DRAFT

Massachusetts Bay Transportation Authority:

Orient Heights Maintenance and Storage Facilities

Current and Future Vulnerabilities to Climate Stressors

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AECOM
1 Federal Street
Boston
MA 02110

Charles D. Baker, Governor
Karyn E. Polito, Lieutenant Governor
Stephanie Pollack, MassDOT Secretary & CEO
Luis Manuel Ramirez, General Manager & CEO

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Abstract

The purpose of this vulnerability assessment is to study the impact of rising sea level and storm surge on the existing assets at Orient Heights Maintenance and Storage Facility. After a detailed study, AECOM has recommended mitigation measures with maps that display inundation probability and potential depth for 2030 and 2070. The scope of this high level climate change vulnerability assessment (CCVA) is to assess the exposure, sensitivities, and impact on existing assets of the Blue Line Orient Heights facility to sea-level rise and storm surge events.

This report only focuses on sea level rise and storm water surge and doesn't include weather stressors such as heat, heavy precipitation, inland flooding, snow, ice and wind.

Introduction

The Massachusetts Bay Transportation Authority's (MBTA) goal is to identify vulnerabilities within its system in order to minimize service disruptions and thereby, ensure reliable transportation to support their customers, boost the regional economy, and protect taxpayer investments. Transportation systems are sensitive to short-term intense weather events, as well as to long-term incremental changes in climate (Rowan et al. 2013; FTA 2011). The climate-related stressors of concern for transportation professionals include extreme heat events, heavy precipitation, storm surge, and sea-level rise. In order to ensure that transportation systems are resilient when exposed to such stressors, decision-makers from all levels of government are conducting vulnerability assessments to determine which transportation assets and services are the most susceptible to climate and weather stressors.

As per the MBTA Blue Line climate change vulnerability assessment report, it is predicted that the Boston area will experience sea-level rise of three to seven feet (not including the impacts of storm surge events) and as many as 90 extreme heat (> 90°F) days each year by the end of this century (Climate Ready Boston 2016). Intense rain events are also trending upward. The anticipated 25-year, 48-hour storm of the 2030s and the 2070s is 8.6 inches and 9.8 inches, respectively. This represents an increase of 22-40% over the baseline of seven inches. Similarly, the anticipated 100-year, 48-hour storm of the 2030s and the 2070s is 10.2 inches and 11.7 inches, respectively. This represents an increase of 32-57% over the baseline of ten inches.

The MBTA is committed to providing its customers safe, accessible, cost-effective, resilient, sustainable, dynamic, and responsive service.

The Orient Heights Car Yard and Facility is a critical component in that system. It is the single central maintenance facility in support of the MBTA Blue Line Heavy Rail System. It is centrally located along the Blue Line Service route and is adjacent to the Orient Heights Transit Station in East Boston MA Figure 1.

The Orient Heights Maintenance and Storage Facility is vulnerable to climate stressors, mainly in the form of water, but wind also plays a role. Building on the work of the Blue Line Vulnerability Assessment and the MassDOT Vulnerability Assessment for the Central Artery, AECOM conducted a detailed assessment of the Orient Heights Maintenance Facility looking at factors such as heavy precipitation, inland flooding, sea level rise and storm surge and wind.

However the Maintenance Facility itself benefits from the fact that, although it will be flooded in the 2070 storm surge scenarios, it can also recover quickly once the water recedes. This quick recovery can be ensured through the hardening of identified critical components that are currently vulnerable. There are some critical vulnerabilities relative to power supply, operations in the pits within the building and the office trailer yard.

The following report includes maps of the flood elevations along with plans delineating the extent of the 2030 and 2070 flood plain on the facility, identification of assets within the mapped scenarios and an inventory of electrical equipment, maintenance equipment and facilities that are susceptible to extremes of water, wind and heat.

AECOM has identified and made recommendations on the most critical improvements needed to improve the resilience of this important facility. This vulnerability assessment involved the evaluation of the natural hazards identified in the table 1, including how those hazards are likely to evolve as a result of climate change. The natural hazards are organized by primary climate drivers, and representative related climate change impacts are also provided.

Primary Climate Driver	Natural Hazard	Related Climate Change Impacts
	Coastal Flooding (including daily tidal flooding from sea level rise)	Inundation of coastal and facility footprint
Sea Level Rise and Storm Surge	2030 100 year and 500 year probability	
	2070 100 year and 500 year probability	

Table 1: Natural hazards evaluated

The initial assessment plan involved checking the facility for only the conditions brought about by the 2070 design storm surge and flood, 100 and 500 year occurrence interval. The flood inundation mapping was obtained from the MassDOT Vulnerability Assessment which encompasses Boston Harbor and the immediate Coastal area.

Almost immediately it was recognized that under the 2070 projected sea level rise and storm surge that the entire OH Car yard facility is inundated by several feet of water, including water intrusion into the buildings themselves of several feet in depth. Accordingly, to aid in setting priorities we added an assessment of the 2030 sea level rise and storm surge scenario as a comparison.

The OH Car Yard is located immediately adjacent to Boston Harbor and sits up against the Belle Isle Marsh. There is currently no barrier between the footprint of the existing facility and those two potential sources of inundation. The topography of the site is fairly flat and level, an exception is a low area in the Northwest quadrant of the site that is currently the location of several temporary office trailers and serves as an outdoor storage area for bulk items, cable spools, spare cabinets, and miscellaneous utility structures.

The facility consists of a maintenance building including a train wash bay and paint booths. There are also administrative offices, parts storage and outdoor layover tracks for the trains. The maintenance building was renovated in 2002.

