CONCEPTUAL ENGINEERING REPORT

REPLACEMENT OF NEW HAVEN LINE RAILROAD BRIDGE OVER THE NORWALK RIVER

NORWALK, CONNECTICUT
(WALK BRIDGE; Bridge No. 04288R; MP 41.5)

CTDOT Project No. 0301-0040

HNTB

CONNECTICUT DEPARTMENT OF TRANSPORTATION

DRAFT

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Table of Contents

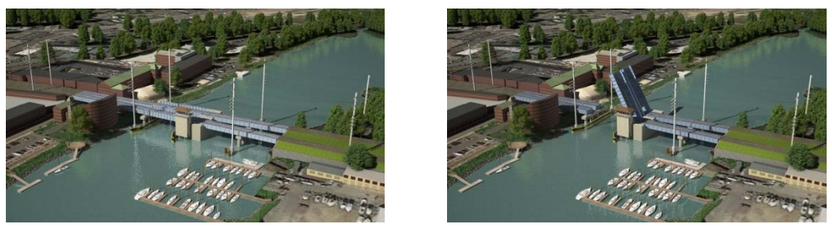
1 Executive Summary 1
2 Project Description and Background 3
3 Conceptual Engineering Scope of Work 4
4 Environmental Review Process 6
4.1 Federal Permits, Reviews, and Authorizations 6
4.1.1 National Environmental Policy Act (NEPA) Review 6
4.1.2 U.S. Coast Guard Bridge Permit 6
4.1.3 U.S. Army Corps of Engineers Permits 6
4.1.4 Section 106/Norwalk Historic Commission Reviews 6
4.1.5 Section 4(f) Assessment 6
4.1.6 Project/Site Review, Section 7 of the Endangered Species Act 6
4.1.7 Project/Site Review, Magnuson-Stevens Fishery Conservation and Management Act 6
4.1.8 Federal Aviation Administration, Notice of Proposed Construction or Alteration 7
4.2 State Permits and Authorizations 7
4.2.1 Connecticut Environmental Policy Act 7
4.2.2 Structures, Dredge and Fill and Tidal Wetlands Permit 7
4.2.3 Section 401 Water Quality Certificate 7
4.2.4 General Permit for Discharge of Stormwater and Dewatering Wastewaters from Constr. Activities 7
5 Description of Replacement Options 8
5.1 Development of Replacement Options 8
5.1.1 Background 8
5.2 Additional Considerations for Replacement Option Development 10
5.2.1 Resiliency 10
5.2.2 Railroad Operations 11
5.2.3 Waterway Users and Navigation Clearances 11
5.2.4 Construction Staging 14
5.3 Description of Bridge Replacement Options 17
5.3.1 Option 2G 17
5.3.2 Option 3A 19
5.3.3 Option 4S 20
5.3.4 Option 8A 22
5.3.5 Option 11C 24
5.4 Track Alignment Options 26
5.4.1 Existing Conditions 26
5.4.2 Proposed Alternatives 26
5.4.3 Option 3A Track Alignment 27
5.4.4 Option 8A/11C Track Alignment 27
5.4.5 Option 2G/4S Track Alignment 27
5.4.6 Run-around Alignment 27
5.4.7 Temporary Track 1 and Track 2 Connection 28
5.5 Catenary 28
5.6 High Tower Relocation 29
5.6.1 Conductor/Cable Layout 29
5.6.2 Clearance Requirements 29
5.6.3 High Tower Relocation Options 30
5.6.4 Construction Sequence - - VLS/Bascule Span (Option 1 and 2) 31
5.6.5 Construction Sequence - - VLS/Bascule Span (Option 3) 31
5.7 Signals and Communications 31
5.8 Additional Considerations for Replacement Options 31
5.8.1 Approach Spans 31
5.8.2 Bridge Mechanical 32
5.8.3 Bridge Electrical 33
5.8.4 Bridge Architectural Criteria 33
5.8.5 Geotechnical 33
5.8.6 Channel Hydraulics 35
5.8.7 Civil 36
5.8.8 Utilities 36
5.8.9 Vessel Collision Loading Pier Protection 39
5.8.10 Structural Steel Protective Coating Systems 40
5.8.11 Right-of-Way and Construction Access 40

6 Additional Considerations 41
6.1 Environmental Resources and Considerations 41
6.1.1 Tidal Wetlands 41
6.1.2 Intertidal Habitat 41
6.1.3 Benthic Resources 41
6.1.4 Essential Fish Habitat 41
6.1.5 Floodplain 41
6.1.6 Potential Unsuitable Sediment 41
6.1.7 Noise Sensitive Receptors 41
7 Construction Schedules, Construction Cost, Lifecycle Costs 42
7.1 Construction Schedules 42
7.2 Construction Costs and Overall Project Costs 43
7.3 Life Cycle Costs 43
8 Comparative Analysis of Replacement Alternatives – Discussion and Recommendation 45
8.1 Environmental Analysis 45
8.1.1 Overview of the Environmental Screening Process 45
8.1.2 Results of the Environmental Screening of Alternatives 46
8.1.3 Summary 47
9 Summary 48
9.1 Recommended Option 48
9.2 Cost 48
9.3 Schedule 48
9.4 Effects on Track and Channel Operations 48

1 Executive Summary

This Conceptual Engineering Report for the Walk Bridge Replacement has been prepared by HNTB Corporation in Hartford, CT for the Connecticut Department of Transportation (CTDOT). This report is based on a Conceptual Engineering Study of available information for the existing Walk Bridge and the data collected during this conceptual study phase. The primary purpose of the Conceptual Engineering Study is to identify and develop technically feasible schemes to replace the existing Walk Bridge with dual, double-track movable spans. The development of the feasible schemes is followed by a recommendation of a preferred replacement option. The conceptual engineering, in coordination with the NEPA process, has identified the type, size, and location of options for the new railroad bridge structures; track alignments and profiles; rail systems that will provide four tracks capacity within the project limits; and preliminary environmental impacts. Additionally, the Conceptual Engineering Study identified construction strategies and constructability issues with each replacement option that would maintain railroad operations to the greatest extent possible.

Initially, sixty-nine replacement options were initially identified for evaluation as outlined in Appendix A. This broad array of choices was initially screened and subsequently narrowed to a total of five that best met the goals of the project and include the following:

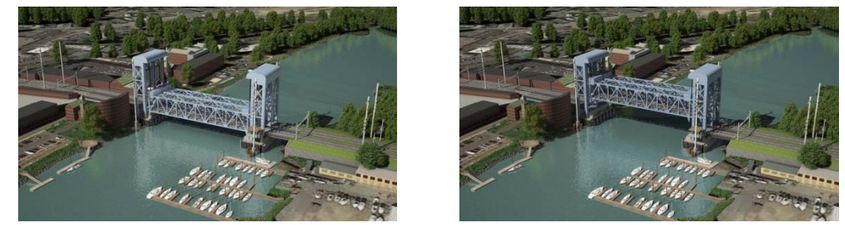


Option 2G – Through Girder Trunnion Bascule (120’ span)

Option 3A – Deck Girder Rolling Lift Bascule (120’ span)

Option 4S – Through Truss Rolling Lift Bascule (204’ span)

Option 8A – Through Truss Span Drive Vertical Lift (180’ span)



Option 11C – Through Truss Tower Driver Vertical Lift (250’ span)

Concept drawings of the 5 replacement options, including all features for bridge, track, OCS and high tower relocations were prepared, and the drawings for each project element are included in Appendices B through E. Suggested construction sequences were also developed to evaluate the constructability of each alternative and to assess the associated impacts to rail traffic and waterway users while the replacement bridge is implemented.

As part of the refinement of the 5 replacement options, construction schedules and construction cost estimates were prepared using the suggested construction sequence for each of the replacement option as the basis. The estimated construction duration for each replacement option is outlined below and includes the overall construction duration (through contractor demobilization) as well as the construction period necessary for the new movable spans to be placed into service. The estimated duration, in months, for each option is as follows:

Construction Duration	Replacement Option				
	2G	3A	4S	8A	11C
Total Construction Duration (months)	36	32	32	38	42
New Movable Spans in Service (months)	36	30	30	34	38

While developing the overall construction schedule, disruptions to rail service (as needed to construct the replacement bridge) were identified for each option and quantified below:

Rail Closure	Replacement Option (Duration of Rail Impacts)				
	2G	3A	4S	8A	11C
All Tracks Closed (hours)		24	24	24	24
Tracks 1 and 3 Closed (weeks)	14	30	16	27	40
Track 3 only Closed (weeks)			49		
Tracks 2 and 4 Closed (weeks)	67	44	16	43	44

Impacts to waterway users are classified by 3 unique distinctions - - a full channel closure in which no waterway traffic can transit through the bridge; a vertical restriction resulting from a temporary fixed structure placed over the waterway; and a horizontal restriction in which new pier placements block the navigation channel and restrict the free flow of vessels.

Channel Impacts	Replacement Option (During Channel Impacts)				
	2G	3A	4S	8A	11C
Channel Closed (days)	4	4	4	3	3
Vertical Restriction (weeks)	71	50	68	90	38
Horizontal Restriction (weeks)	65	50	4	12	16

Upon evaluating all project factors for bridge, track, catenary and high tower relocations, detailed cost estimates were developed for each replacement option. The estimated construction costs and total project costs are shown below.

OPTION	ESTIMATED BASE BID COST (2014)	ESTIMATED CONSTRUCTION COST (2018)	TOTAL CONSTRUCTION COSTS	TOTAL PROGRAM COSTS
OPTION 2G - - 120' Through Plate Girder Trunnion Bascule	$ 225,927,000	$ 254,283,000	$ 427,197,000	$ 462,713,000
OPTION 3A - - 120' Deck Plate Girder Rolling Bascule	$ 177,318,900	$ 199,574,900	$ 335,286,900	$ 364,236,900
OPTION 4S - - 204' Through Truss Rolling Bascule	$ 202,642,000	$ 228,076,000	$ 383,169,000	$ 415,540,000
OPTION 8A - - 180' Through Truss Vertical Lift Span (Span Drive)	$ 279,092,000	$ 314,121,000	$ 527,726,000	$ 570,423,000
OPTION 11C - - 250' Through Truss Vertical Lift Span (Tower Drive)	$ 304,281,000	$ 342,471,000	$ 575,354,000	$ 621,453,000

Following a screening of the 5 replacement alternatives against a set of evaluation criteria, a preferred alternative that most favorably meets the overall goals of the project was selected by CTDOT.

2 Project Description and Background

In cooperation with the Federal Transit Administration (FTA), the Connecticut Department of Transportation (CTDOT) proposes to replace the New Haven Line Railroad Bridge (Walk Bridge), Bridge No. 42.88R; MP 41.5, over the Norwalk River in South Norwalk, Connecticut.

Walk Bridge, constructed in 1896, is a five-span swing bridge that spans 564 feet over the Norwalk River in Norwalk, Connecticut. Figure 2-1 provides a project location map. Walk Bridge consists of two deck truss swing spans and three fixed approach spans. There are two fixed approach spans to the west of the swing span and one fixed approach span to the east of the swing span. The fixed spans consist of eight 15-foot deep Warren trusses, two per track; and the swing span consists of three planes of double intersection Warren trusses with stringers and floor beams. Power for the trains is supplied by overhead catenary, and high towers are located on either side of the Norwalk River channel to allow power to cross high overhead uninterrupted.

Walk Bridge carries four tracks of the New Haven line of Metro-North commuter rail, and is utilized for intercity and high-speed passenger service by Amtrak on the Northeast Corridor (NEC). Walk Bridge is also utilized for freight service: CSX Transportation, a Class I railroad, provides freight service on the New Haven Line, and Providence & Worcester Railroad, a Class II railroad, has through traffic rights over the New Haven line. Currently, Metro-North operates 92 daily trains (46 round trips) between South Norwalk and Grand Central Terminal. Amtrak operates 42 intercity trains (21 round trips) via the New Haven line. The Metro-North Railroad is the second largest commuter railroad in the nation. The New Haven line, one of three main lines of Metro-North, is the busiest single commuter rail line in the United States.[1] In 2012, the New Haven line had 38.8 million riders.[2]

Walk Bridge is located over a navigable waterway which is used for both recreational and commercial marine traffic. Walk Bridge opens approximately 20 to 30 times per month, primarily for tall barges accessing businesses upstream. The Norwalk Harbor is a working commercial harbor, with a Federal Channel that provides deep-water access to industrial and recreational facilities located north of Walk Bridge, including Devine Brothers, a fuel oil delivery company; O & G Industries, a construction material and services company. Additionally, there are over 1,800 berthing spaces and over 500 mooring locations in the Norwalk Harbor. The Norwalk Harbor Management Commission estimates that there are between 2,000 and 3,000 commercial vessel trips each year to and from Norwalk Harbor's port facilities.[3]

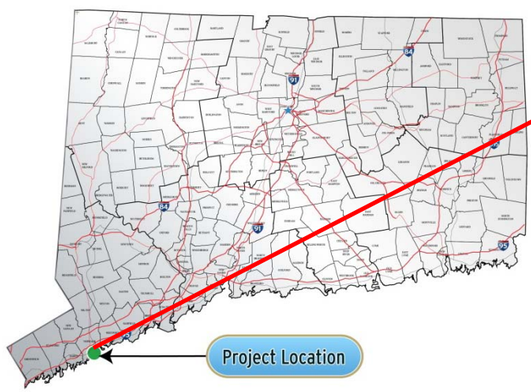


Figure 2 - 1 – Walk Bridge Project Location Map

[1] Northeast Corridor Infrastructure and Operations Advisory Commission, *Critical Infrastructure Needs on the Northeast Corridor*, January 2013.
[2] http://newyork.cbslocal.com/2013/01/29/new-haven-line-leads-in-metro-north-ridership-increase.
[3] Norwalk Harbor Management Commission, *Norwalk Management Plan, 2009 Plan Amendments*, adopted August 11, 2009.

The deteriorating condition of Walk Bridge has been extensively documented over the years. The most recent full rehabilitation of Walk Bridge was conducted in 1990 and addressed repairs to the structural, mechanical and electrical systems. Subsequent studies indicated that major portions of the bridge have exceeded their fatigue life and require replacement. Bridge rehabilitation also has been proposed; even with rehabilitation, however, fatigue-induced damage would remain an important consideration throughout the remaining service life of the structure. In its current condition, the bridge is highly vulnerable to irreparable damage from a storm surge or high wind event, and it also at risk for malfunctions due to extreme temperatures.[4] Additional capacity problems include the curvature of the track and narrow track centers, which force trains traversing Walk Bridge to reduce speeds. Further, due to the bridge's condition, maximum load capacity of freight railcars on the New Haven line is reduced to 263,000 pounds from the standard 286,000 pounds across North America.[5]

In 2011, Walk Bridge failed 12 times out of 138 openings,[6] and in 2013, the bridge failed 16 times out of 271 openings.[7] Closing the bridge after a failure can take up to two hours. In May and June 2014, in two separate but similar incidents within a two-week time span, Walk Bridge failed to properly close. The failures prevented trains from being allowed to cross the bridge for extended periods of time, and impacted thousands of commuters.

In response to these recent bridge failures, in early June 2014, CTDOT established a Short Term Action Team (STAT) to determine the cause of operation failures and determine repairs to improve the system's reliability. The STAT determined that the failures of the Walk Bridge were due to a combination of adjustments and the operating system being close to its maximum limits, due to the age of the structure, age of the operating system components, existing structure condition, and the attempt to use existing worn operating systems with new rail joint systems.[8] In an emergency action in July 2014, the U.S. Coast Guard issued a temporary deviation from the Walk Bridge operating schedule to allow the bridge to open after an 8-hour advance notice under a revised operating schedule.[9]

The primary elements of the Walk Bridge Replacement Project include:

- Installation and commissioning of 2 new movable spans, including all structural, mechanical, electrical, and architectural components;
- Removal of the existing bridge superstructure, substructure and overhead catenary system components, as needed;
- Installation of new bridge approach substructure;
- Retrofit of existing bridge abutments, as needed;
- Installation of new fixed span approach superstructure;
- Track relocations, as needed, within the project limits;
- Retaining wall and civil-related construction, including utility relocations, as needed;
- Installation of new overhead catenary system (OCS) and modifications to existing OCS, as necessary;
- High tower and transmission line relocation;
- Overall construction phasing to limit impacts to rail traffic and waterway traffic that will maintain, at a minimum, 2 tracks in service throughout the project;

[4] "*Replacement of Norwalk Bridge on the Northeast Corridor*," prepared for the 2014 Hurricane Sandy Competitive Resilience Program.
[5] South Western Regional Planning Agency, "Freight Planning Update – 2013."
[6] http://www.stamfordadvocate.com/news/article/Older-rail-spans-prone-to-problems-3500237.php
[7] Blumenthal, Richard, United States Senate. Letter to Admiral Paul F. Zukunft, Commandant of the United States Coast Guard, June 9, 2014.
[8] Connecticut Department of Transportation (DOT) Short Team Action Team, *Emergency Repair and Reliability Report*, Connecticut DOT Br. No. 04288R, July 17, 2014 (Final).
[9] 79 Federal Register 41644 (July 17, 2014).

3 Conceptual Engineering Scope of Work

The Engineering tasks associated with the Walk Bridge Replacement Project will be divided into three distinct phases:

1. Phase 1: Conceptual Engineering (PE) (0% - 15%); Initial Environmental Screening and Data Collection in support of National Environmental Policy Act (NEPA) analysis and Connecticut Environmental Policy Act (CEPA) analysis as well as state and federal permits
2. Phase 2: Preliminary Design (15% - 30%); Final Design (30% - 100%); final NEPA documentation and permitting; Construction Manager-General Contractor coordination
3. Phase 3: Construction Engineering (design services during construction)

The current phase, Conceptual Engineering, consists of investigative and conceptual activities that are needed to better define the project and to understand the feasibility limits of what can be technically done to address the needs for a complete replacement of the existing Walk Bridge. This phase of the overall project will also provide sufficient information of potential project impacts for verifying the NEPA/CEPA process to be undertaken still meets conditions for a documented Categorical Exclusion (CatEx) consistent with Federal Transit Administration (FTA) procedures.

The primary products from Conceptual Engineering are the conceptual (15% level) design of technically feasible schemes for the bridge replacement followed by a recommendation of a preferred alternative.

Conceptual Engineering, in coordination with the NEPA process, will identify the type, size, and location of the new railroad bridge structures; track alignments and profiles; rail systems that will provide four tracks capacity within the project limits; and preliminary environmental impacts. Conceptual Engineering will also identify construction strategies and constructability issues in order to complete the project while maintaining railroad operations. Conceptual Engineering is intended to provide CTDOT and Metro-North with sufficient conceptual design information, costs, and schedule to progress the design to Final Design and Construction. The primary tasks completed during the Conceptual Engineering phase include:

Conceptual Design

- Bridge Structures:
  Develop at least four alternatives that will outline:
  - Movable and fixed approach span structure type and layout
  - Movable span operating machinery and electrical system layout
  - Movable span control house location, size and layout
  - Bridge substructure type and layout, including all abutments and intermediate bents
  - Pier protection system
  - Access for maintenance and inspection
  - Utility supports, as needed

- Track Alignments:
  Develop at least four track alignments in coordination with the Walk Bridge structural alternatives and high-tower relocation alternatives. The track alignment design will establish the limits of work; impact of disturbance on existing surfaces and facilities; and limits of embankments, excavations and/or retaining walls.

- High Tower Relocation:
  Develop at least three options for the high tower relocation in conjunction with the bridge type and track alignment

- Traction Power:
  Outline the requirements for Overhead Contact System (OCS); OCS Support within the bridge limits, including movable bridge terminations; and transmission line routing using current NERC clearance requirements

- Development of Cost Estimates, Life Cycle Costs, Construction Schedules and Construction Staging

Initial Geotechnical Screening
In lieu of a full subsurface boring program during Conceptual Design, a review of historic geotechnical information available for the project site is to be used to develop conceptual subsurface profile along the centerline of the alignment. This soil profile will assess feasible foundation types, constructability and costs for the bridge replacement options.

Channel Hydraulics
For each bridge replacement options, a hydraulic analysis for the Norwalk River in accordance with the 2000 CTDOT Drainage Manual is to be prepared.

Initial Environmental Data Collection, Impact Assessment and Screening
During the conceptual phase, potential environmental conditions that may significantly impact possible structure types and track configurations are to be identified during the development of feasible alternatives. Field activities and remote data collection, along with agency coordination as part of the environmental documentation process, is scheduled to commence. The determination of environmental permits and documents is not included in the conceptual phase.

Navigation Study
Through the collection of information from published sources, agencies, commercial users, marinas, and local boating associations, the navigation study will summarize the horizontal and vertical navigation clearances within the navigable channel, a navigation study will be completed. This study will be used in coordination efforts with the USCG for the final establishment of the recommended navigation clearances for the Walk Bridge replacement.

Traffic Study
As vehicular and pedestrian traffic along Water Street in Norwalk, CT will be impacted by the Walk Bridge Replacement, particularly with the removal of the existing fixed truss approach span over the roadway/sidewalk and the installation of new spans, a traffic study is to be completed to assess these impacts and identify maintenance of traffic and/or traffic detours associated with the bridge replacement options.
Right-of-Way Research
In supporting CTDOT, the various properties potentially requiring acquisition of rights or easements are to be identified, including temporary and permanent easements.

Utility Investigations
Using available existing data as a starting point, all existing and proposed utilities within and immediately adjacent to the site are to be identified and with quantification of the impacts.

