-critical or non-vulnerable components to flood temporarily
- Installing redundant electrical, mechanical, or telecommunications systems so that exposed systems can be shut down temporarily
- Installing permanent or temporary pumps to remove excess water
- Securing components and equipment to avoid buoyant movement during flooding