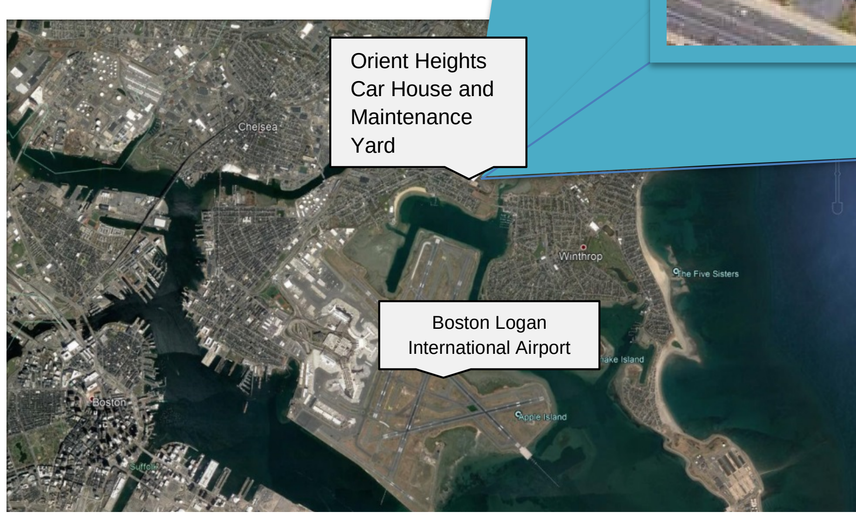

Figure 1: Orient Heights Car House and Maintenance Yard

Figure 2: Orient Heights Car House and Maintenance Yard location

Climate Change Exposure and Sensitivity

With reference to the MBTA report (climate change vulnerability assessment for the Blue Line), the vulnerability of a system, service, or asset to climate change is a function of exposure, sensitivity, and adaptive capacity (FHWA 2012). The conceptual model for determining vulnerability is illustrated in Figure 3.

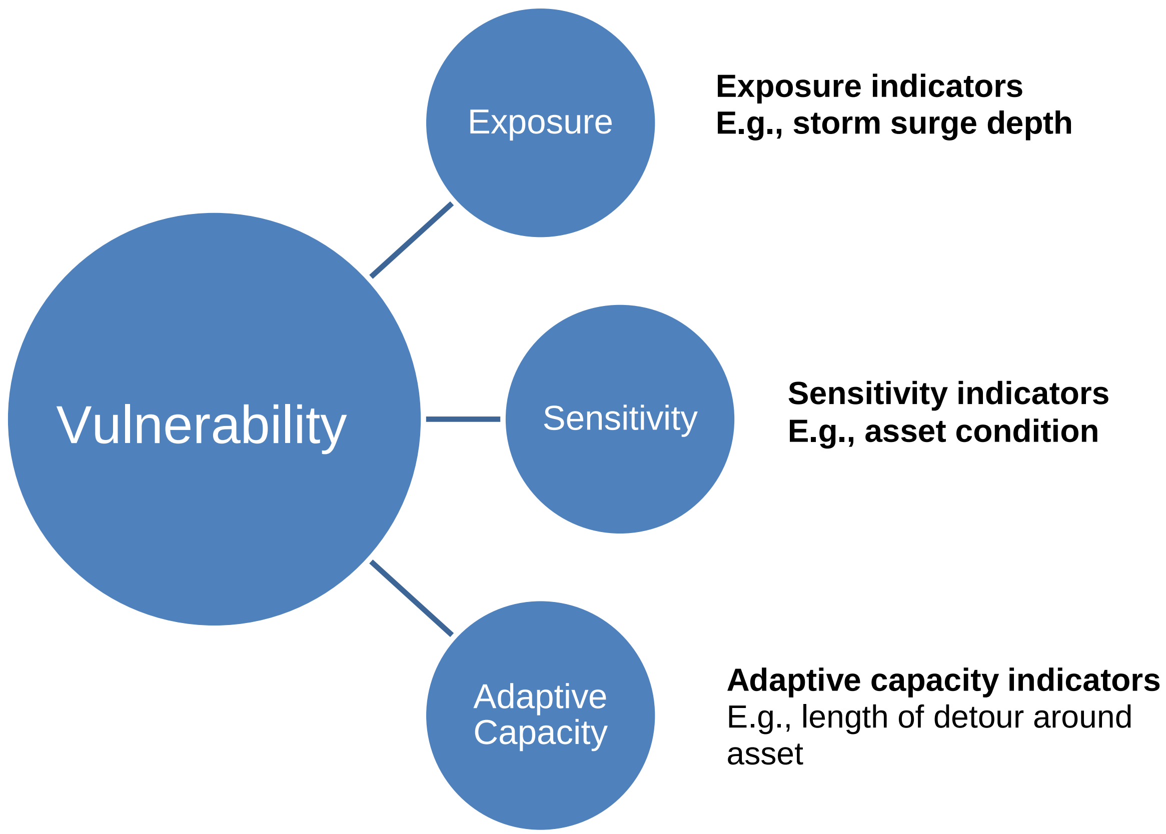

Figure 3: Indicators of Climate Change Vulnerability (FHWA 2014)

- **Exposure** is the degree to which a system, service, or asset is experiencing, or is projected to experience, weather and climate stressors, such as extreme temperatures, intense precipitation, sea-level rise, storm surge, wind, snow, and ice (e.g., will a particular passenger station experience storm surge?).
- **Sensitivity** refers to the impact on a system, service, or asset when exposed to weather and climate stressors (e.g., if a passenger station is exposed to storm surge, how will its ability to function be affected?).
- **Adaptive Capacity** is the ability of a system, service, or asset to adjust to impacts from weather and climate stressors (e.g., how will a passenger station cope with a storm surge event?).