Evaluation of Replacement Options

Feasible replacement options are to be evaluated on a set of established project criteria, including construction cost, ease of construction, environmental impacts, permitting requirements, construction impacts on rail/vehicular/pedestrian traffic, construction schedule, future maintenance costs, and site context/aesthetics. The evaluation of the replacement options will form the basis of the recommendation of the preferred alternative.

The Conceptual Engineering design shall formally be presented in a Conceptual Engineering Report.

4 Environmental Review Process

Removal and replacement of the Walk Bridge will require federal and state permits and reviews. As required to comply with applicable federal and state regulations, CTDOT also will apply for permits and/or request reviews from the City of Norwalk.

4.1 Federal Permits, Reviews, and Authorizations

4.1.1 National Environmental Policy Act (NEPA) Review

The National Environmental Policy Act (NEPA) requires an environmental analysis of actions proposed to be undertaken or funded, in whole or in part, by a federal department or agency. Depending upon the complexity of a project, there are three levels of analysis and documentation required for NEPA reviews: an Environmental Impact Statement (EIS), for an action that significantly affects the environment; a Categorical Exclusion (CE), for an action that does not individually or cumulatively have a significant environmental effect; and an Environmental Assessment (EA), for an action in which the significance of the environmental effect is not clearly established.

It is anticipated that FTA will determine the level of NEPA review required for the Walk Bridge replacement project following initial public review of the project. With appropriate mitigation, it is anticipated that no significant environmental impacts will result from the bridge replacement project. Accordingly, CTDOT will prepare documentation for either a CE or EA for the replacement project per FTA guidance (23 CFR 771). The NEPA documentation will be submitted to the FTA for approval and to other federal agencies as required. It also will be available for public review. If appropriate, CTDOT will prepare the NEPA documentation jointly with Connecticut Environmental Policy Act (CEPA) documentation requirements.

4.1.2 U.S. Coast Guard Bridge Permit

CTDOT will apply for a bridge permit from the U.S. Coast Guard (USCG) per Section 9 of the Rivers and Harbors Act of 1899, as amended, and the General Bridge Act of 1946, as amended (33 CFR 114-115). The bridge permit application will address demolition of the existing bridge, new bridge navigational clearances, placement of overhead utility lines, and bridge construction procedures, including temporary structures. Additionally, it will include a navigation evaluation, details of the bridge protective system, and a bridge lighting plan.

4.1.3 U.S. Army Corps of Engineers Permits

Section 408 Permit. Per 33 USC 408, CTDOT will apply to the U.S. Army Corps of Engineers (USACE) for a Section 408 permit to occupy/use/alter the Federal Navigation Channel (USACE federally authorized civil works project). Included in the Section 408 permit application will be a hydrologic and hydraulics system performance analysis; and an assessment of the project's impacts upon the floodplain, pursuant to Executive Order 11988, Floodplain Management.

Section 404/Section 10 Permit. Per Section 404 of the Federal Clean Water Act (33 CFR 1344) and Section 10 of the Rivers and Harbors Act (33 USC 403), the bridge replacement project will require authorization from the USACE for the following activities: excavation and fill associated with the bridge replacement construction; overhead transmission lines crossing over navigable waters; dredging in navigable waters to reconfigure the federal channel; and potential in-water disposal of dredged material.

4.1.4 Section 106/Norwalk Historic Commission Reviews

Walk Bridge is listed on the National and State Registers of Historic Places and is subject to Section 106 of the National Historic Preservation Act (36 CFR 800). In consultation with CTDOT, the Connecticut State Historic Preservation Officer (SHPO) reviewed the proposed project and determined that rehabilitation of the bridge is no longer sufficient and replacement of the structure is necessary as part of an Emergency Declaration.[10] The SHPO determined that demolition and replacement of the historic bridge will constitute an adverse effect.

In cooperation with FTA, CTDOT will request review of the replacement project by the SHPO. The SHPO will provide advisory assistance to promote compatibility between the replacement bridge and the preservation of the state's cultural heritage. Additionally, CTDOT will seek input from the Tribal Historic Preservation Officers (THPOs) of the Mashantucket Pequot Tribal Nation and the Mohegan Tribal Nation, and the Norwalk Historical Commission. Due to the required demolition of the existing historic structure, it is anticipated that a Memorandum of Understanding will be required per Section 106, including mitigation measures.

The western portion of the project area to Washington Street is located within the South Main and Washington Streets National Historic District, as shown in Figure Q-1 in Appendix Q. Per Section 7-147d of the Connecticut General Statutes, a Certificate of Appropriateness (COA) may be required from the Norwalk Historical Commission for the alteration of the bridge approach located within the historic district.

4.1.5 Section 4(f) Assessment

Pursuant to Section 4(f) of the U.S. Department of Transportation Act of 1966 (49 USC 303), use of publicly-owned and publicly-accessible parks, recreation areas, wildlife or waterfowl refuges and public and private historic sites for transportation projects can be approved only if there is no prudent or feasible alternative. Section 4(f) also requires that all possible planning be undertaken to minimize harm to the Section 4(f) resource.

A Section 4(f) assessment and use documentation will be prepared for FTA's review and approval. The Section 4(f) assessment will include an evaluation of the use of other Section 4(f) sites in the immediate vicinity of the Walk Bridge, including potential temporary use of Section 4(f) properties during project construction.

4.1.6 Project/Site Review, Section 7 of the Endangered Species Act

Walk Bridge is located within an area of state and federal list species and significant natural communities, per the Natural Diversity Data Base for Norwalk,[11] as shown in Figure Q-2. Per Section 7 of the Endangered Species Act, project site reviews may be required from the National Marine Fisheries Service (NMFS) for potential impacts to threatened and endangered species and critical habitat.

4.1.7 Project/Site Review, Magnuson-Stevens Fishery Conservation and Management Act

The National Oceanic and Atmospheric Administration (NOAA)/NMFS Essential Fish Habitat (EFH) mapper (http://www.habitat.noaa.gov/protection/efh/efhmapper) indicates that the Norwalk River at the site of Walk Bridge is

[10] Letter from Daniel Forest, SHPO, to Mark Alexander, ConnDOT Office of Environmental Planning (OEP), regarding Replacement of Bridge No. 04288R, Norwalk, CT, August 8, 2014.
[11] Connecticut Department of Energy and Environmental Resources, "Natural Diversity Data Base Areas, Norwalk, CT, June 2014.

an Essential Fish Habitat (EFH)[12] for multiple species. Project site reviews will be required from the NMFS for potential impacts to EFH, per the Magnuson-Stevens Fishery Conservation and Management Act.

4.1.8 Federal Aviation Administration, Notice of Proposed Construction or Alteration

The Walk Bridge replacement project will include replacement of the approximate 200-foot high towers abutting the bridge. Per the Federal Aviation Administration (FAA) regulations, 14 CFR 77.9(d), proponents of new construction exceeding 200 feet in height are required to submit a notice of proposed construction to FAA for review of potential impacts to federal air space.

4.2 State Permits and Authorizations

4.2.1 Connecticut Environmental Policy Act

The Connecticut Environmental Policy Act (CEPA) requires an environmental assessment of actions proposed to be undertaken or funded, in whole or in part, by a State department, institution or agency. Per the Environmental Classification Document (ECD) for CTDOT (April 13, 2011), demolition of the National/State Register-listed Walk Bridge is an action which could have significant impacts. Accordingly, early public scoping process of the project will be conducted, followed by preparation of the required CEPA documentation. It is anticipated that the NEPA/CEPA documentation will be prepared concurrently.

4.2.2 Structures, Dredge and Fill and Tidal Wetlands Permit

The Connecticut Department of Energy and Environmental Protection's (DEEP's) Office of Long Island Sound Programs (OLISP) has regulatory jurisdiction over activities occurring in tidal wetlands and/or waterward of the high tide line. A Structures, Dredge and Fill, and Tidal Wetlands Permit will be required for the bridge replacement project, which will include demolition of the existing bridge superstructure and substructure, and construction within the waterway and bordering tidal wetlands.

4.2.3 Section 401 Water Quality Certificate

Per Section 401 of the Clean Water Act (33 USC 1341), an applicant for a USACE permit for work which would result in the discharge of dredged or fill material into the waters of the United States, including wetlands, is required to obtain a state Water Quality Certificate (WQC) from DEEP. Water Quality Certification will be requested in conjunction with the Structures, Dredge and Fill and Tidal Wetlands Permit.

4.2.4 General Permit for Discharge of Stormwater and Dewatering Wastewaters from Construction Activities

Due to anticipated land disturbance and disturbance and pumping of surface water associated with the bridge replacement project, coverage will be required under the Connecticut's General Permit for Discharge of Stormwater and Dewatering Wastewaters from Construction Activities.

[12] EFH is defined by the U.S. Congress in the 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act, or Magnuson-Stevens Act, as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity."

5 Description of Replacement Options

5.1 Development of Replacement Options

5.1.1 Background

Due to the critical rail traffic that utilizes the tracks, any proposed replacement is expected to minimize the impact on train operations during construction. Likewise, the existing bridge crosses the Norwalk River, a navigable waterway used by both commercial and recreational vessels. The bridge site is confined by high towers carrying overhead electric transmission lines, and the Norwalk Maritime C enter (IMAX Theatre and Aquarium), a sewer treatment facility, a local marina, and other commercial and residential properties (Figure 5-1). Therefore, this study examines replacement alternatives and construction schemes that address maintenance of Metro-North, Amtrak and freight service, the needs of maritime traffic, and any conflicts with existing structures and facilities.

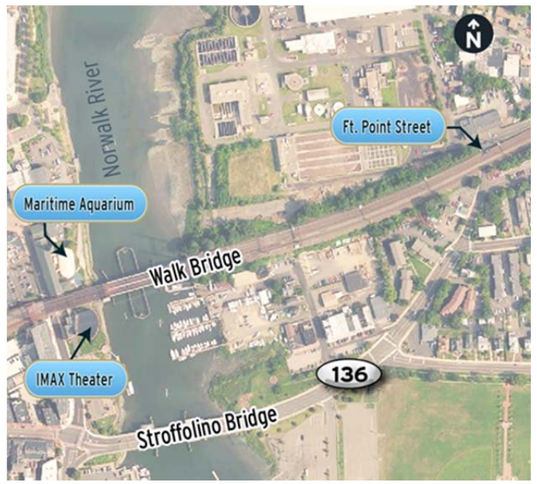


Figure 5 - 1 – Project Site Constraints

To improve the reliability of the corridor, the overall design strategy is predicated upon providing system resiliency and operational redundancy. In this context, *system resiliency* describes the ability to return the bridge to use, either partially or completely, in a relatively short period of time in the aftermath of a compromising event. It also refers to minimizing the vulnerability of critical elements of the bridge in order to facilitate its return to use. *Operational redundancy* means the ability to maintain train service on a limited number of tracks following an event that would have otherwise rendered all tracks inoperable. Designs of the structural, mechanical, and electrical systems are all considered in a coordinated manner to maximize both system resiliency and operational redundancy.

The Scope of Services requests the development and screening of at least four alternatives in order to identify a replacement solution that is most likely to meet the goals of the project as established by CTDOT. Determining the alternatives to be evaluated began by compiling a pool of candidate structure types and configurations from all possible permutations of the following characteristics which are described in more detail below and graphically in Appendix A:

- Structure Type
- Span Length
- Pier Placement
- Vertical Position of the Counterweight (overhead or under-deck)
- Horizontal Position of the Counterweight (for single-leaf bascule options)
- Spacing of Tracks 1 and 2 as required to accommodate the dual movable span configuration

Structure Type

Various movable structure types were considered based on known practical limitations and each type and their applicability to the span lengths being considered. Single-leaf plate girder bascule structures are efficient at shorter span lengths, while vertical lift spans are optimal for longer spans. For the mid-range span length, a “long” through-truss bascule span and a “short” vertical lift span were considered to capture the transition between bascule and vertical lift structure types.

Span Length

By observation, four nominal span lengths—120’, 180’, 200’ and 250’—were chosen to represent the range of tangible benefits offered by varying the length of the movable span. The short span length provides the minimum size of a proposed movable span while maintaining the horizontal clearance of one side of the existing navigation channel. The medium length spans provide an opportunity to extend the USACE channel through the bridge crossing and avoid conflicts with existing bridge components during construction by simultaneously spanning one half of the existing navigation channel and the pivot pier. The long span length was selected for its ability to limit impacts to the USACE channel; potentially minimize navigation outages; and avoid existing foundation conflicts by spanning the entire length of the existing swing span.

Pier Placement

Consistent with these span length options, five conceptual movable span pier positions were identified in distinctly different regions along the length of the existing bridge. As shown in Figure 5-2, positions A and E represent pier locations outside of the existing navigation channel and clear of the existing swing span. Positions B and D are locations within the east and west sides of the existing navigation channel, and Position C is considered any pier position in conflict with the existing pivot pier and/or fender system. All logical combinations of A through E that yield spans the meet the descriptions of the nominal span lengths were considered for evaluation. In general, combinations of pier position that promote construction without removal of existing and maintain navigation to the greatest extent possible are viewed as most favorable.

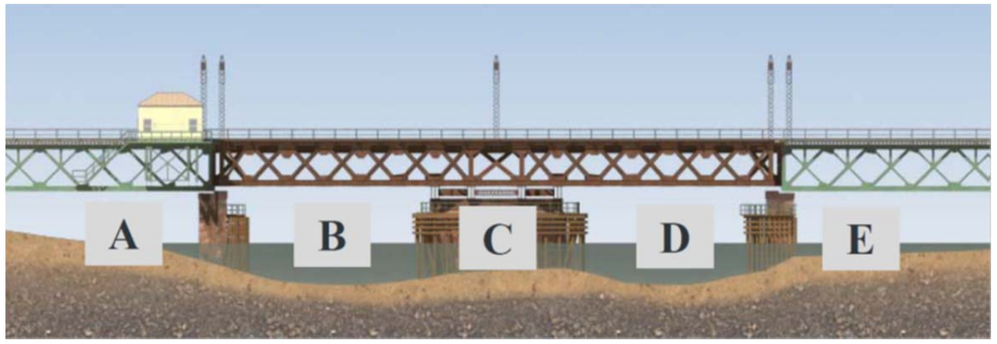


Figure 5 - 2 – Pier Placement Locations

Vertical Position of Counterweight

The vertical position of the counterweight is a function of the type of structure to which it is attached. For instance, counterweight options for tower-supported vertical lift spans are limited to the overhead type, while tower-less lift spans are limited to counterweights below the deck. Through type bascule spans have the flexibility of either an overhead or under deck counterweight attached to the rear of the rotating leaf, while deck type structures are limited to under deck configurations.

Horizontal Position of Counterweight

Single leaf bascule structures possess the unique characteristic of asymmetry with a single counterweight and set of drive machinery on one side of the navigation channel only. Therefore, east and west locations of the counterweight were considered and found to exhibit significant advantages and disadvantages related to constructability and permissible track alignments for the bascule span alternatives.

Track Spacing

The spacing of existing Tracks 1 and 2 on the single swing span structure is approximately 13'. However, it was identified that this existing track spacing could not be maintained under the final conditions of dual movable spans. The proposed distance between the two center tracks (Tracks 1 and 2) is a direct result of space required to accommodate structural and/or mechanical components between the structures at the movable pier locations. Because all of the alternatives being considered are dual-bridge structures with machinery at the span ends instead of centered beneath the structure, each alternative requires center track spacing in excess of the existing alignment. The spacing required, however, varies widely among the movable span types. Initial studies found that the various structure types under evaluation could be classified based on the minimum requirement of 16', 25', or 33' between the center tracks. For example, for through-truss vertical lift span options, a Track 1-to-Track 2 spacing of 25' is necessary to provide the minimum cross sectional width while meeting all AREMA clearance requirements as well as providing sufficient space between the dual movable spans for operating equipment and maintenance/inspection (see Figure 5-3).

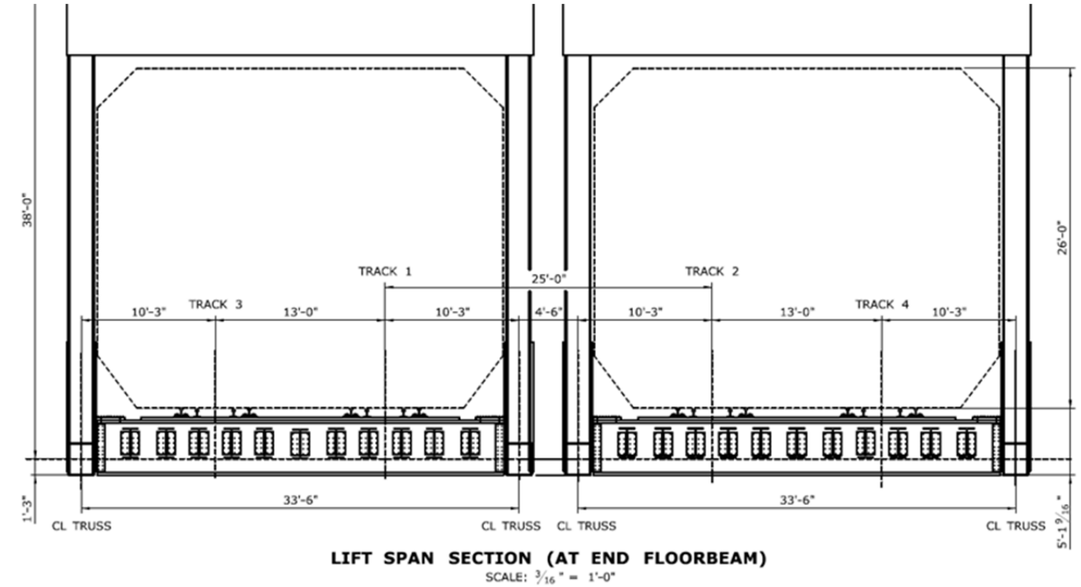


Figure 5 - 3 – Track Spacing at new Movable Spans (lift span shown

Considering geometric constraints at the Norwalk Maritime Center on the west end, alternatives associated with each of these track spacing requirements could be further classified as those able to accommodate proposed track alignments that are effectively parallel offsets of the existing alignment (16' and 25') without impacting the buildings, and those requiring non-parallel offsets (33') to avoid impacting the buildings, producing a bifurcated arrangement between the north and south track pairs. In order to provide adequate walkways on both sides of either leaf in the absence of the other leaf, the minimum practical spacing between tracks was determined to be 16'.

A summary of the replacement movable span structure types and attributes is shown in Table 5-1 below.

Option	Movable Span Type	Superstructure Type	Independent Characteristics												Dependent Characteristics							
			Span Length			Counterweight		Counterweight		Pier Location					Minimum Center Track Spacing				Horizontal Clearance		Vertical Clearance	
			120'	180'	250'	Under	Over	West	East	A	B	C	D	E	13'	16'	25'	33'	80'	125' +	60'	Unl.
1	Trunnion Bascule	Deck	x			x		x	x	x	x	x	x	x		x			x			x
2	Trunnion Bascule	Through	x			x	x	x	x	x	x	x	x	x				x	x			x
3	Rolling Bascule	Deck	x	x		x		x	x	x	x	x	x	x		x			x	x		x
4	Rolling Bascule	Through	x	x		x	x	x	x	x	x	x	x	x				x	x	x		x
5	Towerless Vertical Lift	Deck	x	x		x		x	x	x	x		x	x		x				x	< 60'	
6	Span Drive Vertical Lift	Deck		x	x		x	x	x	x	x		x	x				x		x	x	
7	Span Drive Vertical Lift	Through Girder		x	x		x	x	x	x	x		x	x				x		x	x	
8	Span Drive Vertical Lift	Through Truss		x	x		x	x	x	x	x		x	x			x			x	x	
9	Tower Drive Vertical Lift	Deck		x	x		x	x	x	x	x		x	x				x		x	x	
10	Tower Drive Vertical Lift	Through Girder		x	x		x	x	x	x	x		x	x				x		x	x	
11	Tower Drive Vertical Lift	Through Truss		x	x		x	x	x	x	x		x	x			x			x	x	

Table 5 - 1 – Classification of Replacement Option Attributes

Possible permutations of the attributes for each movable structure type were used as guidance in developing the initial pool of candidates from which five movable span alternatives were selected for detailed evaluation. As the possible characteristics are varied for each structure type, multiple options are introduced within each movable span type classification. For example, Option 2 (Through-girder trunnion bascules) resulted in twelve potential replacement options denoted 2A through 2L. Similar nomenclature was used to identify all of the options within the eleven movable span type categories. Overall, a total of 69 potential Walk Bridge replacement options were identified and all are included in the Summary of Options Matrix included in Appendix A. Yet, because of limitations associated with pier locations, counterweight location and overall constructability, the following five movable span alternatives were identified as viable options and carried forward for detailed development and screening with the objective of making a final recommendation:

- Option 2G – Through Girder Trunnion Bascule (120' span)
- Option 3A – Deck Girder Rolling Lift Bascule (120' span)
- Option 4S – Through Truss Rolling Lift Bascule (200' span)
- Option 8A – Through Truss Span Drive Vertical Lift (180' span)
- Option 11C – Through Truss Tower Driver Vertical Lift (200'span)

Attributes of these options are summarized in Table 5-2.