As per the climate stressors analyzed in the MBTA climate change vulnerability assessment, the sensitivities of transportation assets to sea-level rise and storm surge would likely be the most consequential for the Orient Heights Car Yard.

Unlike extreme heat events, the potential exposure of each asset to sea-level rise and storm surge varies by location and by timeframe (current, 2030s, or 2070s). AECOM has estimated exposure for each asset based on the Boston Harbor-Flood Risk Model (BH-FRM) (MassDOT 2015) – refer to table 2 for further details. Per the guidance provided by the BH-FRM maps, the exposure potential for a 0.1 percent storm surge event (i.e., a storm like 2012's Superstorm Sandy at high tide) for the Orient Heights Maintenance & Storage Facility. Maps displaying inundation probability and potential depth for 2030 and 2070 are provided in the next page.

This section presents the results of the evaluation of the OH Car Yard's exposure and sensitivity to natural hazards and climate change. Detail is provided for the critical assets and functions, when possible. For future risk, the original scope had the evaluation focus on the 2070 planning horizon only for its assessment of exposure and sensitivity to future conditions. Once the information from the MassDOT Vulnerability Assessment was plotted on the existing topography of the OH Car Yard it was readily apparent that the entire facility would be inundated under the 2070 flooding scenario for both the 100 and 500 year intervals, Figure 2. At the year 2070 predicted 100 year recurrence the depth of water inside the Maintenance Facility building ranged between 2 to 3 feet above the floor. Outside near to the building depths ranged from 3 to 4 feet and in some areas of the Car Yard, for example, the location of the Office Trailers and outdoor storage, even greater depths were noted.

It is apparent that during the year 2070 predicted storm event, the facility could not continue to function. Therefore, the focus of this evaluation turned to identifying those key assets that would inhibit the quick recovery of the facility once the flood had receded. These assets; Life Safety, Power and Security are discussed further in Section 3 of this report.

For prioritization purposes, the 2030 predicted storms were also evaluated. Flood surge elevations were again obtained from the MassDOT Vulnerability Assessment. Elevations of storm surge, for both the 100 year recurrence and 500 year recurrence level, were plotted onto existing topographic information available for the OH Car Yard.

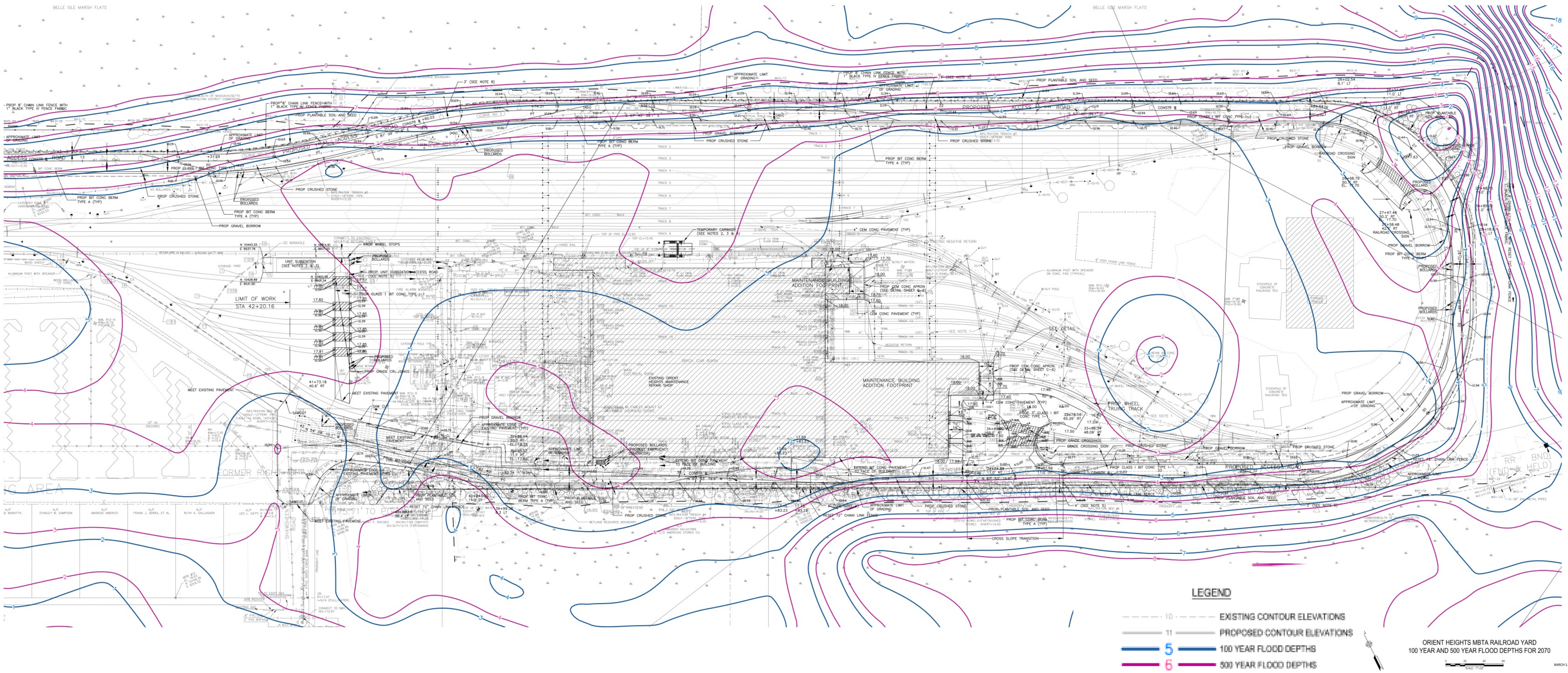

Figure 4: 2070 Inundation Depths 100 Year and 500 Year Recurrence Interval

During the 2030 predicted storms the inundation depths were less, and for the most part, did not reach to the Maintenance Buildings. For both 100 and 500 year predicted recurrence frequency, flood waters still did encroach onto the OH Car Yard footprint, however flooding did reach some key components as well as the Maintenance Trailers and outdoor storage.

Overall, the analysis found that, with some investment, the Facility could function in a limited capacity during the 2030 storm scenario.

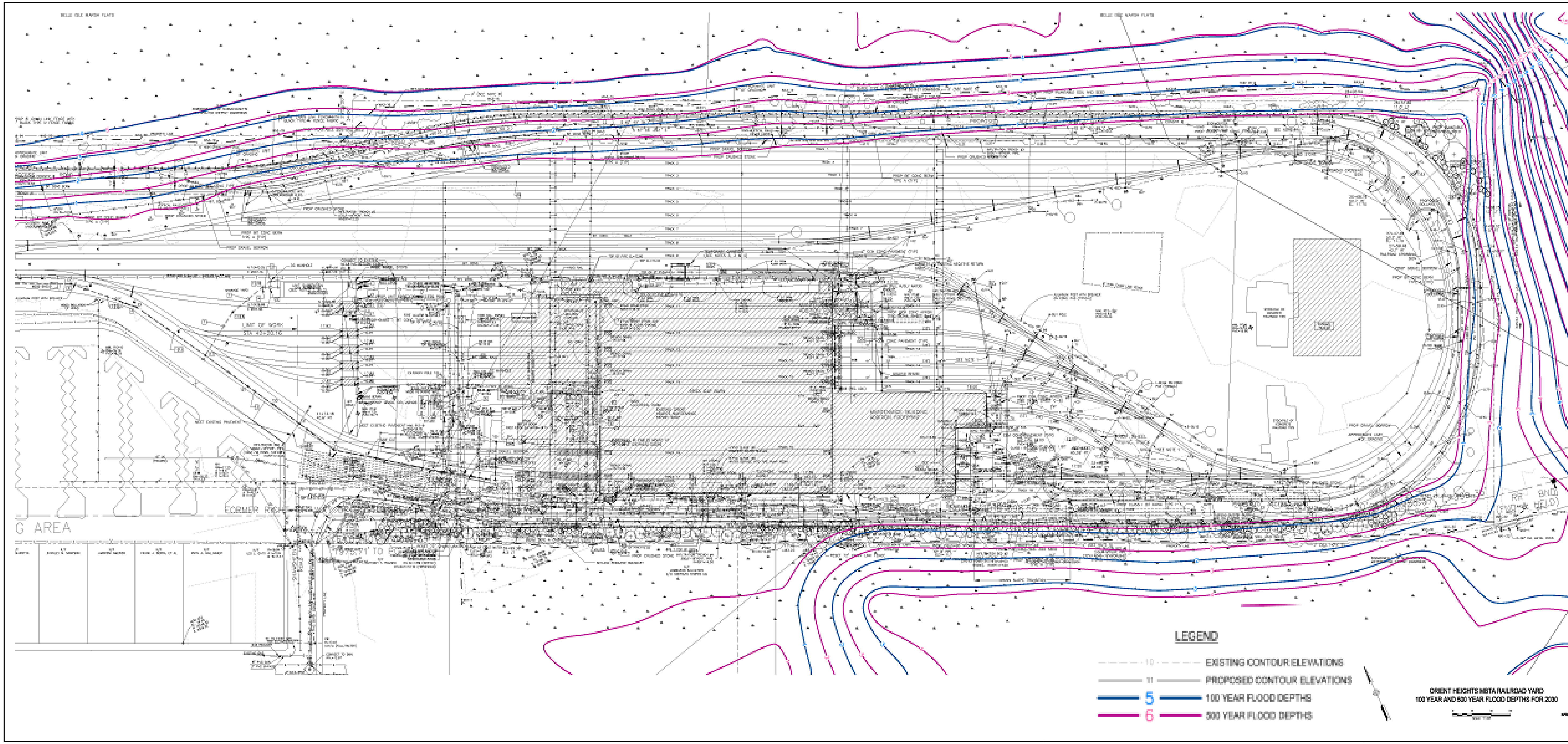

Figure 5: 2030 Inundation Depths 100 Year and 500 Year Recurrence Interval

Near Term and Long Term Study

The study shows:

- Inundation of the facility, damaging or destroying its contents such as records and electrical equipment. Exposure to saltwater would destroy sophisticated electronic equipment, in particular the wheel truing machine.
- Inundation can cause rail sensor failure, as well as other electrical failures (switches, gates, signals). There are also potential corrosive damages from salt. For example, metal and electrical components exposed to salt water from Hurricane Sandy are experiencing accelerated corrosion. MTA has seen long term deterioration of small gauge electrical connections (MTA, 2017).
- Subsurface ventilation systems could be inundated in a flooding event, with the possibility of corrosion if exposed to salt water.
- In flooding events, catenary poles may be damaged by debris carried in the water. Additionally, moving water may damage earthen supports for poles. If any catenary lines are exposed to saltwater, they may experience corrosion.
- Inaccessibility of maintenance facilities due to flooding can shut down operations and maintenance activities.