Option	Variation	Movable Span Type	Superstructure Type	Independent Characteristics												Minimum Center Track Spacing		
				Span Length			Counterweight		Counterweight		Pier Location							
				120'	180'	250'	Under	Over	West	East	A	B	C	D	E	16'	25'	33'
2	G	Trunnion Bascule	Through Girder	x			x			x	x		x					x
3	A	Rolling Bascule	Deck Girder	x			x		x		x		x			x		
4	S	Rolling Bascule	Through Truss		x			x		x	x			x				x
8	A	Span Drive Vertical Lift	Through Truss		x			x	x	x	x			x			x	
11	C	Tower Drive Vertical Lift	Through Truss			x		x	x	x	x				x		x	

Table 5 - 2 – Summary of Final Replacement Option Attributes

This list serves as a preliminary means of identifying the most feasible alternative for replacement of the existing swing span. In order to do so objectively, all of the alternatives were sufficiently developed, enabling the project team to evaluate them against weighted criteria based on project development characteristics (e.g., costs, permitting, stakeholders, etc.); construction, maintenance, inspection; and the end-user experience. Refer to Section 8 of this report for a thorough listing of preliminary design evaluation criteria, as well as the evaluation results for all five alternatives against these criteria.

Replacement Options Eliminated for Consideration

While the initial focus for movable span replacement options was placed on vertical lift and bascule spans, other alternatives were initially considered but eliminated from further consideration:

- Tower-less Vertical Lift Spans: For short- and medium-span structures, a less conventional tower-less vertical lift configuration was also considered as a means of addressing bridge aesthetics and functionality. However, because of the required vertical clearance with the span fully opened, the tower-less vertical lift span options were eliminated from additional evaluation.
- Swing Span Options: Both center-pivot and bobtail swing spans were deemed undesirable by the Owner and eliminated from consideration prior to compiling the list of alternatives for initial screening. Additionally, replacement of the swing span in-kind was not considered due to uncertainties related to extending the service life of the existing swing span substructure as well as providing no improvement to the current navigation clearances.
- "No Build" and "Rehabilitation" Options: Due to the current operational problems and the unreliability of the existing swing span to function in a safe and reliable manner, in conjunction with the likelihood of a costly, comprehensive maintenance and rehabilitation program, the "No Build" option was discarded and not included in the evaluation matrix. Overall, the "No Build" and "Rehabilitation" options do not satisfy the system redundancy and operational redundancy goals of the project.
- "Fixed Bridge" Option: A high-level "Fixed Bridge" option would provide for a new 4-track bridge constructed on a new alignment. The vertical track alignment associated with the fixed bridge would be such that the statutorily-required vertical and horizontal navigation clearances would be provided by a fixed main span, eliminating the need for a movable span. However, due to the anticipated environmental permitting requirements and likely right-of-way impacts all contributing to increased project costs and implementation schedule, the "Fixed Bridge" option was eliminated from further consideration.

Although critical in defining the overall schedule, construction cost, redundancy and resiliency of the various options, mechanical and electrical characteristics were not primary differentiators during the initial screening stage. Development of these operational features commenced once the five alternatives were identified. All conceptual design effort was performed in accordance with AREMA Chapters 8, 9 and 15 (Parts 1 and 6), and the overall design objective was to develop the framework for a comprehensive structural-mechanical-electrical system that not only satisfies the minimum requirements of AREMA, but that also provides acceptable levels of system resiliency and operational redundancy, as described at the beginning of this section.

5.2 Additional Considerations for Replacement Option Development

5.2.1 Resiliency

As the lead federal agency, FTA has mandated that the replacement bridge exhibit characteristics of resiliency in order to enhance the safety and reliability of the corridor. As previously defined, both system resiliency, the ability to return the bridge to use, either partially or completely, in a relatively short period of time in the aftermath of a compromising event, and operational redundancy, the ability to maintain train service on a limited number of tracks following an event that would have otherwise rendered all tracks inoperable, are both incorporated in the development of the replacement options. Additional resiliency attributes are incorporated into the concept development:

System and Operational resiliency - - For each option, there are two separate movable spans, including complete structural, mechanical and electrical systems as well as all rail system elements. One movable span will carry Tracks #1 and #3 and one will carry Tracks #2 and #4, providing system resiliency. Placement of the movable spans' mechanical and electrical systems is also critical to promoting system resiliency. For example, bascule spans with under-deck counterweights have machinery placed within confined piers and at the highest elevation as possible to provide protection from damage from high-water events. For movable span options having overhead counterweights, including bascules and vertical lift spans, mechanical and electrical systems are placed above deck level, promoting resiliency from high water events as well as potential vandalism.

Internal and Load path redundancy - - Internal and Load Path Redundancy is related to the ability of the structure carrying load following the loss of a single member. With each of the movable and fixed span cross sections, there are

a minimum of 4 floorsystem members holding each track providing a load path redundancy. The failure of a single stringer in will not result in failure of the entire bridge system. Similarly, the main piers for each option have more than 1 column proving a load path redundancy. Internal resiliency relates to the fact that the failure of one element of a structural member will not result in the failure of other elements of the members. The floorbeams of truss and girder spans are made up of bolted built up section which will provide internal redundancy by guarding against a fatigue-generated crack to propagate through the entire member. For truss spans, main members are comprised of built up box sections to achieve better internal redundancy.

5.2.2 Railroad Operations

The Metro North Railroad – New Haven Line is a four track line equipped with an overhead contact system of electrification and is a vital transportation link within the State of Connecticut and along the Northeast Corridor. Based on the available train data, more than 90 trains per day pass over the Walk Bridge in both the eastbound and westbound directions (Table 5-3).

CP241-CP248				
Service	Westbound		Eastbound	
	Track 3	Track 1	Track 2	Track 4
Amtrak	0	19	21	0
Metro-North	54	21	16	57
Subtotal	54	40	37	57
Total	94		94	

Table 5 - 3 – Summary of Daily Trains Operating in Walk Bridge Vicinity

It should be noted that these numbers do not include freight or maintenance vehicle movements. During the construction of the Walk Bridge Replacement, rail traffic will be affected as various tracks are placed in and out of service in order to complete the implementation of the new bridge. Overall, the desire is to maintain a minimum of two tracks in services throughout construction.

To better understand the impacts to railroad operations, a rail operations analysis was completed to better understand the overall construction staging and the impacts to rail traffic. A study area was developed between Control Point (CP) 241 at South Norwalk, which is also the junction point with the MNR – Danbury Branch and Control Point (CP) 248 at Southport, with the Walk Bridge being located within the limits of CP241 (Figure 5-4).

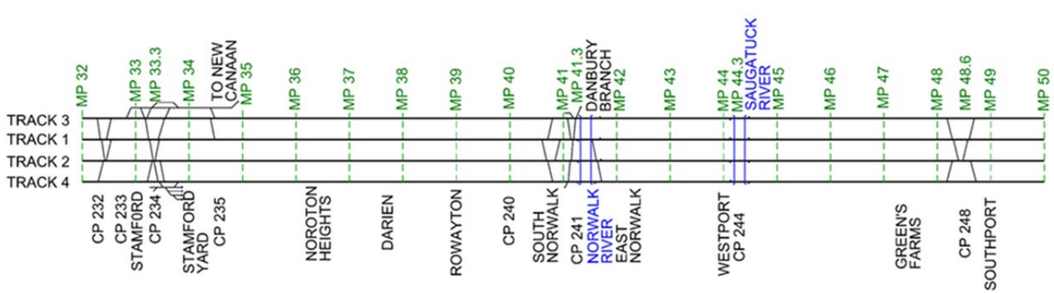


Figure 5 - 4 – Metro North Railroad – New Haven Line Stamford (CP232) and Southport (CP248)

The Railroad Operations Analysis Report is included as Appendix K.

5.2.3 Waterway Users and Navigation Clearances

As a designated navigable waterway, bridge replacement options will be required to provide vertical and horizontal navigation clearances as prescribed by the USCG. The navigation clearance requirements have a direct bearing on the selection of movable span types; their respective span length and pier placement; and the movable span superstructure type. In the development of bridge replacement schemes, HNTB consulted with the USCG, USACE, and waterway users who have direct interaction with the existing Walk Bridge.

Nearby Norwalk River Crossings

Walk Bridge is bound on the north by the I-95 bridge and to the south by the Route 136 Stroffolino Bridge. The I-95 Bridge (Figure 5-5) is located approximately 0.53 nautical miles (approximately 3,300 feet) upstream of the Walk Bridge and provides approximately 60' of vertical navigation clearance. Based on consultation with the USCG, the I-95 bridge forms the basis of establishing the initial vertical clearance requirements for the new Walk Bridge. The 5 bridge replacement concepts were developed having a minimum vertical clearance of 60' when the movable span is fully opened.

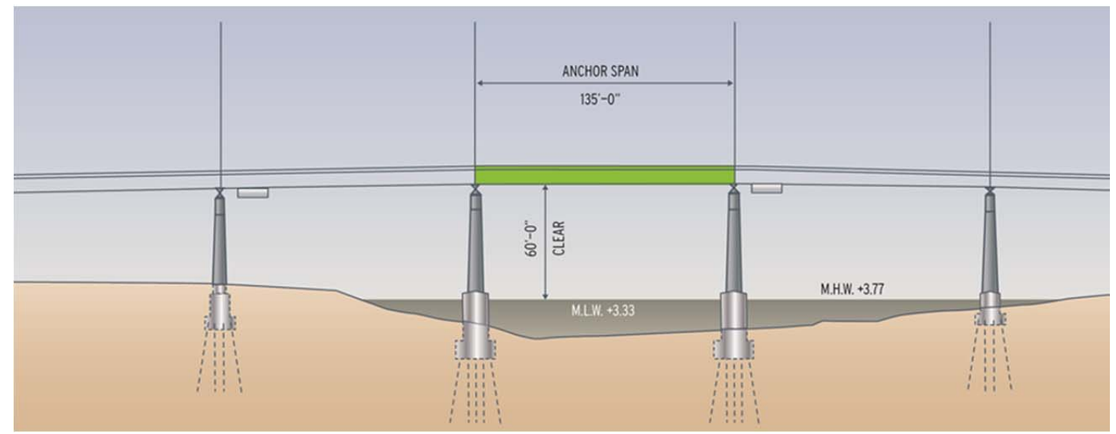


Figure 5 - 5 – Partial Elevation of I-95 over the Norwalk River

The existing four-span Route 136 Bridge (Stroffolino Bridge) consists of a bascule span and three fixed approach spans. The vertical clearance with the bascule span closed is 8 feet above MHW (Figure 5-6). With the bascule span open, the vertical clearance within the clear channel is unlimited. The horizontal clearance is 100 feet at the channel span. The bridge is located approximately 0.1 nautical miles (approximately 500 feet) downstream of the Walk Bridge.

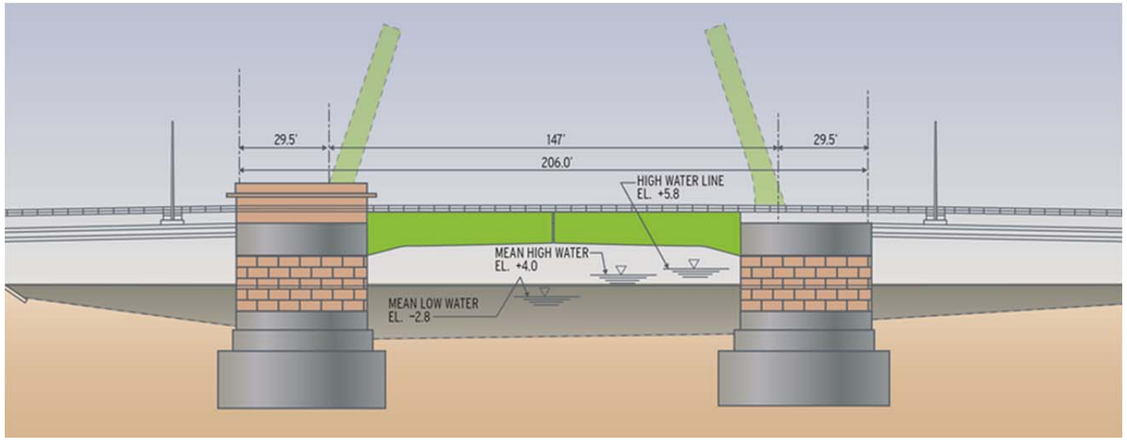


Figure 5 - 6 – Partial elevation of Route 136 (Stroffolino Bridge) over the Norwalk River

Vessels requiring a Walk Bridge opening also typically transit through the Stroffolino Bridge. Because of their proximity to one another along the Norwalk River, the navigation openings provided by both structures are poorly aligned. For larger commercial vessels, including tugs with single-wide barges, northern movements through the Walk Bridge, in particular, can be challenging due to the existing shear fence and the location of the swing span's west navigation channel relative to that of the Stroffolino Bridge.

To promote a more favorable channel alignment and to reduce potential elisions and damage with pier protection systems on the new bridge, the Walk Bridge replacement concept development focused on movable span configurations that not only improve on the horizontal navigation clearance provided by the new bridge but to also incorporate a slight shift of the navigation channel to the east of its present location to improve navigation through the Walk-Stroffolino bridges that more closely matches the true sailing line of the river.

Waterway Users

A series of docks and marinas providing service to a mix of commercial and recreational vessels is located both north and south of the Walk Bridge. The primary commercial interests that interact with the Walk Bridge are Devine Brothers and United Marine. Both facilities are located north of the I-95 bridge. Barges and tugs servicing Devine Brothers and tall mast sail boats that are maintained by United Marine generally require an opening of the Walk Bridge in order to reach their final destination. Likewise, these same vessels are capable of passing beneath the fixed I-95 fixed span. There are several vessels that must pass beneath the I-95 at low tide due to their overall height.

Several marinas are located south of the Stroffolino Bridge. Despite a large presence of tall mast sail boats that moor at these locations, these vessels rarely travel north on the Norwalk River and have very little interaction with the Walk Bridge and generally do not affect the frequency of Walk Bridge openings.

Bridge opening data was obtained for the Walk Bridge and the Washington Street Bridge for the period from September 2013 to September 2014 and trends were identified and incorporated into the development of bridge replacement concepts, construction schedules and construction sequences for each option.

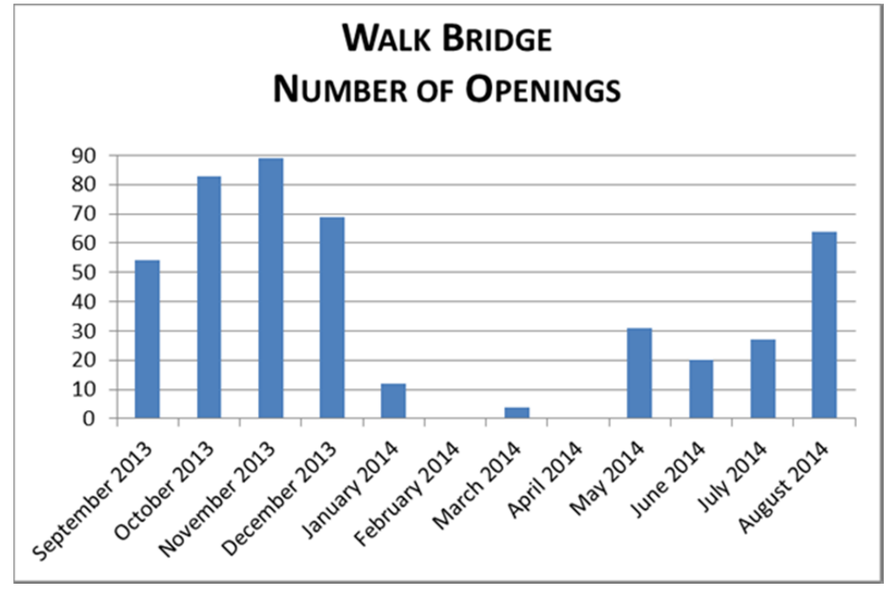


Figure 5 - 7 – Walk Bridge Openings per month (September 2013 – September 2014)

Figure 5-7 illustrates the number of Walk Bridge openings per month during the period of available data and indicates that the highest frequency of bridge openings occur between August and December. The data also suggests that the number of openings falls off sharply after December and that few, if any, bridge opens occur during the months of February, March and April. Bridge opening become more frequent beginning again in May. This trend is consistent with input provided by Norwalk River waterway users when questioned about seasonal navigation trends and bridge openings. Seasonal trends related to waterway traffic and Walk Bridge opening needs were considered in the development of movable bridge replacement concepts and their associated construction sequences. Current navigation trends, particularly for those periods when Walk Bridge movements are needed will need to be considered into the final construction schedule development of the recommended alternative.

Although the majority of vessels requiring a Walk Bridge opening transit the channel during the May to December timeframe, use of the waterway continues year-round, and the replacement concepts have been developed with this in mind. Additionally, the assessment of the overall construction schedule and construction sequencing takes the seasonal trends into account.

Existing Horizontal Clearance and New Pier Placement

The existing swing span provides approximately 58' of horizontal clearance in the west navigation channel and 53' of horizontal clearance in the east navigation channel (Figure 5-8). Both east and west channels provided by the swing span currently support navigation. Based on consultation with waterway users, commercial and larger recreational

vessels primarily use the west channel; the east channel is used by smaller vessels and is typically used to launch crew "skulls" used by the vibrant rowing community along the Norwalk River.

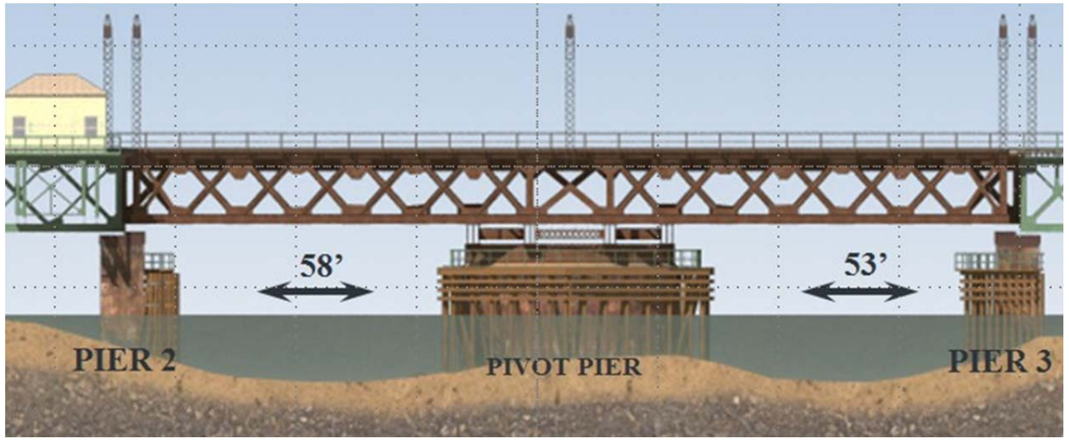


Figure 5 - 8 – Existing Horizontal Navigation Clearances (view looking north)

Based on initial consultation with the USCG, the replacement movable spans are at a minimum, to match the existing horizontal navigation clearance provided by one channel of the existing swing span. Horizontal clearance provided by the replacement movable spans will also be dictated on the placement of new bridge substructure within the federal channel that is maintained by the USACE. The existing channel width at the bridge location is approximately 175', essentially in line with the channel-side faces of the existing rest piers. North of the bridge, the federal channel width transitions to 125'. As part of the development of feasible alternatives, HNTB investigated both "short" and "long" movable span lengths that allowed for an evaluation of span configurations having piers located within the USACE channel as well as for pier placements that fall outside of the federal channel.

The federal USACE channel also requires a 12' channel depth in the vicinity of the Walk Bridge. Singe-beam bathymetric survey data of the channel bottom indicates that the existing mudline meets, and in many locations exceeds, the federally required channel depth.

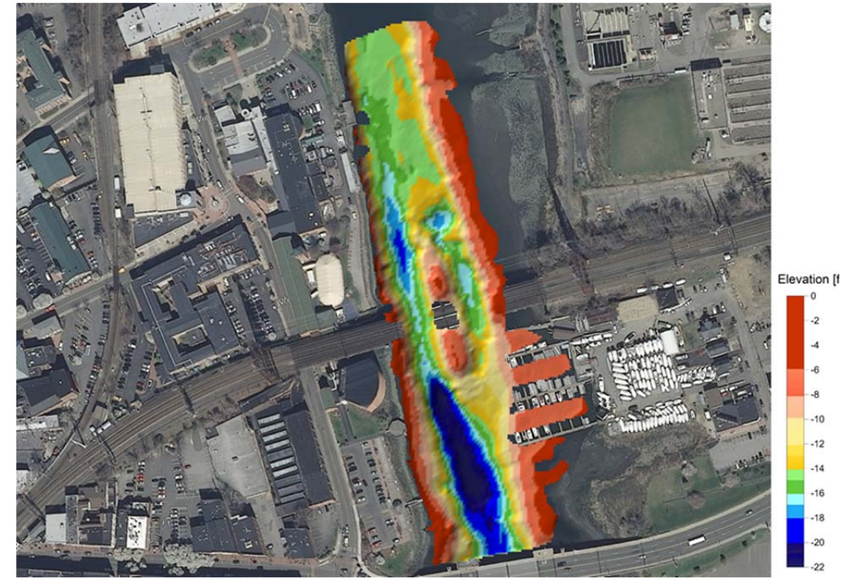


Figure 5 - 9 – Single beam bathymetric survey of the Norwalk River (October 2014)

The bathymetric data also demonstrates the channel depth is greater through the west navigation channel of the swing span in comparison to the east channel. This greater channel depth supports the navigation of deeper draft vessels and is consistent with the input received from waterway users relative to the channel predominately used by larger vessels (Photo 5-1).

Photo 5-1 – Commercial vessel transiting west channel of existing swing span

In the development of bridge replacement concepts, pier placements within the existing west channel were avoided in order to better maintain the navigation through the Walk Bridge during construction. Likewise, the existing west channel would, at a minimum, be "reused" in the final span configuration for each of the final alternatives. For these two reasons, all final replacement options result in an increase in the horizontal navigation clearance from the existing conditions.