Impact on Existing Assets

With the focus on an expedited recovery of the OH Car Yard post storm event, the evaluation team examined those assets that would be critical to returning the facility back to full functionality, as quickly as possible.

It must be noted that during the evaluation it was observed that within the facility there was a significant amount of materials stored on the floor, some on pallets and other materials directly on the floor. One key observation was the number of Traction motors stored on the floor. In the event of a predicted event these materials would have to be moved to preserve them for future use. Providing a storage system that would elevate these materials a minimum of 4 feet above the finished floor would eliminate the requirement of moving all of these materials at the last minute in the face of a predicted major storm.

The evaluation team focused on Power, Security and Life Safety assets, determining that these assets held the key to an expedited recovery. These assets are listed in Table 1, along with an estimated level of inundation during both the 2070 and 2030 predicted 100 year storm event. For the purpose of this evaluation, the predicted flood levels as a result of the 500 year recurrence events were considered inconsequential to the impact evaluation.

AECOM reviewed the current and projected exposure, sensitivity, and impact of Orient Heights Blue Line assets to sea-level rise and storm surge. To summarize those detailed analyses, Table 2, provides a qualitative overview of the relative “level of concern” for exposure and sensitivity of each of the MBTA’s Orient Heights assets, categorized as Medium (Green) and High (Red).

OH Car Yard Vulnerable Assets					
Asset	**Figure**	**Est. 2070 100 year depth**	**Est. 2030 100 year depth**	**Recommendation**	**Priority**
Security Control Cab. 1	21	3	0	Reset Cabinet, min. 4ft. above grade (a.g.)	**Medium**
Security Control Cab. 2	21	2	0	Reset Cabinet, min. 4ft. a.g.	**Medium**
Security Control Cab. 3	21	4-5	1-2	Reset Cabinet, min. 4ft. a.g.	**High**
Power Unit Substation	9	4	0	Reset Substation, min. 4ft. a.g.	**Medium**
Emergency Generator	24	3-4	0	Reset GenSet, min. 4ft. a.g.	**Medium**
Ext. 600 VDC Disconnects	22	1-2	0	Reset Disconnects, min. 4ft. a.g.	**Medium**
Int. Fire Protection Pump	17, 26	3	0	Reset fire pump, min. 4ft. above floor	**Medium**
Int. Fire Control Panel	16, 25	3	0	Reset Fire Control Panel, min. 4 ft. above floor	**Medium**
Int. Hoist Control Panel	28	3	0	Reset Hoist Control Panel, min. 4 ft. above floor	**Medium**
Int. Hoist MCC	23	3	0	Reset Hoist MCC, min. 4 ft. above floor	**Medium**
Int. Hoist Power Disconnect	19	3	0	Reset Hoist Disconnect, min. 4 ft. above floor	**Medium**
Int. 600 VDC Disconnects	27	3	0	Reset Int. 600VDC disc., min. 4 ft. above floor	**Medium**
Maintenance Trailers	12	5-6	2-3	Relocate Trailers or Replace with Perm. Structure	**High**
AC Power Feed Trailer Park	13	5-6	2-3	Relocate AC Power Feed Trailer Park	**High**
Wheel Truing Machine	18	4	2-3	Cannot be relocated, Provide Spare	**Medium**
Signal Bunglow	20	3	0	Reset Signal Bunglow, min. 4ft above grade	**Medium**
Security gates controller box	14	3	0	Reset box, min. 4ft. above grade	**Medium**
Hoist Break Panel	22	3	0	Reset Hoist Breaker Panel, min. 4 ft above floor	**Medium**

Table 2: Critical Assets

The ability of the Facility to recover and resume maintenance operations after the effects of the 2070 storm is directly related to the restoration of power and a determination that the buildings are safe to occupy.

Under the *2070* storm the unit power substation that powers the facility will be inundated with up to 4 feet of storm water, most probably rendering the electrical components useless and unable to be restored for the resumption of operations at the facility. Compounding that damage, the emergency backup power generator will also be inundated in the range of 3 plus feet and also be damaged beyond repair. Both primary and backup power sources will be rendered useless during the 100 year design event.

The perimeter security system and the control of the access gates will similarly be damaged by several feet of storm water, disabling perimeter security and likely disabling the control gates to enter the facility. In addition, the ability to isolate power both inside the building for facility, and traction power and on the exterior to control power to the outdoor catenary will be damaged beyond repair. The interior fire control and fire pump will be damaged, as well as the controls for all of the hoists within the building.

The wheel truing machine will be completely submerged and has to be assumed to be a total loss. Due to the nature of this piece of equipment in cannot be set at a higher elevation since it must rest below the vehicle. During the site visit and the interview with facility personnel it was reported that with the recent high storm levels this past winter storms of 2017-2018, some of the work pits, including the one with the wheel truing machine, experienced some flooding and the staff had to use emergency pumping to keep the water from damaging any equipment.

On the exterior, in addition to the critical electrical and security components already mentioned, the numerous temporary office trailers used by the maintenance departments were identified as a flooding hazard. Not only will the trailers and the power substations that serve the trailer complex be inundated by several feet of storm water, estimated upwards of 5 to 6 feet in depth, but these trailers will likely float during the storm surge and become floating debris that could cause consequential damage, such as blocking the tracks or access to the facility.

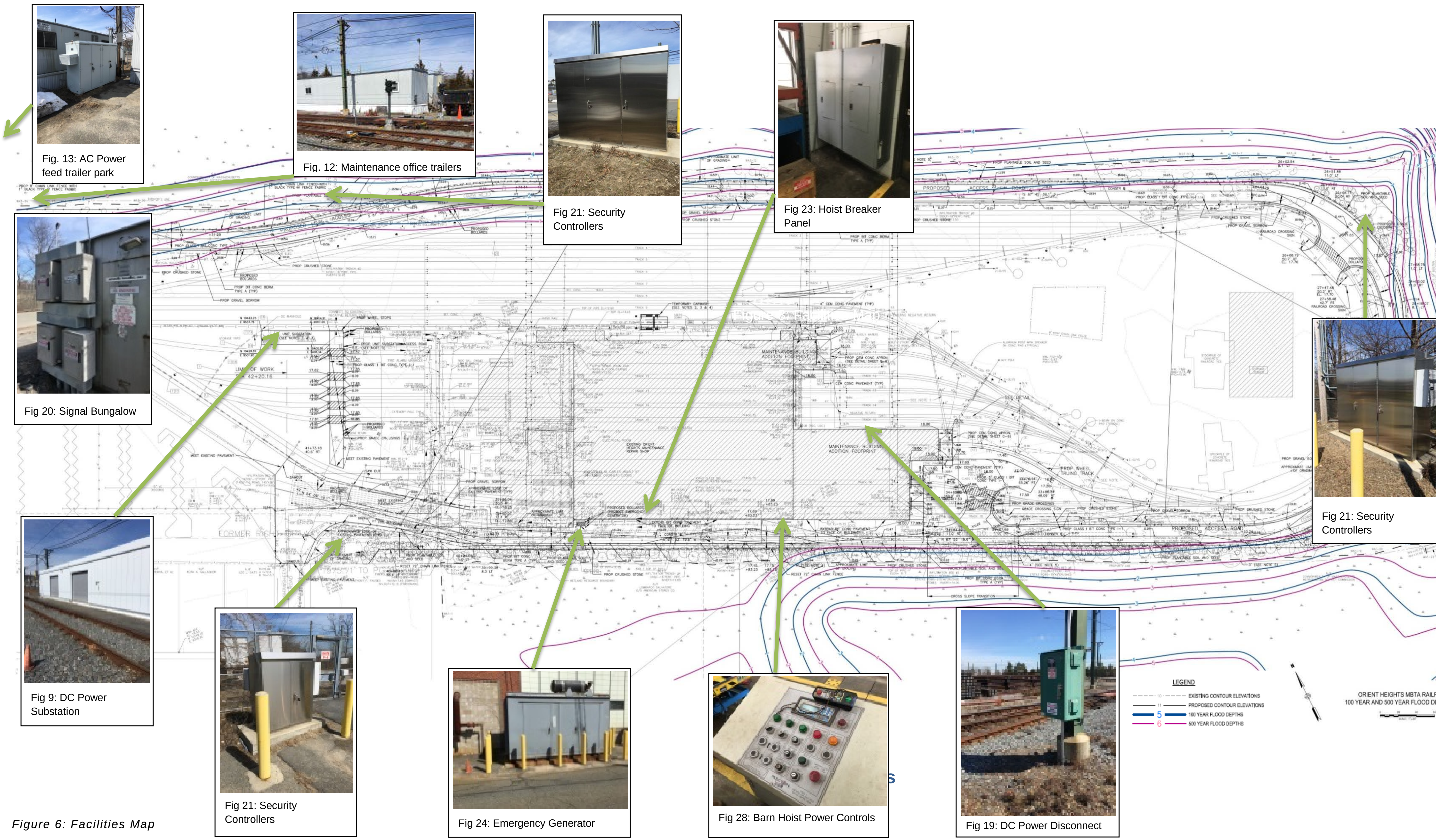

Figure 6: Facilities Map

Recommendations

Flood effects on essential systems and equipment can destroy a facility's ability to function and can prevent the facility from serving its community when it is needed most. The process of vulnerability identification represents a very important contribution to decrease and control the damage caused by natural hazard and to identify steps to be taken to minimize downtime at the facility and expedite the return to operations. The MBTA's Orient Heights Car Yard serves a critical function in supporting the operations of the Blue Line. It is also a fact that the OHCY is located adjacent to a coastal bank already today exposed to some impacts as a result of a storm surge. When the predictions of the impact of climate change and sea level rise are factored in, it is likely in the long term condition that the OHCY could be fully inundated by a storm surge to a level of several feet both outside and interior of the facility. In that extreme case and even in the near term if a significant tropical storm was to strike the Boston Harbor the only option would be to close down the facility, secure it and evacuate the staff and vehicles. Post storm the goal would be to have minimal clean up and to have the facility ready to return to full operation as soon as possible.

This vulnerability assessment has identified critical assets and services at the Blue Line Orient Heights facility that are vulnerable to weather- and climate-related stressors. If these assets were exposed to coastal flooding from a superstorm sandy-like storm, the consequences could be the inability of the Blue Line to function, requiring a large, medium-long term mobilization of alternative transit options in order to ensure that tens of thousands of East Boston and Revere residents are able to reach medical facilities, schools, and places of employment. The MBTA regards climate change resiliency as a living process, the approach to and goals for which will be iteratively updated as new information is available.

In case of 2070, long term 100 year flood event, most of the critical assets (ref. Table 2) such as security control cabin, power unit substation, emergency generator, external 600 VDC disconnects, int. fire protection pump, int. fire control panel, int. hoist control panel, int. hoist MCC, int. hoist power disconnect, int. 600 VDC disconnects, maintenance trailers, and wheel truing machine will be submerged approximately ranging from 1 to 6 feet and 0 to 3 feet respectively. These approximate levels are also mentioned in the appendix section figures 9-27.
In the near term, 2030 100 year flood event, several assets including Security control cabinets, OHCY site office trailers and portions of the outdoor yard will be impacted and that information is also contained in the referenced tables.