Additionally, the placement of new bridge piers for the replacement concepts avoids a complete blockage of the east channel in order to avoid the temporary conditions during construction in which all navigation would be required to use the west channel. Despite potential construction activity and new pier placements in the existing east channel, adequate horizontal clearance is provided by the replacement options to ensure the continued use of the east channel throughout construction.

Existing Vertical Clearance and Movable Span Type

When the existing swing span is fully opened, vertical clearance is limited by the overhead transmission lines which currently have an approved clearance above the waterway of 203 feet. Presently, Walk Bridge provides approximately 16' over vertical clearance when closed (Figure 5-10).

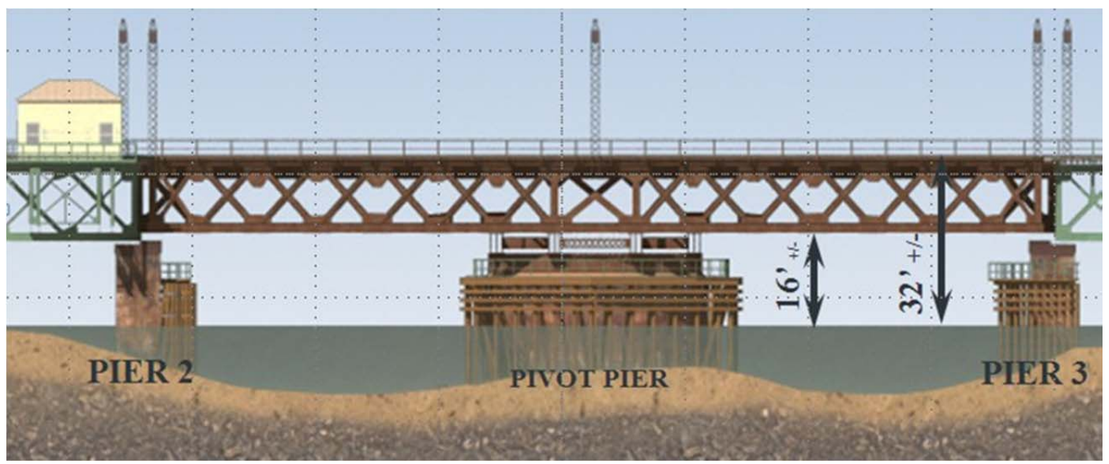


Figure 5-10 – Existing Vertical Navigation Clearance, Span Closed (view looking north)

With a limited ability to improve the top of rail elevation, and subsequent low chord elevation in when the span is in the closed position, specific focus was placed on developing movable span superstructure types that would improve the vertical clearance with the movable closed in comparison to the clearance provided by the existing swing span. By limiting the structure depth of the new movable spans, a reduction in the number of required bridge movements is anticipated. Span length and movable span type are integral to the development of the bridge's superstructure type. HNTB investigated both deck-type superstructures and through-truss superstructures of various span lengths, all of which provide an increase in the vertical navigation clearance when the span is closed. By reducing the number of openings/closings of the replacement structure, safety and operational efficiencies of both rail traffic and waterway users are enhanced. Additionally, the resiliency of the new movable spans' mechanical and electrical systems is enhanced by reducing the number of span movements.

See Appendix N for the Navigation Study associated with the Walk Bridge Replacement Conceptual design.

5.2.4 Construction Staging

The construction of the Walk Bridge replacement will require the implementation of a well-planned, detailed construction sequence that outlines major construction operations and the effects, if any, of these operations on rail and navigation traffic. For rail operations, the desire is to maintain service on as many tracks as possible during the construction of the new bridge. At a minimum, 2 tracks are to remain in service at all times. For navigation needs, periods of time when the channel is restricted, either horizontally resulting from new pier construction or vertically resulting from a temporary fixed structure placed over existing navigable channels, will be kept to a minimum.

In the span arrangement and construction staging development of the 5 conceptual replacement options, three primary construction staging strategies were considered to maintain rail and navigation operations to the greatest extent possible throughout construction. All strategies are related to the swing span, including complete removal and partial removal in order to facilitate construction of the new bridge. These strategies are outlined as follows:

Run-around Structure

With this construction staging strategy, a temporary offset, or "run-around", alignment to the north of the existing bridge would be constructed to carry Tracks 1 and 3. A temporary fixed bridge would be placed on the run-around alignment consisting of an open deck bridge, overhead catenary and fully capable rail systems. A run-around alignment evaluated as part of the study is shown in Figure 5-11.

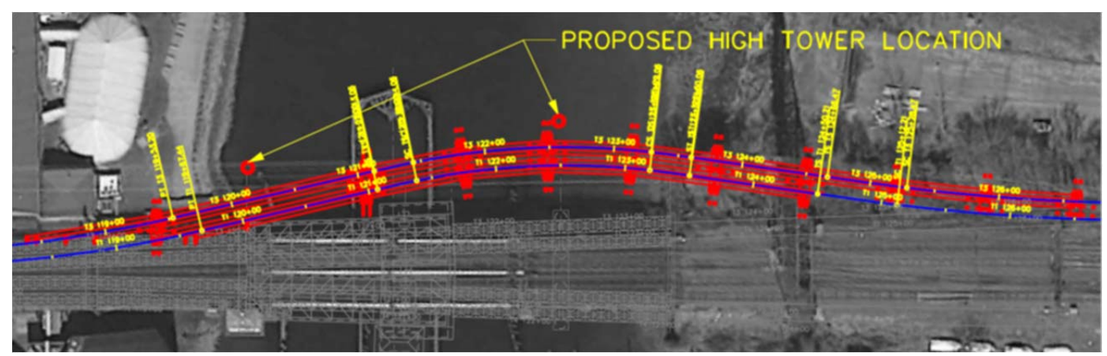


Figure 5-11 – Conceptual Run-around Alignment

The construction of the temporary run-around structure will require intermittent closures of Tracks 1 and 3, with rail traffic shifted to Tracks 2 and 4 during this time. Once the construction of the run-around is complete, all traffic will be shifted to Tracks 1 and 3, now carried over the Norwalk River by the run-around structure. Upon shifting all traffic to Tracks 1 and 3, the entire existing bridge, including the swing span, can be removed. Construction of the new bridge can commence in the area formerly occupied by the existing Walk Bridge, with no interruptions to rail traffic resulting as the new bridge is constructed.

With the temporary run-around bridge in place, a vertical restriction to navigation is introduced. To limit the impacts to navigation, the structure depth of the span over the navigable channel is optimized in order to increase the navigation clearance that is provided by the run-around bridge. Based on the initial layout of the run-around bridge, the navigation clearance is improved from 16' with the existing swing span closed to 24' minimum with the run-around bridge in place.

See the discussion on run-around track constraints in the description of conceptual track alignments.

Temporary Channel Spans

An alternate solution to the implementation of the temporary run-around structure is to introduce the use of temporary channel spans in place of the swing span. Similar to the run-around alignment, the existing swing span is taken off of the critical path by completely removing the span carrying all four tracks. By removing the swing span, generates greater flexibility is introduced in the overall staging and implementation of each of the bridge replacement concepts.

Figure 5-12 – Existing Swing Span

Figure 5-12 depicts the existing conditions with the 4-track swing span in place. Once the swing span is removed, temporary fixed spans are installed in order to reinstate rail service as shown in Figure 5-13.

Figure 5-13 – Replacement of Swing Span with Temporary (fixed) channel spans

To accommodate the use of the temporary channel spans, a one-time full closure of all tracks is required. Once the swing span is removed and the temporary spans are installed, railroad operations would be resumed along the current alignment, with no compromise to alignment-induced speed restrictions outside that which may be currently present along the corridor.

Depending on the specific staging needs, a minimum of 2 tracks would initially be placed in service; it is possible to reinstate all 4 tracks on the current alignment. For each track, one span is placed over the west navigation channel while a separate simply supported span is placed over the east navigation channel. Temporary spans are fully fabricated at the time of installation, including catenary structures and supports, to reduce the overall duration of reinstating rail service.

The temporary channel spans are supported at each end by at an existing rest pier. At the existing pivot pier location, these spans would be supported directly at the pivot pier, with support provided by a grillage set on the swing span's rim girder once the swing span is removed. Alternatively, the temporary spans would be supported by temporary bents placed adjacent to the pivot pier. In this case, a total of 3 spans per track would be required in order to limit the overall depth of structure and any potential navigation impacts.

With the temporary channel spans in place, a vertical restriction to navigation is introduced. To limit the impacts to navigation, the temporary structure depth is optimized in order to increase the navigation clearance that is provided by the temporary spans. Based on the initial layout of the temporary spans, the navigation clearance is improved from 16' with the existing swing span closed to 22' minimum with temporary spans in place.

Depending on the final span configuration of the replacement options, these temporary spans can be relocated and used as approach spans on the final alignment.

Partial Removal of Swing Span

The existing 4-track swing span consists of three planes of double-intersection Warren trusses with stringers and floorbeams. The existing swing span cross section shown in Figure 5-14 details the support of Tracks 1 and 3 by one exterior truss and the interior (middle) truss plane; Tracks 2 and 4 are supported by the middle truss plane and the opposite exterior truss.

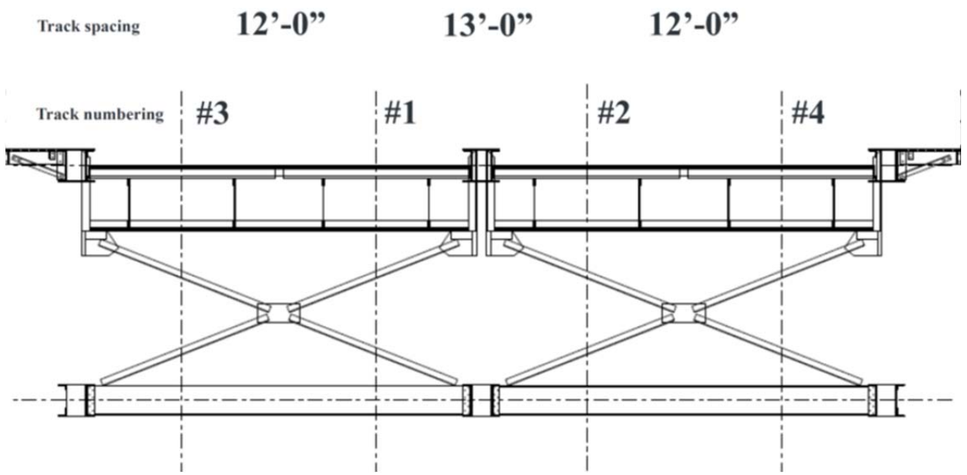


Figure 5-14 – Cross Section of Existing Swing Span (Looking East)

Using a strategy similar to the Temporary Channel Spans by maintaining service on a minimum of 2 tracks on the current alignment at all times, the partial removal of the existing swing span involves the removal of one half of the existing swing span. In the temporary conditions, the remaining portion of the existing movable span will consist of the interior (middle) truss plane, one exterior truss plane and remaining floorsystem, cross frames and lateral bracing between the 2 truss planes. Once the swing span is partially removed, construction of one half (for 2 tracks) of the Walk Bridge Replacement can commence while 2 existing tracks remain in service.

The framing system of the existing swing span lends itself to a relatively straightforward removal operation. Mainly, floorbeams supporting each pair of tracks are not continuous at the interior truss as shown in Photo 5-2. With that, the floorsystm, bracing and cross frames of a particular truss plane can be removed while a portion of the swing span truss (and 2 tracks) remains in place.

Photo 5-2 – Swing Span floorbeam-to-truss connection

However, additional investigation of the partial removal of the existing swing span is required in order to assess the overall benefits and risks of implementing this strategy as the recommended option is further refined. Implementing a strategy of partially removing the existing swing span results in:

Swing Span converted to a fixed span - - once material removal of the swing span commences, the existing movable span will become a fixed span, resulting in a vertical navigation restriction for the duration that the existing span remains in place. While the other construction staging strategies incorporate temporary fixed spans, the depth of the existing swing span is greater than the temporary spans outline in the other solutions. Because of the depth of the existing truss, the navigation impacts resulting from the fixed truss are anticipated to be greater than the other temporary span strategies.

Eccentric loading of the existing pivot pier - - the existing pivot pier and rest piers are concentrically loaded with the swing span fully intact. Removal of a portion of the swing span will result in loading conditions for which the 118 year old piers and timber piles were not designed nor intended. Thorough analysis of the pivot pier load carrying capacity and stability under the eccentric loading will be required to assess the performance of the existing substructure under these loading conditions.

Unpredictable camber of the swing span - - once material removal of the swing span commences, only 2 tracks will remain open. As material is removed, the dead load carried by the middle truss will be reduced, resulting in an upward camber of this inner truss along its span length. Upward cambering of the remaining swing span has the potential of affecting the vertical profile of the two operating tracks remaining in service.

Environmental requirements - - removal of a portion of the existing truss span will require agency approval for work over the waterway, including removal of lead-based based. Containment during the removal operation and other requirements are anticipated.

In the development of the Walk Bridge Replacement concepts, the following construction staging strategies were used:

Replacement Option	Construction Staging Approach
2G	Run-around
3A	Temporary channel spans
4S	Temporary channel spans
8A	Temporary channel spans
11C	Temporary channel spans

Table 5-4 – Construction Staging Strategies for Replacement Options

Estimated project costs, construction schedules, life cycle costs and overall evaluation of the concepts are based on the construction staging strategies listed above for each option. It should be noted that run-around alignments have the potential to be incorporated with Options 3A, 4S, 8A and 11C, but further investigation of the run-around track alignment with these structure types and layout is required. It should also be noted that the potential for partial removal of the existing swing span could be incorporated into each of the options, yet this affects the overall staging by requiring a set of track pairs (Track 1/3 or Track 2/4) to remain in place.

5.3 Description of Bridge Replacement Options

5.3.1 Option 2G

Option 2G replaces the existing swing span with a pair of single-leaf through girder trunnion bascule spans with 120' span lengths, providing at least 80' of horizontal navigation clearance. Vertical clearance in the closed position will be approximately 25' when the span is closed (approximately 9' greater than the existing conditions) and 60' minimum at the edge of the navigation channel when fully raised. Each of the movable structures carries two tracks—Tracks 1 and 3 on one leaf, Tracks 2 and 4 on the other—and is independently supported and operated to provide the operational redundancy desired. Conceptual Bridge Plans for Option 2G, including a suggested construction sequence, are included in Appendix B.

A comparative view of Option 2G and the existing bridge is shown in Figure 5-15.

a)

b)

Figure 5 - 15 – Comparative Elevation - - a) Option 2G and b) Existing Bridge

The bifurcated, or "non-parallel", track alignment provides adequate spacing between the two center tracks to accommodate structural and mechanical clearances at the bascule pier without significantly impacting the existing structures of the Norwalk Maritime Center building and IMAX theater on the west bank of the river. The minimum track spacing between Tracks 1 and 2 at the CL of trunnion is 33'. A temporary structure on a run-around alignment facilitates single-stage construction of the bascule pier in nearly the same location as the existing pivot pier. The run-around structure will consist of fixed spans supported on temporary bents erected in the river, and during removal of the pivot pier and construction of the bascule pier, navigation will be limited to vessel heights that can pass beneath the existing span in the closed position.

This type of movable span lends itself to shorter span lengths, making it well-suited to the navigation requirements at this site. The span length of 120' evaluated in this study provides for a 30 to 40 percent increase in horizontal clearance while minimizing the length of the most expensive span of the replacement bridge (based on $/linear foot of bridge length).

Each bascule leaf is an open-deck, two-track structure made up of two main girders with floorbeams supporting track stringers, a counterweight below the track, and a ballasted-deck span over the counterweight and machinery at the bascule pier. All structural steel elements are of built-up welded plate or rolled section construction, which generally translates into economy during fabrication and erection. The through-girder configuration minimizes the depth of structure below the rails and promotes a deck break ahead of the trunnions. This feature maximizes navigation clearance when the span is closed and reduces the number of openings required for vessel traffic, improving train

operations and enhancing the longevity of the drive system. It also eliminates the need for tail locks to stabilize the back end of the span and provides an element of protection for the drive machinery in the form of a closed deck.

The bascule pier is a large, fully enclosed structure that houses the counterweights, drive machinery, electrical components, and controls for operating the span. The control house is the only part of the structure above the track elevation and, as a result, provides the bridge operator unobstructed 360° views of the track and the river. Access to the interior of the pier and the fender system is restricted through the control house. Floor elevations for machinery and electrical components, including submarine cable terminals, can be set to minimize vulnerability to extreme flooding in the event the pier structure becomes inundated. The downward swing of the counterweight when the span operates requires an open pit below the water level. Therefore, a cofferdam is required for construction, and a sump pump is needed to remove any incidental water that finds its way into the pit.

The span accommodates taller vessels by rotating about a fixed horizontal axis (centerline of trunnion) within the bascule pier to provide the minimum navigation clearance to the underside of the leaf at the edge of the fender system (Figure 5-16).

Figure 5 - 16 – Option 2G, Full Open Position

To demonstrate the channel alignment of Option 2G relative to the East and West Navigation channels provided by the existing swing span in the closed position, yellow clearance diagrams representing the swing span navigation channels are included in Figure 5-16. The span has the flexibility to provide unlimited vertical clearance (overhead transmission lines notwithstanding) by designing the structure and operating system for an opening angle sufficient to move the tip of the leaf beyond the vertical projection of the fender system, if desired.

Situating the bascule pier on the east side of the navigation channel provides the aforementioned advantages to the track alignment, and it potentially reduces the number of existing timber piles to be extracted. With the existing pivot pier foundation contained entirely within the footprint of the proposed pit pier, it may be possible to remove only those piles in conflict with the proposed drilled shafts. The remaining piles can be cut off and buried in the seal slab of the cofferdam. Leaving the piles in place minimizes soil capacity concerns related to sloughing due to voids created by removing them. Leaving the piles in place will require agency approval.

A cap beam supported on large-diameter drilled shafts comprises the rest pier. The rest pier supports bearings for the approach span, the submarine cable terminal, live load shoes, span locks, a centering device, overhead catenary supports (if needed), and access to the fender system. For the span length evaluated, the proposed rest pier can be built behind the existing rest pier, prolonging the potential use of the existing rest pier as a structural support during construction.

The bascule pier is founded on twelve 8’-diameter drilled shafts and the rest pier is supported on four 9’-diameter shafts, all socketed into rock approximately 100’ below water.

Construction costs, construction schedules and lifecycle costs are presented in the following sections. Mechanical, electrical and architectural features are outlined in Appendix G.

Summary

The following table highlights advantages and disadvantages of Option 2G relative to other main span alternatives.

Advantages	Disadvantages
Discuss relative initial and life cycle Cost $xx,xxx,xxx	Discuss relative initial and life cycle Cost $xx,xxx,xxx
Discuss relative schedule of reduced track operation	Discuss relative schedule of reduced track operation
Discuss relative schedule of limited vertical clearance	Discuss relative schedule of limited vertical clearance
Discuss relative overall schedule	Discuss relative overall schedule
1. Minimum length of the movable span 2. Increase in horizontal navigation clearance of 30 to 40 percent over existing conditions 3. Approximately 9’ of additional vertical clearance relative to the existing conditions when the span is in the closed position 4. Span type is capable of unlimited vertical clearance when the span is open 5. Potential to reuse west abutment 6. Minimal potential impacts to buildings at the west approach 7. Potential for minimal removal of existing pivot pier foundation 8. Fabrication and erection of systems comprised of welded plate girders and rolled sections are generally more economical than bolted truss systems 9. One set of drive machinery and associated electrical components to install and maintain per movable structure 10. Unobstructed visibility from control house operator level	1. Minimum channel width of the proposed alternatives 2. Runaround structure required for construction of pit pier 3. Proposed hydraulic channel is narrower than the overall federally maintained USACE channel 4. Increased risk of scour at bascule pier foundation 5. Extensive track work at east approach 6. Extensive earthwork at east approach 7. New utility connections required

5.3.2 Option 3A

Option 3A replaces the existing swing span with a pair of single-leaf rolling lift bascule spans with 120’ span lengths, providing at least 80’ of horizontal navigation clearance. Vertical clearance in the closed position will be approximately 20’ when the span is closed (approximately 4’ greater than the existing conditions) and 60’ minimum at the edge of the navigation channel when fully raised. Each of the movable structures carries two tracks—Tracks 1 and 3 on one leaf, Tracks 2 and 4 on the other—and is independently supported and operated to provide the operational redundancy desired. Conceptual Bridge Plans for Option 3A, including a suggested construction sequence, are included in Appendix B.

A comparative view of Option 3A and the existing bridge is shown in Figure 3-17.

a)

b)

Figure 5 - 17 – Comparative Elevation - - a) Option 3A and b) Existing Bridge

This option presents a unique opportunity to minimize the overall width of the proposed facility within the project limits. Proposed track alignments are parallel offsets of the existing geometry. Track 3 effectively retains its existing alignment and modest inter-track spacing increases result in Track 4 approximately 6’ to the south, which represents the nominal width increase of the project. Physical impacts to surrounding properties and structures are minimal. Given the bascule pier size and location, the geometry of a run-around alignment may be physically restrained, thereby eliminating the single-stage construction benefits of the run-around. An overall construction sequence utilizing temporary channel spans over the existing pivot pier to maintain a minimum level of service on two tracks is proposed. Navigation will be limited to low-height vessels while the temporary spans are in place. The duration of this stage of construction can be minimized by taking advantage of foundation work that can be accomplished while the swing span is still in operation.

This type of movable span also lends itself to shorter span lengths, making it well-suited to the navigation requirements at this site. Similar to Option 2G, the span length of 120’ evaluated in this study provides for a 30 to 40 percent increase in horizontal clearance while minimizing the length of the most expensive span of the bridge (based on $/linear foot of bridge length).

Each bascule leaf is an open-deck, two-track structure made up of two main girders with floorbeams supporting track stringers. All structural steel elements are of built-up welded plate or rolled section construction, which generally translates into economy during fabrication and erection. The deck-girder configuration requires that the break in the deck be located at the rear of the span. As a result, no fixed pier span is required. Instead, the counterweight extends up to deck level and supports the track all the way to the rail joints at the approach span. The additional depth provided in the counterweight can offset length to provide the same weight, thereby reducing the length and depth of the pit required to accommodate it during operation. In general, the pit pier has the potential to be smaller than for a fixed trunnion bascule bridge with a pier span. Because live load is supported behind the center of roll, tail locks are required to stabilize the heel of the leaf.

The bascule pier is a large, fully enclosed structure that houses the counterweights, drive machinery, electrical components, and controls for operating the span. The control house is the only part of the structure above the track elevation and, as a result, provides the bridge operator unobstructed 360° views of the track and the river. Access to the interior of the pier and the fender system is restricted through the control house. Floor elevations for machinery and electrical components, including submarine cable terminals, can be set to minimize vulnerability to extreme flooding in the event the pier structure becomes inundated. The downward swing of the counterweight when the span operates requires an open pit below the water level. Therefore, a cofferdam is required for construction, and a sump pump is needed to remove any incidental water that finds its way into the pit.

The span accommodates taller vessels by rotating about a transverse horizontal axis (center of roll) that translates away from the channel as the span rolls backward within the pit pier to provide the minimum navigation clearance to the underside of the leaf at the edge of the fender system (Figure 5-18).

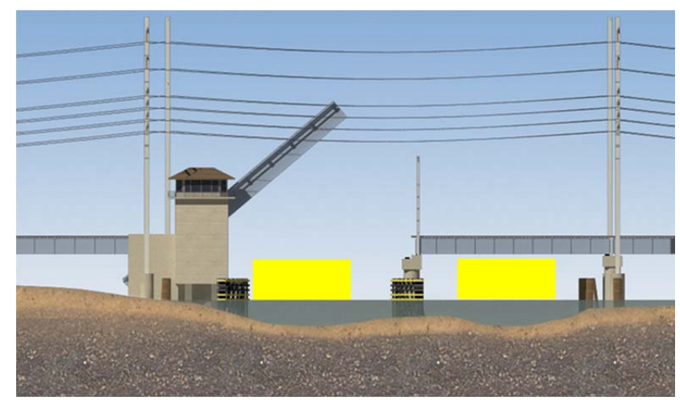


Figure 5 - 18 – Option 3A, Full Open Position

To demonstrate the channel alignment of Option 3A relative to the East and West Navigation channels provided by the existing swing span in the closed position, yellow clearance diagrams representing the swing span navigation channels are included in Figure 5-18. The span has the flexibility to provide unlimited vertical clearance (overhead transmission lines notwithstanding) by designing the structure and operating system for an opening angle and roll distance sufficient to move the tip of the leaf beyond the vertical projection of the fender system, if desired. Because this span type translates as it rolls, it requires a shorter operating time to achieve the same channel clearance as a trunnion bascule.

Situating the bascule pier on the west side of the navigation channel behind the existing rest pier makes it possible to construct the foundation prior to taking the swing span out of service. The entire pit pier can be constructed to the track support elevation beneath the existing span. The south side of the pier can then be completed and prepared to receive the first bascule leaf (carrying Tracks 2 and 4). Because the machinery is located on the moving leaf, it can be completely installed and aligned in the fully assembled leaf prior to the leaf being set in the pier. Once the leaf is set in the pier, it can be made operable in as little as one day. This characteristic has the potential for minimizing the duration of a complete track outage if installation of the leaf can be strategically coordinated with removal of the swing span.

The rest pier is similar to that described for Option 2G, and it is located on the east side of the proposed channel within the existing pivot pier fender system.

The bascule pier is founded on 12 8’-diameter drilled shafts and the rest pier is supported on four 9’-diameter shafts, all socketed into rock approximately 100’ below water.

Construction costs, construction schedules and lifecycle costs are presented in the following section. Mechanical, electrical and architectural features are outlined in Appendix G.

Summary

The following table highlights some of the advantages and disadvantages of Option 3A relative to other main span alternatives.

Advantages	Disadvantages
Discuss relative initial and life cycle Cost $xx,xxx,xxx	Discuss relative initial and life cycle Cost $xx,xxx,xxx
Discuss relative schedule of reduced track operation	Discuss relative schedule of reduced track operation
Discuss relative schedule of limited vertical clearance	Discuss relative schedule of limited vertical clearance
Discuss relative overall schedule	Discuss relative overall schedule
1. Minimum length of the movable span 2. Increase in horizontal navigation clearance of 30 to 40 percent over existing conditions 3. Approximately 4’ of additional vertical clearance relative to the existing conditions when the span is in the closed position 4. Minimal potential impacts to buildings at the west approach 5. Runaround structure is not required for construction of pit pier 6. Potential for minimal removal of existing pivot pier foundation 7. Fabrication and erection of systems comprised of welded plate girders and rolled sections are generally more economical than bolted truss systems 8. One set of drive machinery and associated electrical components to install and maintain per movable structure 9. Possible to utilize existing utility connections 10. Unobstructed visibility from control house operator level	1. Minimum channel width of the proposed alternatives 2. Proposed hydraulic channel is narrower than the federally maintained USACE channel 3. Increased risk of scour at rest pier foundation 4. Reconstruction of west abutment 5. Extensive track work at east approach 6. Extensive earthwork at east approach 7. Removal of existing pivot pier foundation is required

5.3.3 Option 4S

Option 4S replaces the existing swing span with a pair of single-leaf rolling lift bascule spans with 204’ span lengths, providing at least 175’ of horizontal navigation clearance. Vertical clearance in the closed position will be approximately 26’ when the span is closed (approximately 9’ greater than the existing conditions) and 60’ minimum at the edge of the navigation channel when fully raised. Each of the movable structures carries two tracks—Tracks 1 and 3 on one leaf, Tracks 2 and 4 on the other—and is independently supported and operated to provide the operational redundancy desired. Conceptual Bridge Plans for Option 4S, including a suggested construction sequence, are included in Appendix B.

A comparative view of Option 4S and the existing bridge is shown in Figure 5-19.

a)

b)

Figure 5 - 19 – Comparative Elevation - - a) Option 4S and b) Existing Bridge

Like Option 2G, this option is placed on a non-parallel track alignment that provides adequate spacing between the two center tracks to accommodate structural and mechanical clearances at the bascule pier on the eastern side of the bridge. The existing structures of the Norwalk Maritime Center building and IMAX theater on the west bank of the river realize limited impacts with this track and structure configuration. The minimum track spacing between Tracks 1 and 2 at the center of roll is 33'. Because of the overall length of the movable span and the non-parallel alignment, construction of Option 4S is possible utilizing temporary channel spans over the existing pivot pier to maintain a minimum level of service on two tracks. Additionally, it is possible to keep three tracks in service for a significant duration while under construction. Navigation will be limited to low-height vessels during the period while the temporary spans are in place. The duration of this stage of construction can be minimized by taking advantage of foundation work that can be accomplished while the swing span is still in operation.

This type of movable span lends itself to shorter-to-medium movable span lengths, and the span length of Option 4S is greater than that which is necessary to meet the navigation requirements at this site. Rather, the span length is driven by pier placements and overall constructability. The span length of 204' evaluated in this study provides horizontal clearance that is nearly three times greater than either of the navigation channels provided by the existing swing span.

The rolling bascule spans are comprised of 204' movable truss spans with overhead counterweights. As the span moves, the structure is supported by curved segmental girders that are connected to the bascule span and the counterweight. As the span rotates during movements, it also translates, or rolls, horizontally, with the movements guided by the curved segmental girder. The overhead counterweights are configured to permit the counterweights to pass to the outside of the adjacent fixed approach spans. The drive machinery, electrical components, and controls for operating the span are all located above track level, improving the resiliency of the systems by offering protection from high water events. The opening and closing of each bascule span is accomplished by two pinions (per span) engaging a rack which is supported on a frame adjacent to the span.

Each bascule leaf is an open-deck, two-track structure made up of trusses with floorbeams supporting track stringers. All structural steel elements are of built-up welded plate or rolled section construction, with chords, verticals and diagonals bolted together with gusset plates at their points of intersection. The bascule spans, at the counterweight end, are flanked by a 40' track girder and track girder span. The track girder span consists of two independent structures. One structure consists of two steel box girders (known as the track girders) that will provide direct support of the bascule span during openings and closings. The transverse spacing of the track girders will match the transverse width of the rolling bascule trusses. As the span rotates open, the movement is controlled by the guide track plates that are connected directly to the top of the track girders. The other structure consists of a 4-girder (per railroad track) track girder span that will directly support the bridge deck and rails. The track girder span will be a steel open deck span to support the movable span miter rail joints.

The control house is situated on the south end of the bascule pier, supported on top of pier. The location of the control house provides unobstructed views of the channel to the south. When the span is down, views to the north are partially obstructed because of the configuration of the bascule spans' segmental girder and rack frame elements.

The bascule pier consists of two adjacent, open piers that support the track girder, track girder span, rack frames and bascule spans. Drilled shafts with cap beams make up the bascule pier foundations. The construction of the bascule pier does not require a cofferdam and the open nature of the substructure promotes hydraulic flow through the limits of the bridge. Situating the bascule piers to the far-east edge of the navigation channel makes it possible to construct a portion of the foundations prior to taking the swing span out of service. The complete bascule pier straddles the existing east rest pier in order to limit the horizontal navigation restriction on the east channel during construction. Consideration can be given to reducing the overall span length by placing the entire bascule pier within the east channel. As an open foundation, navigation through the existing east channel would be only moderately restricted.

The span accommodates taller vessels by rotating about a transverse horizontal axis (center of roll) that translates away from the channel as the span rolls backward along the track girder to provide the minimum navigation clearance to the underside of the truss at the edge of the fender system (Figure 5-20).

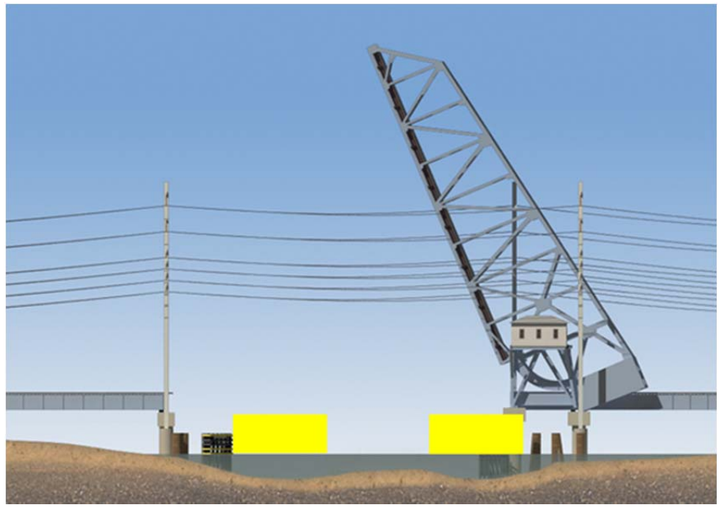


Figure 5 - 20 – Option 4S, Full Open Position

To demonstrate the channel alignment of Option 4S relative to the East and West Navigation channels provided by the existing swing span in the closed position, yellow clearance diagrams representing the swing span navigation channels are included in Figure 5-20. The span could potentially provide unlimited vertical clearance (overhead transmission lines notwithstanding) by designing the structure and operating system for an opening angle and roll distance sufficient to move the tip of the leaf beyond the vertical projection of the fender system, if desired. Given the overall length of the span, the roll length required to accommodate such a condition would exceed practical limits for structural and mechanical elements as well as the time of operation.

Because the machinery is located on the moving leaf, it can be completely installed and aligned in the fully assembled leaf prior to the leaf being set on the pier. Once the leaf is set on the track girder, it can be made operable in as little as one day. This characteristic has the potential for minimizing the duration of a complete track outage if installation of the leaf can be strategically coordinated with removal of the swing span.

A cap beam supported on large-diameter drilled shafts comprises the rest pier. The rest pier supports bearings for the approach span, the submarine cable terminal, live load shoes, span locks, a centering device, overhead catenary supports (if needed), and access to the fender system. For the span length evaluated, the proposed rest pier can be built behind the existing west rest pier, prolonging the potential use of the existing rest pier as a structural support during construction.

Each bascule pier is founded on three 12’-diameter drilled shafts and the rest pier is supported on three 11’-diameter shafts, all socketed into rock approximately 100’ below water.

Construction costs, construction schedules and lifecycle costs are presented in the following section. Mechanical, electrical and architectural features are outlined in Appendix G.

Summary

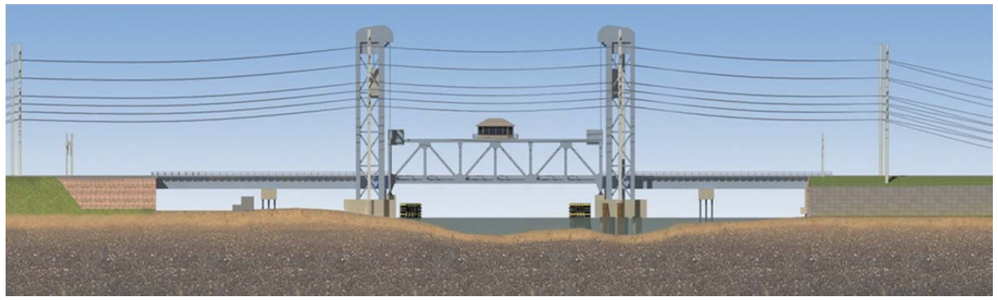
The following table highlights some of the advantages and disadvantages of Option 4S relative to other main span alternatives.

Advantages	Disadvantages
Discuss relative initial and life cycle Cost $xx,xxx,xxx	Discuss relative initial and life cycle Cost $xx,xxx,xxx
Discuss relative schedule of reduced track operation	Discuss relative schedule of reduced track operation
Discuss relative schedule of limited vertical clearance	Discuss relative schedule of limited vertical clearance
Discuss relative overall schedule	Discuss relative overall schedule
1. Optimum span length for bascule truss span 2. Increase in horizontal navigation clearance and improved alignment with Stroffolino Bridge 3. Approximately 9’ of additional vertical clearance relative to the existing conditions when the span is in the closed position 4. Improved channel hydraulics with open bascule piers 5. No cofferdams required for bascule pier construction 6. Minimal potential impacts to buildings at the west approach 7. One set of drive machinery and associated electrical components to install and maintain per movable structure 8. Operating machinery and electrical controls are installed on the movable span prior to span installation 9. Construction staging allows for 3 tracks to remain in service for a significant duration during construction.	1. Restriction of east navigation channel for extended duration. 2. Extensive track work at east approach 3. Extensive earthwork at east approach 4. Partially obstructed visibility from control house operator level. 5. Scale of structure in stark contrast with existing bridge. 6. Track girder bearings will be supported by pier pedestals.

5.3.4 Option 8A

Option 8A is a span-driven vertical lift bridge with 180’ open-deck through-truss lift span providing a minimum of 125’ horizontal navigational clearance and 60’ vertical clearance when the span is fully raised. There are two separate lift spans, one through-truss for Tracks 1 and 3 and one through-truss for Tracks 2 and 4, providing some system redundancy. Each lift span has its own machinery and counterweights to allow each span to operate independently. Track spacing of 25’ between Tracks 1 and 2 is required for structural and mechanical clearance between the lift spans. The alignment of Tracks 1 and 3 alignment remains close to the current alignment while Tracks 2 and 4 are shifted to the south to accommodate the increase in center track spacing. Conceptual Bridge Plans for Option 8A, including a suggested construction sequence, are included in Appendix B.

A comparative view of Option 8A and the existing bridge is shown in Figure 5-21.



a)

b)

Figure 5 - 21 – Comparative Elevation - - a) Option 8A and b) Existing Bridge

The lift spans can be span-driven (as shown in this Conceptual Report) or tower-driven. For the span-driven option, the machinery is located at midspan above the upper lateral bracing of the lift span truss. Operating drums are housed at each end of the span inside the box-shaped lifting girders. The counterweight ropes are anchored on the span side to the lifting girders which span transversely between truss upper chords at the end panel points. The estimated load to lift each span is 2800 kips for the span-drive option. The tower-drive variation will have a slightly lighter load to lift because the drive machinery is supported at the tower as opposed to the riding on the moving structure.

Pier 2, the West tower pier, is placed west of the existing West rest pier, and Pier 3, the East tower pier, is located within the existing East channel, limiting the channel usage to the west side of the existing swing pier during construction of the new bridge.

Two steel deck-girder approach spans on each of the west and east sides flank the lift span. Pier 1 is placed between the existing Pier 1 and the enclosed walkway that passes between adjacent buildings and may require a special configuration to maintain pass-through access at the walkway garage doors. The west approach span lengths are such that the proposed deck-girder spans could possibly double as temporary spans over the channel (spanning from rest pier to swing pier to rest pier) after the swing span is removed during construction. Approach Pier 4 is placed east of existing Pier 4. New abutments are required at both ends because the existing substructure is unable to accommodate the overall width increase of the bridge.

The lift span has an open-deck floor system of simply supported stringers (one below each track) between floorbeams at every panel point. The structural steel truss is a Warren-type with verticals with six 30’ panels. The overall depth of each truss is 35’ and with transverse spacing of 33’-4” between truss planes. This truss configuration provides 26’ of vertical clearance from Top of Rail to the overhead structure and 9’ lateral clearance from the track centerline for trains crossing the span. Lateral bracing is provided in the horizontal planes of both top and bottom chords. The lift span provides approximately 25’ of clearance in the down position, approximately 9’ more than the existing swing span. To achieve 60’ of vertical clearance at mean high water, the lift span is raised 35’ (Figure 5-22).

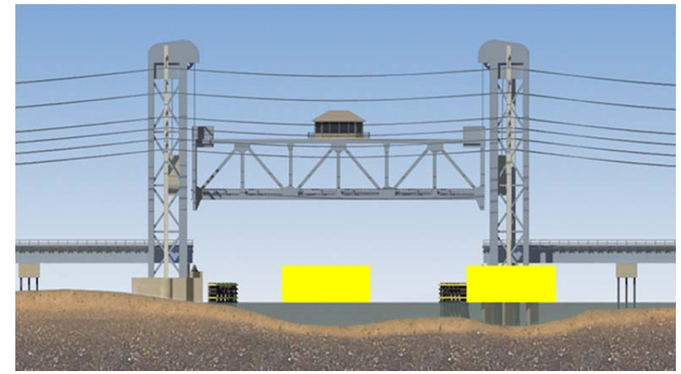


Figure 5 - 22 – Option 8A, Full Open Position

To demonstrate the channel alignment of Option 8A relative to the East and West Navigation channels provided by the existing swing span in the closed position, yellow clearance diagrams representing the swing span navigation channels are included in Figure 5-22.

Because much of the machinery is located on the lift span, it can be installed and aligned in the fully assembled truss prior to the movable span being set between the towers. Once the leaf is installed, it can be made operable in as little as one day.

Foundations for the bridge are anticipated to be deep foundations socketed into rock. The approach piers can be micropile foundations with a pile cap to allow for low vertical clearance installation below the existing structure. Each main tower pier is supported on six 8’-diameter drilled shafts and a cap slab. Each pier supports a six-column steel tower from which the lift spans are suspended. The tower pier caps support the tower columns as well as the approach span bearings, lift span bearings and centering devices on top of reinforced concrete pedestals.

The towers are approximately 145’ tall from the top of the foundation to the centerline of the counterweight sheaves. The machinery enclosure on top potentially conflicts with the existing high tower lines. During construction, the high towers are likely to require relocation prior to fully erecting the towers. The spacing between the front and back legs of each tower is controlled by the spacing required for the mechanical and electrical equipment.

The structural separation between the center tracks facilitates the construction phasing to maintain a minimum of two tracks active during construction at all times (except for a brief weekend closure for all tracks). Eight drilled shafts of the tower piers are located outside of the existing structure footprint and can be constructed without disrupting rail and waterway traffic.

Construction costs, construction schedules and lifecycle costs are presented in the following section. Mechanical, electrical and architectural features are outlined in Appendix G.

Summary

The following table highlights some of the advantages and disadvantages of Option 8A relative to other main span alternatives.

Advantages	Disadvantages
Discuss relative initial and life cycle Cost $xx,xxx,xxx	Discuss relative initial and life cycle Cost $xx,xxx,xxx
Discuss relative schedule of reduced track operation	Discuss relative schedule of reduced track operation
Discuss relative schedule of limited vertical clearance	Discuss relative schedule of limited vertical clearance
Discuss relative overall schedule	Discuss relative overall schedule
1. Optimum span length for bascule truss span 2. Increase in horizontal navigation clearance and improved alignment with Stroffolino Bridge 3. Approximately 9' of additional vertical clearance relative to the existing conditions when the span is in the closed position 4. Improved channel hydraulics with open lift span piers 5. No cofferdams required for lift span pier construction 6. Minimal potential impacts to buildings at the west approach 7. One set of drive machinery and associated electrical components to install and maintain per movable structure 8. Operating machinery and electrical controls are installed on the movable span prior to span installation 9. Unobstructed views from the control house 10. Span arrangement and staging allows for reuse of temporary channel spans in the final span layout.	1. Span length is generally considered on the lower end for efficient vertical lift spans 2. Reconstruction of west abutment 3. Moderate track work at east approach 4. Moderate earthwork at east approach 5. Scale of structure in stark contrast with existing bridge.