Short term and long term cost options have to be looked. Equipment damage and replacement needs to be considered as well. Water pumping can be a temporary resolution but the facility needs a permanent solutions. After conducting this comprehensive, system-wide vulnerability assessment, MBTA has suggested the following recommendations:

Elevating Equipment:
The most effective mitigation method is to elevate all essential equipment above the highest anticipated flood elevation or the elevation of the 0.2-percent-annual-chance flood recommended by FEMA, whichever is higher. When essential equipment is located below grade, elevating typically requires relocating the equipment to higher floors in the building. Unless space is already available, moving the equipment to a higher floor will displace other equipment, tenants, or functions. Facility owners may need to evaluate all available space, including the attic and, to determine whether a small elevated second floor addition would be an acceptable solution. When elevating equipment is not practical, dry flood proofing may be an option.

Dry Flood proofing:
Essential equipment can be protected with dry flood proofing methods. Dry flood proofing involves constructing flood barriers or shields around individual pieces of equipment or areas that contain essential equipment to prevent floodwaters from coming into contact with critical equipment. For dry flood proofing to be effective, the barrier must be high enough to protect equipment from floodwater, strong enough to resist flood forces, and sealed well enough to control leakage and infiltration. Dry flood proofing measures must also satisfy applicable codes and standards. For example, a dry flood proofed room created to protect a fuel tank will need mechanical ventilation to meet code requirements.

The on-site office trailers should be relocated to a raised berm above the predicted storm levels or replace them with permanent structures. Provide spare components for those equipment's, e.g. Wheel truing machine that cannot be relocated in the facility.

Vehicle protection:
Finally procedures should be established that identify locations along the Blue Line right of Way or within the tunnel network that can serve as an area of refuge for the rolling stock during an extreme storm event. Trains that currently lay over at OHCY will need to be stored elsewhere. It is assumed at some point during extreme weather for the safety of the public and staff that transit operations will temporarily halted.

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Appendix

1. Orient Heights Flood Analysis 2030 aerial photo
2. Orient Heights Flood Analysis 2070 aerial photo
3. Photos of affected equipment