5.3.5 Option 11C

Option 11C is a tower-driven 250' vertical lift bridge with an open-deck through-truss lift span providing a minimum of 220' horizontal navigational clearance and 60' vertical clearance when the span is fully raised. The main span length is dictated by the locations of the proposed lift span piers (Pier 2 and 3) relative to the existing rest piers. Each lift span will have its own machinery, electrical system and counterweights to allow each span to operate independently. Track spacing of 25 between Tracks 1 and 2 is required for structural and mechanical clearance between the lift spans. The alignment of Tracks 1 and 3 alignment remains close to the current alignment with the new tracks 2 and 4 shifted further south from the current location. Conceptual Bridge Plans for Option 11C, including a suggested construction sequence, are included in Appendix B.

A comparative view of Option 11C and the existing bridge is shown in Figure 5-23.

a)

b)

Figure 5 - 23 – Comparative Elevation - - a) Option 11C and b) Existing Bridge

Similar to 8A, the lifts spans can be either span-driven or tower-driven (as shown in this Conceptual Report). For the tower-driven option, the machinery is housed within an enclosure at the top of each tower, yielding a modest reduction in the weight of the movable span relative to the span-driven variation of this structure type. The counterweight ropes are anchored on the span side to the lifting girders which span transversely between truss upper chords at the end panel points. The estimated load to lift each span is 4000 kips for the tower–driven option.

Pier 2, the West tower pier, is placed west of the existing West rest pier, and Pier 3, the East tower pier, is located outside the existing East rest pier, minimizing disruptions to maritime traffic in both the East and West channels during construction. Pier 1 is placed between the existing Pier 1 and the enclosed walkway that passes between adjacent buildings. New abutments are required at both ends because the existing substructure is unable to accommodate the overall width increase of the bridge.

The lift span has an open-deck floor system of simply supported stringers (one below each track) between floorbeams at every panel point. The structural steel truss is a Warren-type with verticals with ten 25' panels. The overall depth

of each truss is 38' and with transverse spacing of 33'-6" between truss planes. This truss configuration provides 26' of vertical clearance from Top of Rail to the overhead structure and 9' lateral clearance from the track centerline for trains crossing the span. Lateral bracing is provided in the horizontal planes of both top and bottom chords. The panel length was selected to limit the span length and, in turn, the depth of the floor system to provide for maximum vertical clearance when the span is closed. The lift span provides approximately 28' of clearance in the down position, approximately 12' more than the existing swing span. To achieve 60' of vertical clearance at mean high water, the lift span is raised 32' (Figure 5-24).

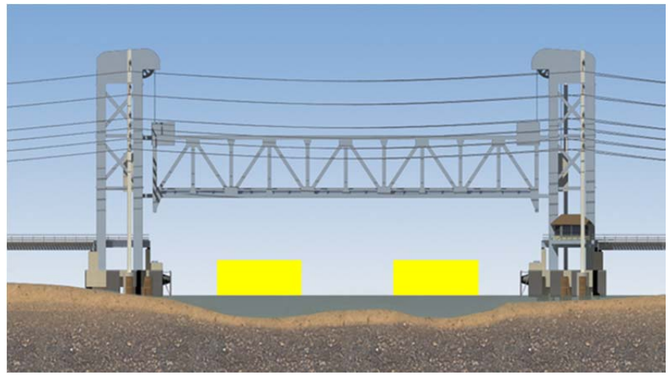


Figure 5 - 24 – Option 11C, Full Open Position

To demonstrate the channel alignment of Option 11C relative to the East and West Navigation channels provided by the existing swing span in the closed position, yellow clearance diagrams representing the swing span navigation channels are included in Figure 5-24.

Operating machinery is located at the top of each lift span tower and housed within a machinery enclosure. The control house is located on the south side of Pier 3.

Foundations for the bridge are anticipated to be deep foundations socketed into rock. The approach piers can be micropile foundations with a pile cap to allow for low vertical clearance installation below the existing structure. Each main tower pier is supported on six 12'-diameter drilled shafts and a cap slab. Each pier supports a six-column steel tower from which the lift spans are suspended. The tower pier caps support the tower columns as well as the approach span bearings, lift span bearings and centering devices on top of reinforced concrete pedestals.

In lieu of a free-standing fender system, the main piers can be protected from vessel collision by a super cone system mounted to the face of the piers due to the excessive width of the navigation channel and corresponding reduction in the risk of vessel collision. This type of system eliminates the need to drive piles for a fender system in the channel.

The towers are approximately 145' tall from the top of the foundation to the centerline of the counterweight sheaves. The machinery enclosure on top potentially conflicts with the existing high tower lines. During construction, the high towers are likely to require relocation prior to fully erecting the towers. The spacing between the front and back legs of each tower is controlled by the spacing required for the mechanical and electrical equipment.

The structural separation between the center tracks facilitates the construction phasing to maintain a minimum of two tracks active during construction at all times (except for a brief weekend closure for all tracks). Eight drilled shafts of the tower piers are located outside of the existing structure footprint and can be constructed without disrupting rail and waterway traffic.

Construction costs, construction schedules and lifecycle costs are presented in the following section. Mechanical, electrical and architectural features are outlined in Appendix G.

Summary

The following table highlights some of the advantages and disadvantages of Option 11C relative to other main span alternatives.

Advantages	Disadvantages
Discuss relative initial and life cycle Cost $xx,xxx,xxx	Discuss relative initial and life cycle Cost $xx,xxx,xxx
Discuss relative schedule of reduced track operation	Discuss relative schedule of reduced track operation
Discuss relative schedule of limited vertical clearance	Discuss relative schedule of limited vertical clearance
Discuss relative overall schedule	Discuss relative overall schedule
1. No bobtailing of the swing span is needed. The longest time of a bridge project is the substructure construction. With the long vertical lift option, the substructure can be built by having 16-24 hrs. track closure for 4 tracks. 2. Resilient structure due to system, internal and load path redundancy. 3. Less impact on the main channel due to the location of proposed main piers outside the existing channel. 4. Reduced risk of vessel collision. 5. Reduced risk of potential scour due to the location of proposed main piers outside the existing channel. 6. Potential use of composite fender system which eliminates the need of driving fender piles in the channel. 7. Increased horizontal navigational clearance 8. Increased vertical clearance between the proposed low steel and mean high water when span is in down position. 9. Provides the opportunity to the contractor to construct the piers from work platforms rather than from a barge. 10. Favorable environmental permitting, as the piers are outside the main channel and no piles are driven for the proposed composite fender system.	1. Longer movable span compared to required channel width though there is one less number of rest pier. 2. Removal of existing pivot pier and pivot pier piles under the new span is challenging. 3. Superstructures will be sitting on the top of pier pedestal. Long term maintenance of the pedestals may not be cost effective. 4. Scale of structure in stark contrast with existing bridge.

5.4 Track Alignment Options

5.4.1 Existing Conditions

The Walk Bridge in Norwalk, Connecticut is located on the Metro-North Railroad New Haven line on the Northeast Corridor at approximately Milepost 41.5 between the South Norwalk Station and the East Norwalk Station. The bridge is oriented in east/west direction and carries 4 tracks with a track spacing between 12’ and 13’. The track designations from north to south are Track 4 (eastbound), Track 2 (eastbound), Track 1 (westbound) and Track 3 (westbound). The existing horizontal track alignment situates the movable swing span on a horizontal tangent between reverse curves that is approximately 750’ in length. To the west of the movable span are simple and compound curves that swing to the south and are capable of 45mph. To the east of the movable span are two right-hand #10 crossover moves between Tracks 1 and 2 and between Tracks 2 and 4. These crossovers are tightly fit between the eastern bridge abutment and the start of 70mph curve that swings to the north. A schematic of the track configuration between South Norwalk Station and the East Norwalk Station can be seen in Figure 5-25.

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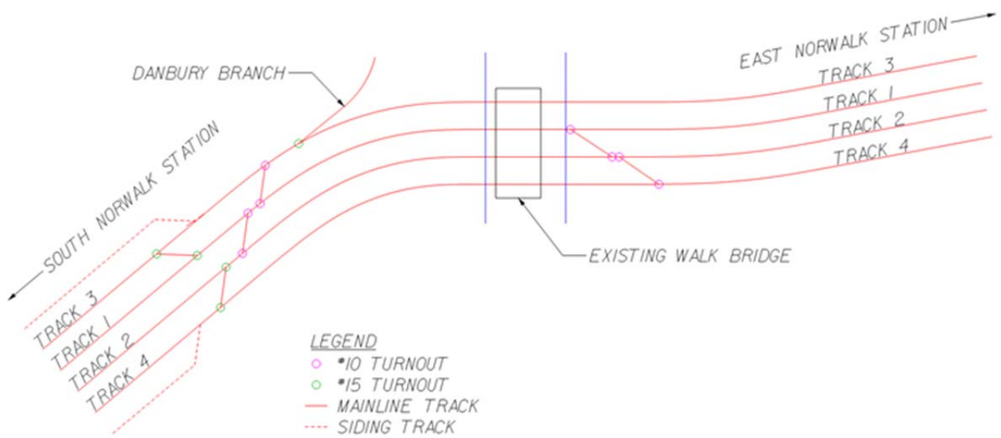

Figure 5-25 – Existing Walk Bridge Track Schematic

5.4.2 Proposed Alternatives

The main challenge associated with replacing the existing single movable span is achieving the required track spacing to facilitate having two separate movable spans. This is in large part due to the close proximity of buildings adjacent to the existing tracks. Specifically on the west approach is the Maritime Aquarium which has buildings located as close as 18.5’ on the north side and 38’ on the south side, both of which are located east of Water Street. On the west side of water street, along Track 4, there is a residential building with condos as well as commercial space that is as close as 30’. Further west, just east of the bridge over Main Street, the tracks are elevated on a retained fill section whose retaining structure is less than 8’ from the centerline of the existing Track 4 with what is essentially zero clearance between this wall and buildings adjacent to the wall. This location proved to be the controlling constraint in terms of how far Track 2 and Track 4 modification are able to extend to the west and therefor controlling how much these tracks are able to shift to the south and still meet the design criteria.

For the purposes of this report three different alignment alternatives have been developed that work with the five proposed bridge options. In addition to the alignments developed for the final configurations and temporary run-around alignment has been developed along with temporary connections from Track 1 to Track 2 west of the bridge to facilitate the construction staging of the different options. Below is a summary of the different alignment options with the corresponding bridge type.

- Track Alignment Option 3A: 16’ Track centers between Tracks 1 and 2

  3A – Bascule Bridge

- Track Alignment Option 8A/11C: 25’ Track centers between Tracks 1 and 2.

  8A – Lift Bridge

  11C – Lift Bridge

- Track Alignment Option 2G/4S: Non-parallel parallel alignment

  2G – Bascule Bridge

  4S – Bascule Bridge

- Run-around alignment: 15mph temporary alignment on structure north of Track 3
- Temporary Track Throw Alignment: Track 1 to Track 2 throw to facilitate construction staging.

All of the proposed options increase to the existing track space on the bridge to a minimum spacing of 13’ between Tracks 1 and 3 and between Tracks 2 and 4 with an additional increase in spacing between Tracks 1 and 2 to facilitate two separate movable spans. The alignment options 3A and 8C/11A maintain parallel tracks through the new bridge while the 2G/4S option establishes the new movable spans as being non-parallel.

All of the proposed alternatives shift Tracks 2 and 4 to the south on the east end of the bridge. This has the effect of shifting the Track 4 curve east of the bridge to the west which results in a decrease in the length of tangent track between the existing west abutment of the bridge and the beginning of the shifted curve. The existing length of this tangent is only just long enough to allow for the crossover moves between Track 1 and 2 and between Tracks 2 and 4 to be located on tangent track. Any reduction in this length would require the crossovers to be partially located on the bridge, partially located on the curve or shifted to a new location entirely. Because of the need to maintain optimal operations during construction and the desire to use standard turnout geometry that is kept of the bridge, the preference is to replace the displaced #10 crossovers with a full universal interlocking comprised of #20 tangential turnouts, the likely location of which would be in the vicinity of the tangent geometry to the east and west of the East Norwalk Station.

All options are described in greater detail below and Conceptual Track Alignments are included as Appendix C.

5.4.3 Option 3A Track Alignment

Of the options developed for this report the 3A options requires the least amount of track re-alignment. For this option the existing geometry for Track 3 is maintained for the final configuration with Tracks 1, 2 and 4 being realigned to be parallel to Track 3 with 13’ spacing between Tracks 1 and 3, 16’ spacing between Tracks 1 and 2 and 13’ spacing between tracks 2 and 4. For Track 1 the realignment required is minimal as the shift in track on the new span is approximately 6”. The impact on the curves to the west and east are also minimal allowing for the same curve attributes to be maintained. For the Track 1 curves to the west the existing degree of curvature is maintained at Dc=4^-5’-30” along with the existing superelevation of Ea=3.75” resulting in an unbalance of Eu=2.05”. For the Track 1 curve to the east the curve is maintained at Dc=2^-0’-0” but the superelevation is increased from Ea=3.75” to Ea=4” in order to keep the unbalance elevation below the maximum of 3” resulting in a Eu=2.86” at 70mph.

In order to achieve the Track 1 to Track 2 spacing of 16’ Track 2 was required to shift approximately 3.5’ through the location of the bridge span from its existing location. Due to the horizontal clearance restraints of the building adjacent to Track 4 the Track 2 realignment could not extend beyond a point approximately 200’ east of the Main Street Bridge. This required the introduction of a third circular curve into the existing compound curve by inserting a 62’ spiral that transitioned from the existing degree of curvature of Dc=4^-5’-22” to a Dc=4^-24’-0”. Maintaining the existing superelevation of Ea=3.75” the unbalance increases slightly from Eu=2.05” to Eu=2.49”. For the curve to the east the existing degree of curvature is maintained at Dc=2^-0’-0” with a slight increase in the superelevation from Ea=3.75” to Ea=4” in order to keep the unbalance below the maximum of 3” resulting in a Eu=2.86” at 70mph.

Track 4 is established parallel to the relocated Track 2 with a track spacing of 13’ which constitutes an approximate shift from its existing location of 4’. Similarly to Track 2 the Track 4 realignment cannot extend beyond a point 200’ east of the Main Street Bridge due to horizontal clearances to buildings adjacent to Track 4. As was necessary for Track 2 any shifting of Track 4 through the bridge span requires the insertion of an additional circular curve to the existing compound curve west of the bridge. This is accomplished by inserting a 62’ spiral to transition from a curve with a degree of curvature of Dc=4^-9’-8” to Dc=4^-24’-0”. Maintaining the existing superelevation of Ea=3.75” the unbalance elevation increases slightly from Eu=2.14” to Eu=2.49”. For the curve to the east the existing degree of curvature is maintained at Dc=2^-0’-0” with a slight increase in the superelevation from Ea=3.75” to Ea=4” in order to keep the unbalance below the maximum of 3” resulting in a Eu=2.86” at 70mph.

5.4.4 Option 8A/11C Track Alignment

This option is identical in nature to Option 3A in that it provides for parallel track alignments that are based on the existing Track 3 geometry and build out the wider track spacing to the south. The only difference between the options is that 8C/11A increases the track spacing between Tracks 1 and 2 from 16’ to 25’ requiring Track 2 to shift from its existing location by approximately 12.5’ and Track 4 to shift approximately 13’ from its current location. Similarly to Option 3A the modifications required for Tracks 2 and 4 cannot extend beyond the point 200’ east of the bridge over Main Street due to the restrictive horizontal clearances adjacent to Track 4. For both tracks the introduction of a third circular curve into the existing compound curves is required to achieve the new track spacing. For Track 2 a 62’ spiral is introduced to transition from a degree of curvature of Dc=4^-5’-22” to curve with Dc=4^-50’-46” Through the spiral the superelevation is increased from Ea=3.75” to Ea=4” resulting in an unbalance of Eu=2.87”. For Track 4 the inclusion of a 62’ spiral is used to transition from a degree of curvature of Dc=4^-5’-22” to a curve with Dc=4^-50’-46” and increase the superelevation from Ea=3.75” to Ea=4” resulting in an unbalance of Eu=2.95”.

On the east side of the river the existing 70mph curves are all maintained at the existing degree of curvature of Dc=2^-0’-0” with the superelevation increased from Ea=3.75” to Ea=4” in order to keep the unbalance below the design criteria maximum of 3”. The resulting unbalance elevation for all easterly curves at 70mph is Eu=2.86”.

5.4.5 Option 2G/4S Track Alignment

This option provides for the replacement of the single non-movable span with two non-parallel movable spans by having the tracks splay out increasing the separation between Tracks 1 and 2 as they cross the river to the east. The benefit of this is that it shifts the majority of the impacts to the existing infrastructure and adjacent properties from the west side of the river to the east side where the constraints are fewer.

For the northern movable span carrying Tracks 1 and 3 the new bearing was established my maintaining the existing Track 3 curvature and superelevation while rotating the tangent through the bridge about the center of the curve realigning the track to a more northerly direction. On the east side of the river this has the effect of shifting the curve east and into the limits of an existing bridge over Four Point Street resulting in a shift of approximately 5’ through the bridge. The new easterly curve of Track 3 has a degree of curvature of Dc=1^-30’-0” with a superelevation of Ea=3.75” and an unbalance of Eu=1.4” at 70mph.

Track 1 was established as being parallel to Track 3 with 13’ track centers to Track 1 through the new bridge. The curvature on the west is maintained with a degree of curvature of DC=4^5’33” and superelevation of Ea=3.75” and an unbalance of Eu=2.05”. Similarly to Track 3 the curve on the east end is shifted further to the east and pushed within the limits of the existing Four Point Street Bridge. The new easterly curve of Track 1 has a degree of curvature of Dc=1^-30’-0” with a superelevation of Ea=3.75” and an unbalance of Eu=1.4”.

For the southern movable span the bearing was established by maintaining the existing Track 2 curvature on the west while rotating the tangent through the bridge towards the south until a track spacing of 33’ was achieved in the vicinity of existing swing span pivot pier. This had the effect of pulling the easterly curve on Track 2 approximately 260’ closer to the easterly bridge abutment. This curvature is maintained at the existing degree of curvature of Dc=2^-0’-0” with the superelevation increased from Ea=3.75” to Ea=4” in order to keep the unbalance below the design criteria maximum of 3”. The resulting unbalance elevation for this curve at 70mph is Eu=2.86”.

Track 4 was established as being parallel to Track 2 with 13’ track centers to Track 2 through the new bridge. The curvature on the west is maintained with a degree of curvature of DC=4^-5’-22” and superelevation of Ea=3.75” and an unbalance of Eu=2.05”. Similarly to Track 2 the curve on the east end is shifted closer to the easterly bridge abutment. This curvature is maintained at the existing degree of curvature of Dc=2^-0’-0” with the superelevation increased from Ea=3.75” to Ea=4” in order to keep the unbalance below the design criteria maximum of 3”. The resulting unbalance elevation for this curve at 70mph is Eu=2.86”.

5.4.6 Run-around Alignment

A temporary run-around alignment option was developed for use with the Option 2G/4S geometry in order to allow for accelerated construction of the bridge by being able to construct the two movable spans concurrently and not having to stage the construction. The geometry for the run-around alignment ties into existing Track 3 on the west and into the 2G/4S geometry on the east and allows for 15mph service over the river. Physical constraints near the northwest end of the existing Walk Bridge, as shown in Photo 5-3, prevent optimization of the run-around alignment for the purposes increase track speeds on the temporary alignment.

Photo 5 - 3 – View looking east from Track 3 (north edge of Walk Bridge)

Being that the run-around alignment is only good for 15mph and is tying directly into a 45mph curve with a superelevation of Ea=3.75” the new speed for the existing curve will need to be reduced to 15mph for the duration that the temporary run-around track is in service. In order to facilitate the reduced speed the curve would be resurfaced to reduce the superelevation from Ea=3.75” to Ea=1”. Since equipment is likely be accelerating through the existing curve once clear of the run-around alignment the reduced superelevation would allow for speeds of 15mph through this curve with an unbalance elevation of Eu=-0.35” while accelerating equipment could reach 30mph through curve resulting in an potential unbalance of Eu=1.60”.

The transition from the existing curve to the run-around alignment would take place over a 62’ spiral where the superelevation is reduced from the modified Ea=1” to Ea=0” before transitioning into a 45’ tangent. This tangent length is less than the design criteria stated minimum length of 100’, but due to the low operating speeds and temporary nature of the geometry it is the recomendation of this report that the impacts of operating equipment over the substandard tangent length are outweighed by the benefits of being able to significantly accelerate construction and reducing the duration the run-around track is required to be in service. The 45’ tangent leads into a curve with a degree of curvature of Dc=5^-30’-0” with a superelevation of Ea=0” resulting in an unbalance elevation of Eu=0.87” at 15mph. Because of the limited space required to swing the run-around track out far enough to facilitate the construction of the proposed bridge piers and back in on the east side spirals are not used on this curve. Forgoing the use of spirals and superelevation on the curve are in violation of the design criteria, but again, due to the slow operating speeds and temporary nature of the run-around alignment it is the finding of this report that the benefits of the run-around alignment far outweighs the effects of not meeting these aspects of design criteria for a limited duration.

Beyond this the alignment transitions into a 160’ long tangent before entering a curve with a degree of curvature of Dc=9^-48’-22” with 31’ spirals that provide for a superelevation of Ea=0.50” resulting in an unbalance elevation of Eu=1.04”. Past this curve the run-around swings back towards existing Track 3 to tie into the proposed Option 2G/4S geometry via curve with a degree of curvature of Dc=3^-35’-43” and a superelevation of Ea=0.5” with a resulting unbalance elevation of Eu=0.07” at 15mph. Beyond this curve the alignment is in its final configuration for the 2G/4S option described above.

Track 1 for the run-around alignment is established with a 14’ offset to Track 3 to provide necessary clearance to Track 1 due to the excesses that are the result center and end overhang of the equipment as it navigates the curves. All curve attributes and criteria violations that exist for the Track 3 run-around alignment also exist for the Track 1 run-around alignment.

A run-around alignment located to the south of the Walk Bridge was determined not to be feasible due to physical constraints and right-of-way needs.

5.4.7 Temporary Track 1 and Track 2 Connection

For Options 3A and 8C/11A the construction staging will require the operation of 2 track service on new Tracks 2 and 4 with Tracks 1 and 3 out of service. This requires a temporary connection from Track 1 to Track 2 in order to enable westbound trains to platform on the westbound platform at South Norwalk Station. In order to achieve this shifting of service without realigning Track 1 on the open deck structure over Main Street and second circular curve needs to be added to Track 1 making it a compound curve.

For Option 3A the temporary connection has to connect from existing Track 1 to the west with a new Track 2 that is shifted south 3.5’ from its existing location. This requires the insertion of 62’ spiral to transition from the existing degree of curvature of Dc=4^-5’-33” to a degree of curvature of Dc=4^-51’-27”. The superelevation through the modified curve is increased from Ea=3.75” to Ea=4” resulting in an unbalance elevation of Eu=2.89” at 45mph.

For Option 8C/11A the connection needs to be made to a relocated Track 2 that is even further away from existing location and 9’ further south than it is in Option 3A. In order to facilitate this connection a 31’ spiral is inserted to transition from the existing degree of curvature of Dc=4^-5’-33” to a degree of curvature of Dc=5^-0’-0”. Through the 31’ spiral the superelevation is increased from Ea=3.75” to Ea=4” resulting in an unbalance elevation of Eu=3.09” at 45mph.

5.5 Catenary

There have been recent catenary modifications under state project number 301-0145 on the east and west of Walk Bridge. The catenary is currently being modified east of the east approach. The west approach catenary work has already been completed. As the Walk Bridge replacement will require the modification to catenary structures on the east and west approach, all catenary modifications performed under the recent projects will be taken into account and replaced in kind.

Reconstruction of the existing Walk Bridge will progress by replacing two of the four tracks with an independent lift or bascule bridge system. Revenue service operations must continue during construction, with at least two tracks being open to train traffic at all times. To maintain revenue service, the existing bridge will typically be deconstructed and the new bridge constructed in two track segments. This could be achieved by replacing 2 tracks of the existing swing span, removing the entire swing span and replacing with a temporary two/three track fixed span, or by using a two track temporary run-around bridge.

The catenary on the approach and swing section is presently being supported by portal structures. To facilitate the removal of existing bridge spans, existing portal structures will need to be replaced by temporary cantilever structures, where needed. The new temporary cantilever structures will be attached to the approach span’s external girders, built onto the temporary fixed span, or incorporated in the temporary piers, dependent on which option is chosen.

Upon completion of the new bridge, there will be two new portal structures on the new lift/bascule span; one at each end matching the existing termination structures on the before approach spans. The remaining portions of the catenary within the project limits will be supported over the proposed track alignment by new portal or cantilever structures or by modifying existing structures.

The catenary leading up to the approach spans will be of the constant tension type, while the catenary on the new lift/bascule span will be of the fixed termination, variable tension type. In both cases the messenger wire will be 4/0 copper-copperweld and the contact wire will be 350 KCMIL grooved bronze Alloy 80. All catenary will be supported utilizing Metro North standard components.

For the west approach, fixed conductor rail, support columns and new disconnect switches on the termination structure will be installed. For the east approach, fixed conductor rail, support columns along with movable conductor unit (MCU) and new disconnect switches on the termination structure will be installed, depending on the options. New independent OCS, including conductor rail supports, conductor rail, passive disconnect switches, grounding clips, in-line horns and indication system equipment will be mounted on lift/bascule span and installed while the span is at an off-site location.

Conceptual Catenary Plans are included as Appendix D.

5.6 High Tower Relocation

The existing High Towers will be removed from the critical path and relocated prior to any other construction. The existing MNR bare, aerial power conductors and aerial communication, signal cables, and the CL&P 115kV transmission lines will be relocated from the existing steel lattice towers to new single tubular steel structures. The main goal for the relocation of the high towers is to eliminate temporary supports during construction and to maintain navigation clearances.

5.6.1 Conductor/Cable Layout

This general arrangement of conductors/cables is consistent on every new single tubular steel structure. Conceptual design of the conductor/cable layouts are in accordance with the US Coast Guard, Army Corps of Engineers, NESC and the Northeast Utilities Overhead Transmission Line Standards for horizontal and vertical clearances.

Service	Designation	Voltage	Present Number	Future Number	Present Size	Future Size	Notes
CL&P Transmission Lines	N1, N2, N3,	115	3	3	1590 ACSR	1590 ACSR	
	S1, S2, S3	115	3	3	1272 ACSR	1272 ACSR	
3-phase service	AN1, AN2, AN3, AS1, AS2, AS3	35	6	0	4/0	-	To be removed/not required
Ground Wire	G1, G2, G3, G4	G	4	2	500 KCmil	500 KCmil	
Signal Power	S1, S2, S3, S4	25	4	4	2/0	2/0	
Traction Jumpers	T1, T2, T3, T4	35	4	4	500 KCmil	500 KCmil	
Control Wires	C1, C2	35	2	2	4/0	4/0	
Traction Feeders	F1, F2, F3, F4	35	4	4	4/0	4/0	
Equalizing Strands	M1, M2	-	2	0	-	-	To be removed/not required
Spare	SP	-	2	2	2/0	2/0	

Table 5-5 – High Tower Conductor Layout

5.6.2 Clearance Requirements

The height of the single tubular steel structures will be such that the lowest conductor at maximum sag will maintain a minimum height of 80 feet above the high water elevation. After discussions with the USACE, the vertical clearance heights to be used with for the overhead wires are to be 60’-0” (based from the height of the 95 Bridge plus an additional 20’-0”). The new single tubular steel structures required to comply with this clearance limitation will be significantly shorter than the existing steel lattice high towers.

The cables on the new tubular steel structures on the west approach will pass over buildings (marina and residential) at the west abutment on the north and south sides of the proposed bridge options, aligned with the new piers in the channel. The maximum sag on the lowest attached conductor will maintain a minimum height of 12.5’ with and addition of 0.4” per kV in excess 12kV from NESC 234.G.1 and Table 234-1. Using 115kV in the equation to be conservative the minimum vertical clearance of 16’-0” over buildings is obtained.

Vertical clearances between 115kV, 13.2kV or 12kV wires will be at a minimum of 8’-0” according to the Northeast Utilities Overhead Transmission Line Standards, also vertical clearances between two 115kV wires will be at a minimum of 9’-0. Vertical clearance equation between 13.2kV or 12kV conductors is 40" with and addition of 0.4" per kV in excess of 8.7kV for open supply conductor of different utilities as per NESC Table 235-5. Using 13.2kV in the equation to be conservative a minimum vertical clearance of 4.21’ is obtained.

The horizontal clearance from a building wall or a bridge is 7.5’ with and addition of 0.4” per kV in excess of 22kV from NESC Table 234-1 and NESC 234.G.1. Using 115kV in the equation to be conservative an overall minimum horizontal clearance of 10’-7 1/4” is obtained. To be conservative and for ease of construction for the proposed bridge options, a horizontal clearance of 20’-0” will be utilized. The horizontal clearance between 115kV, 13.2kV or 12kV wires will be set at a minimum of 7’-0” according to the Northeast Utilities Overhead Transmission Line Standards, also minimum horizontal clearance between two 115kV wires are set to 8’-0”. The horizontal clearance equation between 13.2kV or 12kV conductors is 12" with and addition of 0.4" per kV in excess of 8.7kV for supply conductors of different circuits per NESC 235.B.1.a and Table 235-1. Using 13.2kV in the equation to be conservative we get a minimum horizontal clearance of 1.88’. To be consistent and conservative a minimum of 8’-0” was used for all horizontal clearances between wires.

5.6.3 High Tower Relocation Options

Option 1

MNR and CL&P – Aerial on shared structures, conductors on both sides of proposed towers. A total of eight new single tubular steel structures will replace the existing two steel lattice high towers. On the north and south side of the proposed piers in the waterway, four new high towers will be erected. These high towers will be erected on drilled shaft foundations to the depth of bedrock and in line with the piers so they do not affect the new navigation channel. The other four single tubular structures will be on the west and east approaches near the existing steel lattice high tower columns to relocate existing high towers 529 and 530 ancillary wires. All wires will be located on both sides of singular tubular steel structures. The davit arms to support the conductor wires will be designed to support the termination load if the need arises during transfer of the wires to be temporarily deadened.

The single tubular structures will be located approximately 20’ outward from the proposed bridge piers in the waterway and will be approximately 100 feet high. The heights of the tubular steel structures are measured from the top of foundation elevation, which will be approximately equal to the top of the proposed bridge piers. The structures will be tubular steel, fabricated of galvanized steel that will not require painting or similar maintenance. See Figure HT-1 for plan view and Figures OPT-1 B & OPT-1 L for elevation view.

Option 1: Advantage v Disadvantage	
Advantages	Disadvantages
System redundancy Shorter structure lengths	Potential for construction conflicts 4 foundations in waterway

Option 2

MNR and CL&P – Aerial on shared structures, conductors on one side of proposed towers. Option 2 is the same as option 1, however all wires will be located on only one side of the single tubular steel structures. The single tubular structures will be approximately 130 feet high. See Figure HT-2 for plan view and Figures OPT-2 B & OPT-2 L for elevation view.

Option 2: Advantage v Disadvantage	
Advantages	Disadvantages
System redundancy No wires above bridge	Potential for construction conflicts 4 foundations in waterway Longer structure lengths Larger moment on foundations

Option 3

MNR and CL&P – Aerial on shared structures, proposed towers erected on the north side of waterway and proposed deadend towers erected on the south side of the waterway. A total of six new single tubular steel structures will replace the existing two steel lattice high towers. On the north side of the proposed bridge options, two new high towers will be erected in line with the proposed bridge piers to keep the south side clear for ease of construction of the proposed bridge. The remaining four single tubular structures will be on the west and east approach to the north and south of the tracks near the existing steel lattice high tower columns to relocate existing high towers 529 and 530 ancillary wires. All wires will be located on both sides of the singular tubular steel structures. The davit arms to support the conductor wires will be designed to support the termination load if the need arises during transfer of the wires to be temporarily deadened. MNR will deadend the bare wires on the two new structures on the south side of the bridge. The bare wires will be bundled into insulated cables and the cables will travel in conduit down the structure, into a duct bank that will cross beneath the four tracks to the new structures on the north side of the track. The insulated cables will travel up the north structures in conduit where they will finally be transferred to bare aerial to cross the waterway. The 4 new structures on the north side will be approximately 129 feet high. The two new structures on the south side will be approximately 100 feet high. See Figure HT-2 for plan view and Figures OPT-3 B & OPT-3 L for elevation view.

Option 3: Advantage v Disadvantage	
Advantages	Disadvantages
No construction obstructions on south side of bridge 2 foundations in waterway	No system redundancy Longer structure lengths High loads on foundations Requires duct bank under tracks

Option 4

MNR and CL&P – Aerial on shared structures, conductors on one side of proposed towers. Option 4 is similar to Option 2, however all wires will be located on the inside (bridge side) of the single tubular steel structures. This will prevent any transmission wires from being directly over buildings. The only wire that will travel over buildings are static wires, and static wires will be on the top of the structures and they do not carry any current. All wires will all be on their own davit arm. On the north and south side of the proposed piers in the waterway, four new high towers will be erected. These high towers will be erected on drilled shaft foundations to the depth of bedrock and in line with the piers so they do not affect the new navigation channel. The other six single tubular structures will be on the west and east approaches near the existing steel lattice high tower columns to relocate existing high towers 529 and 530

ancillary wires. The davit arms to support the conductor wires will be designed to support the termination load if the need arises during transfer of the wires to be temporarily deadened. The structures will be tubular steel, fabricated of galvanized steel that will not require painting or similar maintenance. The new tubular structures will be approximately 170 feet high.

Option 4: Advantage v Disadvantage	
Advantages	Disadvantages
System redundancy No wires above any buildings	Potential for construction conflicts 4 foundations in waterway Longer structure lengths Larger moment on foundations

5.6.4 Construction Sequence - - VLS/Bascule Span (Option 1 and 2)

Construct drilled shaft foundations all single tubular structures. Install new High Tower structures to allow for the relocation of the existing High Towers ancillary wires (MNR and CL&P wires). Single tubular structures (for the west and east approach, to relocate existing high towers 529 and 530 ancillary wires) will be utilized. On the north and south side of the proposed lift bridge, new high towers will be erected in line with the proposed piers. This approach of shortening the spans will allow the height of the high towers to be greatly reduced. When all new high towers are erected, transfer of the ancillary wires can take place from the existing high towers. Negotiations will be required between CDOT, MNR and CL&P for the relocation of CL&P utility wires to the proposed high tower structures. After all of the cables have been relocated and the unused cables removed, lead paint restrictions will be implemented, necessary shielding will be installed, and the existing steel lattice towers will be carefully disassembled and removed.

5.6.5 Construction Sequence - - VLS/Bascule Span (Option 3)

Construct drilled shaft foundations for all single tubular structures. Install new High Tower structures to allow for the relocation of the existing High Towers ancillary wires (MNR and CL&P wires). Install a duct back underneath the tracks between the proposed structures on the west and east of the bridge approaches. Four Single tubular structures (for the west and east approach, to relocate existing high towers 529 and 530 ancillary wires) will be utilized. On the north side of the proposed lift/bascule bridge, new high towers will be erected in line with the proposed piers. This approach of shortening the spans will allow the height of the high towers to be greatly reduced. When all new high towers are erected, transfer of the ancillary wires can take place from the existing high towers. Deadend the bare wires on the two new structures on the south side of the bridge. Bundle the wires into insulated cables and the run the cables in conduit down the structure, into the duct bank to the new structures on the north side of the track. The insulated cables will run up conduit and will then be transferred to bare aerial when crossing the waterway. Negotiations will be required between CDOT, MNR and CL&P for the relocation of CL&P utility wires to the proposed high tower structures. After all of the cables have been relocated and the unused cables removed, lead paint restrictions will be implemented, necessary shielding will be installed, and the existing steel lattice towers will be carefully disassembled and removed.

Conceptual Plans for High Tower relocations are included as Appendix E.

5.7 Signals and Communications

The control system design for the Walk Bridge Replacement structure will be interfaced with CP 241 Interlocking signal and communication system design. The technical scope of work includes the following:

1. Coordinate with CP 241 Interlocking Vital Microprocessor based Interlocking design.
2. Determine bridge operator control house location.
3. Review cable plans for line circuits between bridge control house, swing bridge equipment and CP241 Interlocking CIH.
4. Review signal and bridge control systems interface design.
5. Provide bridge control designs based on signal system lock/unlock logic.
6. Provide bridge system status indications for application in signal system.
7. Review I/O charts for bridge controls and indications interfacing with CP 241 Interlocking.
8. Review CTC/Local control panel layout and functionality with the new Norwalk Bridge controls and indications incorporated.
9. Review CP 241 Interlocking signal system vital design to ensure necessary signal protection for the bridge.
10. Review design of toe lock, heel lock, and rail seating indication arrangements to comply with Code of Federal Regulation Title 49 Part 236.312.
11. Review speed limiting factors over the bridge.
12. Review signal routing and aspect over the bridge.
13. Review single line and double line plans with the new Norwalk Bridge incorporated.
14. Review signal control line plans with the new Norwalk Bridge incorporated.
15. Review rail continuity for track circuits across the bridge.
16. Review rail continuity for traction power across the bridge.
17. Review design of proximity detectors to detect if the rails are seated.
18. Review miter rail heating element design.
19. Review bridge construction/cutover staging and tie-in design as require.
20. Provide support for testing and final cutover of Norwalk Bridge with CP 241 interlocking.

5.8 Additional Considerations for Replacement Options

5.8.1 Approach Spans

New approach spans for the replacement options are integral in determining the overall project costs, construction schedule and construction staging for each scheme. An evaluation of possible approach span types was conducted in order to identify

Approach Span Track Systems

Multiple track systems for approach spans were evaluated and the comparative analysis of these systems for use on the Walk Bridge replacement is as follows:

Open Deck Approach Spans	
Advantages	Disadvantages
Lower initial costs than either ballasted deck or direct fixation deck systems	More noise and vibration than other systems
Potential reuse of West Abutment	Possibility of debris falling through open deck
	Increased maintenance costs of both track and supporting structures

Ballast Deck Approach Spans	
Advantages	Disadvantages
Lower initial cost than direct fixation deck system	Greater dead load on supporting structure than either open deck or direct fixation deck
Less noise and vibration than open deck system	
Simple and inexpensive maintenance program typical of at-grade track maintenance	

Direct Fixation Approach Spans	
Advantages	Disadvantages
Less noise and vibration than other systems	Greater initial construction cost than other systems
Track locations are inflexible, minor realignments and adjustments are not needed	Inflexible track conditions limit future modifications
	Atypical maintenance and repair requirements

Approach Span Girder Systems

Steel and concrete superstructure systems were evaluated for new approach spans, and the comparative analysis of the structures types is as follows:

Steel Plate Girder or Rolled Beam Systems	
Advantages	Disadvantages
Long span efficiency	Ballasted deck section requires a concrete deck or steel pan
Good quality control is easily obtained	Needs cleaning and repainting periodically
Lighter weight sections to support same loads	Long lead time for fabrication and delivery
Easy to inspect and repair damage	
Adaptable to difficult framing requirements	

Precast Concrete Box or Beam Systems	
Advantages	Disadvantages
Low initial maintenance	Long span inefficiency
Requires minimal deck forming when ballasted deck is used	Heavier superstructure dead loads requiring more substructure capacity
Small deflections under live loads	Difficult to provide quality control during construction requiring more inspection
Short lead time for fabrication and delivery	Difficult to determine deterioration and repair damage

After carefully considering all aspects of open, ballast and direct fixation track systems, as well as steel and concrete approach superstructures, all replacement options have been developed using ballast deck steel deck plate girder or deck beam superstructures. This ballast deck system will reduce noise levels and facilitate future track maintenance. Additionally, the depth of the ballast depth superstructure will provide a vertical clearance improvement for the spans over Water Street.

The movable spans will be open deck and the fixed approach spans adjacent to the movable span will either be entirely open deck (for spans less than 50’) or will have a portion of the span being open deck to accommodate support of the miter rails before transitioning to ballast deck.

5.8.2 Bridge Mechanical

The following are general attributes of the mechanical design approach, applicable to all five alternatives. Additional mechanical design information specific to each alternatives is included in the detailed descriptions of the alternatives included in Appendix G.

a) Wind and ice loads are applied to 85 percent of the plan area for mechanical calculations due to open deck construction on all movable span alternatives.

b) Seismic design requirements dictate requirements for span locks and tail locks.

c) Time to operate the movable span is intended to balance requirements of the railroad and the navigation channel with economy of operation and maintenance.

d) For operational redundancy, movement of each movable span is accomplished by alternating between two main motors and drives in consecutive operations. No separate auxiliary drive will be provided.

e) For system resiliency, drive machinery is maintained above critical flood elevations and drive train components are configured to promote removal of any one component without requiring disassembly of other elements or assemblies.

f) Span locks are provided at the rest piers and, where required, at the bascule piers (tail locks). They are expected to be 10-hp crank-type mechanisms that drive a lockbar through two guides into a receiver located on the movable span when it is seated.

g) Centering devices are provided on the rest piers to align the span in the closed position prior to driving the span locks.

h) Two sets of electro-hydraulic thruster brakes are provided for each driver train, with one set of motor brakes at the main motors and one set of machinery brakes at the output shafts that move the bridge.

i) Flexible grid-type brake wheel couplings connect the motors to the central reducer. The arrangement of the hubs of the brake wheels will allow both motor brakes to remain in service with or without the associated motor being present should there ever be a need to remove the motor for servicing.

j) Mechanical instrument drives are used at the motors, at the shafts, and as required elsewhere for electrical indication and interlocking.

The type of operating equipment for the vertical lift span was a consideration in the overall layout of the structure, constructability and in the overall cost of the project for Options 8A and 11C.

A tower drive system provides the force to raise or lower the lift span to the suspending rope sheaves located at the top of the tower. The motive power is then transmitted to the suspending ropes by friction between the suspending ropes and the suspending rope sheaves. Since there is no mechanical connection between the two separate drive systems located on each tower, electrical controls must be used to unsure that one end of the bridge does not move at a different rate than the other, causing the lift span to skew. Even with electrical controls, there are rare instances where the suspending rope friction is not enough to adequately prevent skewed conditions.

A span driven lift span has the drive machinery located on the span. The machinery is connected to operating ropes at each corner of the span. One rope at each corner, called a downhaul rope, is attached to an operating drum, and the other end is attached to the tower near the bottom of the tower. Another rope at each corner, called an uphaul rope, is attached to the same operating drum, and the other end is attached to the tower near the top of the tower. The ropes are anchored to the operating drum such that when the drum rotates in one direction, the downhaul rope unwinds from the operating drum and the uphaul rope winds onto the drum, causing the span to rise. With a span drive system, the magnitude of the unbalanced forces will not cause any rope slippage or span misalignment.

It should be noted that Option 8A describes a span drive vertical lift span while Option 11C outlines the requirements for a tower drive vertical lift span. For both lift span options, the use of span drive and tower drive operating systems are essentially interchangeable.