Appendix 1: Orient Heights Flood Analysis 2030 Aerial Photo

Figure 7: Areal view: Flood Analysis 2030

Appendix 2: Orient Heights Flood Analysis 2070 Aerial Photo

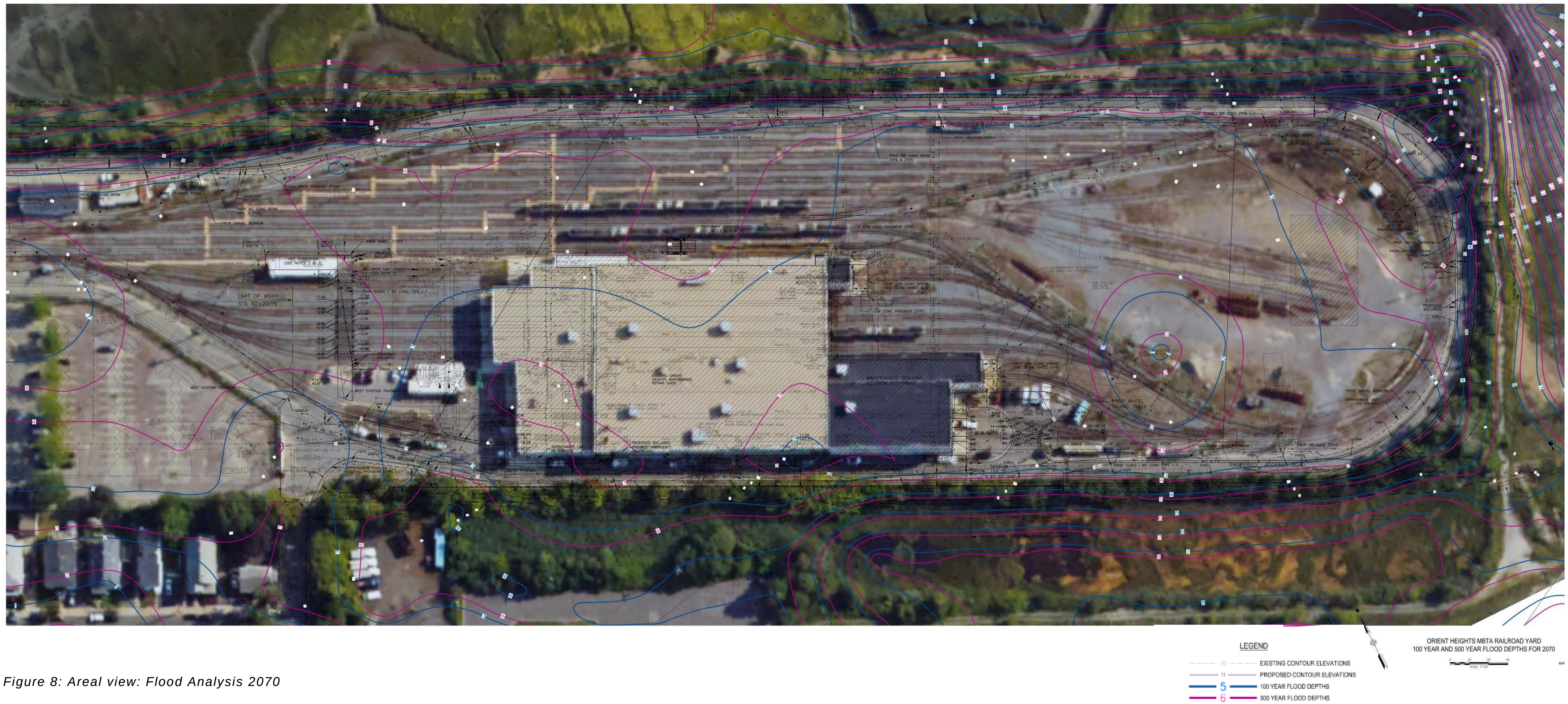

Figure 8: Areal view: Flood Analysis 2070

Appendix 3: Photos of Affected Equipment

Figure 9: OH Car Yard Substation

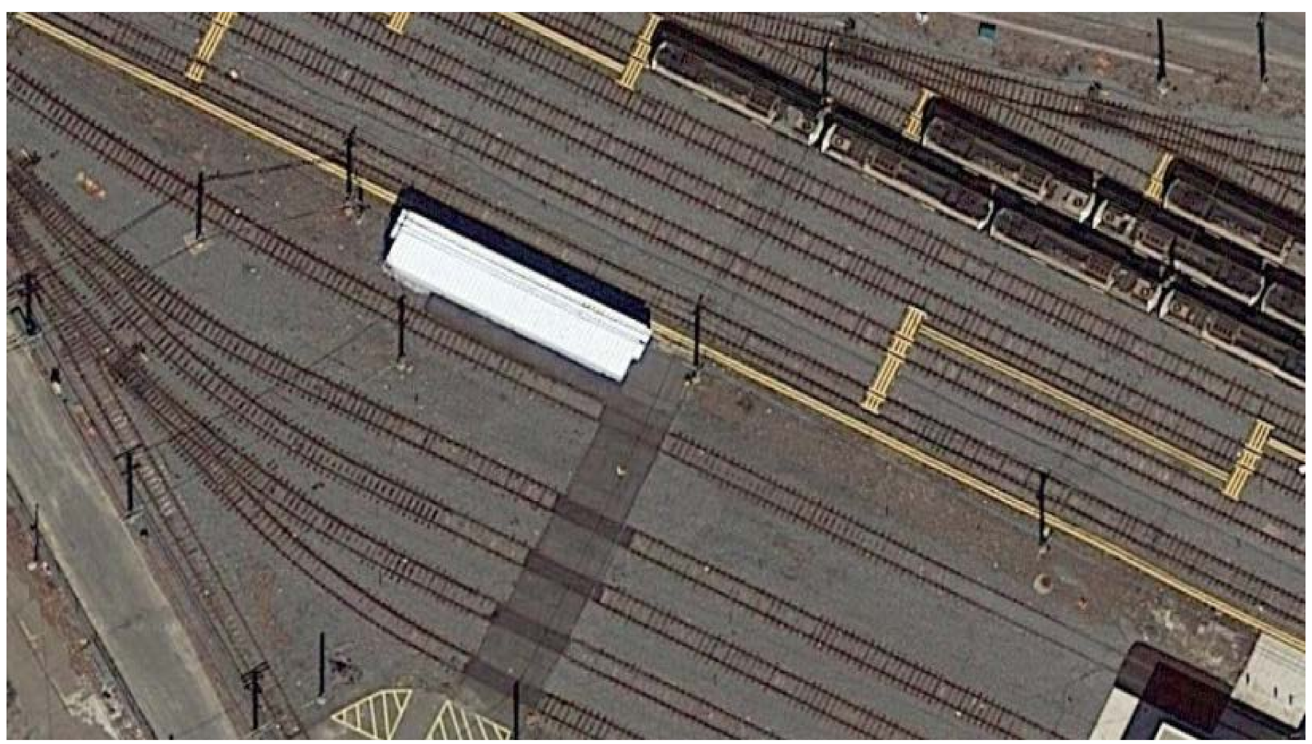

Figure 10: DC Power Substation

Figure 11: Blue Line Operations Signals and Power Switches entering the ROW

Figure 12: Maintenance Office Trailers

Figure 13: AC Power Feed Trailer Park

Legend
2070 100 year depth approx.
2030 100 year depth approx.

Figure 15: Oil Water Separator

Figure 16: Building Systems – Fire Pump Control Unit

Figure 14: Security gate controller box

Figure 20: Blue Line Operations Signal Bungalow

Figure 19: Blue Line Operations Yard Catenary Controller and Disconnect Switch

Figure 17: Building Systems – Barn Fire Pump

Figure 18: Maintenance Equipment – Wheel Truing Pit

Figure 21: Security Controllers (3)


Figure 24: Building Systems – Emergency Generator


Figure 23: Maintenance Equipment – Hoist Breaker Panel


Figure 22: Maintenance Equipment – DC pull box

Figure 27: Maintenance Equipment – DC Power Disconnect

Figure 25: Building Systems – Barn Fire Control Panel Pump

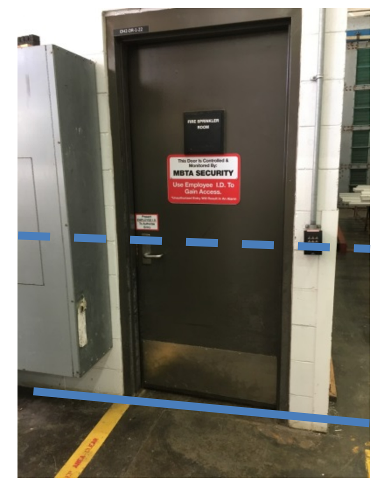

Figure 26: Building Systems – Fire Sprinkler Room


Figure 28: Maintenance Equipment – Barn Hoist Power/Controls