Refer to Appendix G for additional mechanical design criteria.

5.8.3 Bridge Electrical

Conceptual designs of the electrical systems for all five alternatives are formulated around providing a safe, reliable, state-of-the-art system with features designed and configured to promote target levels of system resiliency and operation redundancy. A detailed description of the electrical design approach is included in Appendix G.

5.8.4 Bridge Architectural Criteria

Engineering requirements and constructability needs will dictate the type of movable structure, but the recommended option will also be designed to complement the settings of the current site in South Norwalk. Norwalk has a rich history of architectural styles since its founding as part of the English colonies, to the Revolutionary war, to the Industrial Age of the mid 1800's when the railroad became prominent, its adjacency to the sea, and to the present day with a bustling downtown office center. Yet the historical nature of the older part of South Norwalk, with its revitalization as a "SONO", signifies the importance of respecting the existing architecture without mimicking it completely. The Maritime Aquarium at Norwalk, adjacent to the Norwalk Bridge, is an example of a building that is contemporary yet blends in with the historic district with its use of materials. The new Norwalk Bridge will achieve that with the selected bridge style, including the selected finish and color of its steel superstructure and concrete bridge substructure.

One of the key architectural expressions on a movable bridge is in the design of the control house. For the existing Norwalk swing bridge, which is listed in the National Registry of Historic Places, the control house was more of a utilitarian structure used to house the controls for the swing bridge. The new control house design will need to consider the architecture in the South Norwalk district, whether it is to respect the masonry finish, be it brick or stone, to the roof finish matching existing roofs within the area, and the control house windows may even hark back to the numerous lighthouses that are prominent along the shores. But if desired not to go to the historical theme, it can be a more contemporary design that matches the selected movable bridge style, perhaps a more nautical theme tied to the river and the sea. DOT and community input will be considered in the selection of the design of the control house that will blend in with the architecture of Norwalk. It is anticipated that bridge aesthetic design workshops will be held to facilitate the incorporation of the desired aesthetic finishes and overall appearance of the recommended alternative.

As part of the development of bridge replacement options, a single control house will be located on either the east end or the west end of the movable span, attached to a pier structure adjacent to the navigation channel. The control house is designed to be manned 24 hours per day, 7 days per week. Interior usable space is dictated by required control room equipment, including provisions for furniture and facilities for the operator.

The operator level elevation is established based on the most effective sightline for viewing the tracks and the navigational channel. The configuration of this level provides nearly 360 degrees of visibility from the operator desk, supplemented by a wrap-around balcony and closed-circuit television cameras.

Stairs between levels are housed internally. Access to the control house will be at deck level. Lower levels may provide access to inspection catwalks, as required. Secured parking will be provided for the bridge operator, with access control to the property and the control house (either on east approach, or direct access from North Water Street to the bridge).

For Option 8A – Span Drive Vertical Lift Span, the Control House has been placed on the vertical lift span, providing full 360 degree views of the Norwalk River from the center of the navigation channel.

5.8.5 Geotechnical

During the development of the Conceptual Engineering Report, a detailed subsurface investigation program was not completed. Rather, available existing information was used to develop a conceptual soil profile to better understand

the existing bridge substructure and the subsurface conditions, both of which were used in the conceptual design of the proposed foundations. The available information included the following:

- Original Bridge Plans
- Existing Geotechnical Engineering Report (2007)
- Geotechnical Engineering Reports for New Pier Protection System (2009)
- Stroffolino Bridge Plans

Sufficient geotechnical information was available to develop a conceptual-level soil profile used to develop the replacement options. As the recommended alternative is refined, a comprehensive subsurface investigation program will be implemented.

General Geology

The ground along the river is relatively level with a surface elevation of about 8 feet above sea level. Water depth in the vicinity of the bridge is approximately 10 to 15 feet.

The subsurface can be characterized from the surface to bedrock as very soft estuarian organic silt from the ground surface to approximately Elevation -30, underlain by a variable layer of dense sandy gravel to approximately Elevation -60, followed by a 10 to 15 foot layer of dense sand to roughly Elevation 70, 15 to 20 feet of very dense gravel, and bedrock.The timber piles of the existing bridge are thought to bear a few feet into the layer of dense sandy gravel beginning at approximately Elevation 60. From the limited existing information, bedrock begins at approximately Elevation -90. The conceptual soil profile that was developed from the available information is shown in Figure 5-26. The bedrock is described as fractured metamorphic granitic gneiss of the Norwalk Formation. Borings taken for the bridge fender system indicate fair core recovery and fair to poor rock quality from RQD. The bedrock should be able to carry high loads in end bearing and side resistance for piles, micropiles and drilled shafts.

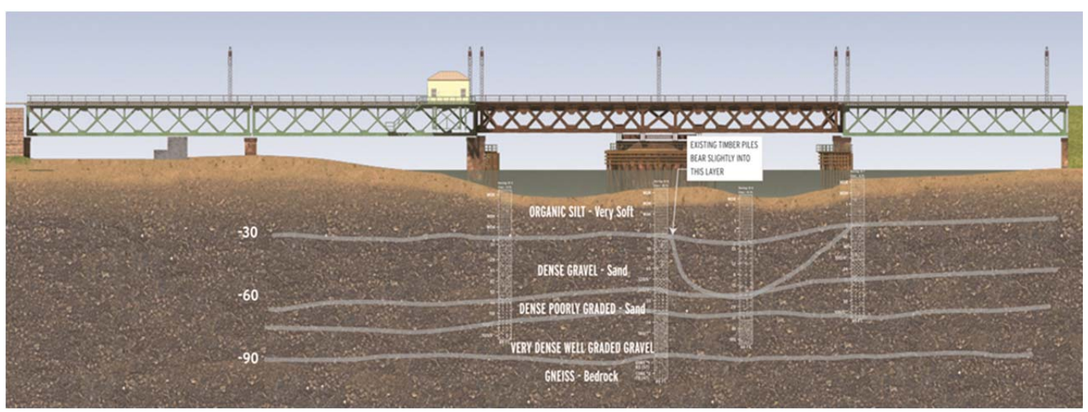

Figure 5-26 – Conceptual Soil Profile

Geotechnical Considerations for Bridge Replacement Options

Based on the findings of the initial geotechnical screening the following, similar foundation types were developed for all replacement concepts. The following paragraphs describe the foundation types considered for various elements of the proposed bridge designs.

Main Span Piers, Approach Piers in the Waterway and High Towers:
Foundations for the movable spans and adjacent fixed approach spans are planned as drilled shaft foundations. The large diameter drilled shafts will be capable of carrying high loads with 25 tons per square foot (tsf) used for preliminary allowable bearing. Drilled shafts will be constructed with rock sockets, providing added long-term resiliency for load carrying and the elimination of scour susceptibility.

The drilled shafts for bascule piers will be constructed with a cofferdam due to the depth of the movable bridge works. The existing swing span pier and timber piles will require removal to construct the shafts and cofferdam. The drilled shafts for “open” substructure configurations, including bascule rest piers, rolling bascule truss piers, vertical lift span piers and high towers, can be constructed without cofferdams with the shafts extending up to the pier cap. Permanent casing extending to rock will likely be required for all shafts. Columns can be extended up from the water line or the drilled shaft and casing may be extended to the pile cap.

Abutments and Proposed Pier 1:
Abutment and Pier 1 foundations call for micropile foundations due to load-carrying requirements and limited space for access and installation. Micropile foundation designs can be developed using 5 tsf for preliminary allowable side friction. Micropiles can be installed in low-overhead and tight spaces. Micropiles can carry high axial loads with low vibration during construction. Used in the waterway or on land, micropiles require footings/pile caps and possibly cofferdams.

Reuse of Existing Foundations:

Based on available information, the existing bridge substructure is founded on shallow timber piles. Because the track spacing required for all bridge replacement options exceeds the available width of the existing bridge piers, modifications to the existing substructure is required in order to support the new bridge superstructure by the existing substructure. These modifications include widening of the existing piers or placing new substructure elements adjacent to the existing piers to accommodate the wider superstructure.

To avoid a portion of the new superstructure being supported by both existing substructure and new substructure elements constructed adjacent to the existing pier, all existing bridge substructure is proposed to be removed in the final conditions for all bridge replacement options. In addition, the USACE has expressed a desire to completely remove all existing substructure units that are not reused from the waterway, including the timber piles.

Foundation Construction Adjacent to Existing Bridge Substructure:

To optimize the length of the new movable span for each of the bridge replacement options, new bridge substructure will be constructed in close proximity to existing bridge piers in certain instances. Given the nature of the existing bridge foundations and the susceptibility to potential settlement, the sensitivity of this construction activity becomes increasingly critical in those instances when the railroad remains active on the current alignment while new foundations are placed adjacent to existing piers.

Drilled shafts and micropiles introduce less vibration risk during construction than driven piles at settlement-sensitive buildings and existing foundations.

West Abutment and Existing Retaining Walls:

A visual inspection of the west abutment was carried out during this phase of the project. There is no visible tilting and bulging of the abutment. The abutment cap stones appear to be in a good condition and exhibit no signs of distress from the superstructure loadings. A preliminary analysis of the existing abutment for potential re-use was completed:

For all bridge replacement options, a new Pier 1 is placed between the covered pedestrian walkway and existing Pier 1. The length of the proposed approach span (Span 1) can be reduced to a minimum span length of 100' from the existing 120'. The lower limit on span length is constrained by the proposed Pier 1 location on the east side of the IMAX theater walkway. Building the new Pier 1 on the west side of the IMAX theater walkway in order to further reduce the span length and, therefore, reactions at the abutment, is not desirable because it would consume space that currently provides parking and access to Maritime Center facilities.

A proposed 100'-0" open deck approach span with an expansion bearing yields the following results:

Load combination	Ecc.	FOS Overturn	FOS Sliding	Max.	Min.
	ft			(ksf)	(ksf)
DL + LL+ EP + LL Surcharge	0.50	1.13	1.65	11.18	7.12
DL + EP	2.63	1.75	1.27	10.40	-0.82

The reduction of the west approach span from its existing 120'-0" to 100'-0" will reduce the live load on the existing west abutment; however, with a ballasted deck system on new approach spans, the overall dead load carried by the existing abutment is expected to increase over the existing conditions.

Previous inspection report indicates settlement of the west abutment as a concern, though it does not appear to be currently compromising the integrity of the superstructure.

The West Abutment is not seismically adequate as indicated by the previous reports and verified as part of this study.

Although new abutments would be constructed behind the existing structure for several of the final bridge replacement options, the original abutment will not be entirely removed. A portion of the existing backwall would be removed in order to allow new girders to span over the existing abutment. Without completely removing the existing abutment, the visual appearance of the existing stone abutment will be maintained along Water Street.

The southward track shifts that are required near the West Abutment for Options 3A, 8A and 11C align Track 4 in the final configuration close to, or directly over, the existing stone retaining wall adjacent to the West Abutment. Additional loading on these walls is not recommended. Likewise, limited information is available on the layout and makeup of these walls. With the recent completion of the Ironworks property in close proximity to the existing retaining wall, limited construction access is available in this area for retrofitting or replacing the existing walls (Photo 5-4). The recommended new west abutment allows for the walls to remain in place for aesthetic and historic purposes.

Photo 5 - 4 – Top of existing retaining wall at west abutment (southeast corner)

East Abutment:

Previous inspection reports indicate that east abutment face shows tilting and bulging, with rehabilitations completed in 1990. The out-to-out track spacing (CL Track 3 to CL Track 4) for all options exceeds the available width of the existing East Abutment. To avoid modifications to the existing East Abutment, new abutments are recommended for all replacement options. The new East Abutment will be supported on micropiles and constructed immediately to the west of the existing substructure, with the existing abutment remaining in place. A micropile foundation will allow for the new abutment to be constructed entirely beneath the existing superstructure, resulting in no impacts to rail operations. The position of the new East Abutment is considered in the overall hydraulic analysis for each bridge replacement option.

Track Approaches:

Consideration should be given for settlement potential of the embankment east of the east abutment for alignments outside of the current footprint. Poor bearing resistance is expected for any type of shallow-founded retaining walls due to the upper stratum of very soft organic silt. Therefore, retaining walls will most likely require deep foundations or ground improvement.

5.8.6 Channel Hydraulics

The conceptual design hydrologic and hydraulic analysis established a baseline for screening conceptual replacement alternatives and their impacts on scour countermeasures needed, and bridge hydraulic performance. The analysis considered both the existing condition and proposed replacement alternatives.

A hydraulic river model was developed for Norwalk River from the head of tide downstream of the Wall Street Bridge to a point 500 ft. downstream of the Washington Street Bridge. A 1-dimensional unsteady hydraulic model to

analyze surge conditions and a steady flow analysis based on the mean lower- low water (MLLW) and the mean higher-high water (MHHW) were run to establish water surface elevations and channel velocity for each alternative. All of the options remove the center swing span from the federal navigation channel and have a minimal impact on water surface elevations and channel velocity up to the head of tide. Water surface elevations are not be increased by more than one foot, nor will they cause damage to upstream properties.

For each of the bridge alternative the initial scour analysis was done based on the lower-low water profile which had the highest velocities through the bridge opening. Since the foundations for the bridge are anticipated to be deep foundations socketed into rock these conservative scour depths do not appear to be critical but will be verified during the final design.

For complete results of the Hydrologic and Hydraulic Analysis please see Appendix L.

5.8.7 Civil

North Water Street is a two lane, bidirectional, local urban roadway located in South Norwalk. The 20 to 22 foot wide bituminous concrete street is bordered with 6” high granite curbing. There is a three foot wide brick paver buffer then a concrete sidewalk. A streetscape project is nearing completion of construction which includes new concrete sidewalk, granite curbing and tree wells. In the southwest quadrant in front of the Ironworks building, defined bump outs for parallel parking were installed as part of the improvements. North of the bridge a speed hump, traffic calming device, was installed. This section of North Water Street is a pedestrian friendly area located between Washington Street, signalized intersection, to the south and Marshall Street, all way stop controlled intersection, to the north.

Walk Bridge is located approximately midblock. The west abutment of the bridge is located behind the concrete sidewalk, 4.5 feet off the edge of pavement of North Water Street. The railroad tracks separate the Washington Street Design District to the south and the Reed Putnam Design District Subarea D to the north.

There are five building structures located in close proximity to the bridge:

- Northeast quadrant – Maritime Museum
- Northwest quadrant – Maritime Square Building – Residential Building
- Southwest quadrant – “Ironworks” Building – Mixed Use Development
- Southeast quadrant – Maritime Center Imax Theater
- Underbridge – Connector between the Maritime Museum and Imax Theater

Parking for the Maritime Museum and the Maritime Center Imax Theater is located to the south of the Theater in a metered public parking area. There is an enclosed pedestrian passageway under the railroad bridge between these two buildings. To the west of the pedestrian passageway and 36 feet from the edge of pavement of North Water Street is the loading dock which serves these two buildings.

The entrance to the surface parking for the Maritime Square Building is located approximately 165 feet north of the bridge; however, the bituminous concrete parking area extends southerly to the railroad retaining wall that supports the north side of the railroad tracks. The Maritime Square Building has a 10 foot wide, one way vehicular access between the building and the existing masonry railroad retaining wall. This access way is the means of egress from the parking lot on the west side of the building.

The entrance to the Ironworks building is located approximately 75 feet south of the bridge. The Ironworks Building is a Mixed Use complex with multiple (100+) units and a parking garage to the south. There is approximately 10 feet separating the buildings and the masonry retaining wall that supports the south side of the railroad tracks.

Following along the length of the Walk Bridge easterly, Pier #1 is located between the Maritime Museum and the Maritime Center Imax Theater approximately 90 feet from North Water Street. Piers #2 and #3 are located within the Norwalk River. The easterly abutment at the end of the 560 foot bridge retains the embankment that the railroad tracks are constructed on. The State of Connecticut Right-of-Way width is approximately 155 feet east of the Norwalk River. The property to the immediate north is a 95 foot wide parcel owned by the State of Connecticut. The City of Norwalk Wastewater Treatment Facility with other associated City of Norwalk Public Work uses is located north of this. To the south of the railroad tracks is a privately owned marina, bordered by Goldstein Place, local dead end street, approximately 380 feet east of the abutment.

5.8.8 Utilities

All utility mains, located within North Water Street, are underground and perpendicular to the Bridge. From the West Abutment heading east, the utilities are as follows:

Electrical - An unknown number and size of electrical conduits. Includes above ground conduit for under bridge lighting attached to the West Abutment

Telephone - An unknown number and size of phone conduits.

Cable Television conduits - Two – 4” diameter PVC conduits

Sanitary Sewer – A single 54” RCP trunk Line

Storm Sewer – A single 12” clay pipe.

Gas – A single 8” main.

Water – The size and type of water pipe are unknown.

Utility Services along North Water Street that serve the buildings that may be impacted by construction activities are as follows:

The Maritime Square Building has a 10 foot one way access drive between the building and the existing Retaining Wall on the north side of the tracks. This access way is the means of egress from the parking lot on the west side of the building. There are also utility services at the rear of the building including the electric, gas and HVAC. In addition, the drainage for the parking lots and roof are collected to the system main that runs in roughly the center of the 10 foot access drive. This drainage system exits the property in an 18” PVC pipe in a southeasterly direction under North Water Street, through and draining the Loading Dock area of the Maritime Center Museum and Imax Theater. The storm sewer crosses under the Loading Dock and the enclosed pedestrian passageway then runs roughly parallel with the Walk Swing Bridge along its southern face before discharging into the Norwalk River east of Pier 1.

The Ironworks Building is a mixed use complex with multiple units and a parking garage to the south. Of concern is the natural gas service for this complex that is located underneath the sidewalk that is located between the retaining wall to the south of the railroad tracks and the buildings. The natural gas services approximately 100 units on the

building closest to North Water Street then heads southerly feeding a standby generator and another 13 meters at the parking garage before terminating.

Maritime Center Imax Theater and the Maritime Museum located on the east side of North Water Street, share a Loading Dock and an enclosed pedestrian passageway underneath the existing bridge. Insulated HVAC lines run between the top of the enclosed pedestrian passageway and the bottom of the existing bridge. The electrical service for the Maritime Center Imax Theater runs underground beneath the southern face of the bridge. The gas service to the Maritime Museum runs underground beneath the northern face of the bridge. In addition to the storm sewer system described previously, a storm sewer system that collects the roof drainage of the Imax Theater, discharges through a 12" PVC pipe to the Norwalk River east of Pier 1 approximately 25 feet south of the bridge.

Additional utility concerns, an electric transformer with service meters and associated conduits is located on the west side of Pier 1 of the existing bridge. An underground submarine cable is located approximately 10 feet from the northeast corner of Pier 1 then running due east for roughly 75 feet before heading due north then northeasterly across the Norwalk River.

The following options have been advanced and will be reviewed for their impacts to Traffic on North Water Street, Pedestrian Movements, Loading Dock Access, Utilities and Retaining Walls required to eliminate or reduce Right of Way impacts. The review of each option will begin at the west abutment and proceed easterly.

General Considerations – All options

With all of the options, there will be time periods when North Water Street will need to be closed to vehicular and pedestrian traffic due to the removal and installation of bridge spans.

Pedestrians and vehicles must be protected when construction is occurring above them.

Coordinate with the Maritime Museum and the Maritime Center Imax Theater on all closures so that field trips are accommodated and deliveries to the Loading Dock or sanitation concerns are addressed.

Advanced Notice on scheduled closures should be given to the adjacent four buildings including residents and tenants, South Norwalk Neighborhood Associations and the City of Norwalk.

Location of Control House

Depending on the replacement option, the control house for the new movable span will be placed on either the East side of the River or the West side.

East side:

The existing utilities within Goldstein Place can be utilized to service the Control House if it is located on the East side of the Norwalk River. An emergency generator can be located within the State of Connecticut Right of Way that can be fed from the existing 8" natural gas main. The power lines would travel parallel with the railroad tracks before penetrating the eastern abutment and then into the Control House. The sanitary sewer and water laterals would originate at the mains located within Goldstein Place and then run parallel with the railroad tracks before penetrating the eastern abutment and then into the Control House.

West side:

The existing utilities within North Water Street can be utilized to service the Control House if it is located on the West side of the Norwalk River. A corridor under the Loading Dock and Enclosed Pedestrian Passageway would be established for the gas, water and sanitary sewer laterals.

Option 2G – Non Parallel Alignment Through Girder Trunnion Bascule

West of North Water Street, the proposed Bridge and Track improvements will not go outside of the existing footprint of the stone masonry retaining walls. The existing utility services to the Maritime Square and Ironworks buildings will not be impacted.

None of the utility mains within the North Water Street foot print will be impacted by construction.

Pedestrian Access on the east side of North Water Street will be maintained. The sidewalk on the west side may need to be closed when there is work at the west abutment. A pedestrian maintenance and protection of traffic plan will be developed to maintain pedestrian access to the area.

Access to the Loading Dock will be maintained or provisions made for an alternate delivery and refuse removal location.

There will be impacts to the electric transformer and associated service meters, conduits and underbridge lighting located at existing Pier 1.

Due to the non-parallel alignment, retaining walls will be required on the north and south sides of the railroad tracks on the east side of the Norwalk River. Property takes, both north and south, will be required for placement of fill slopes in this option. Retaining wall length and heights will be minimized however walls will certainly be required in the vicinity of the Fort Point Rail Bridge widening.

Option 3A – Parallel Alignment Deck Girder Rolling Lift Bascule

The existing west abutment will become a retaining wall with a new abutment installed to the west. A new retaining wall will be required on the south side to prevent additional live loading from impacting the existing stone masonry retaining wall. West of North Water Street, the proposed Bridge and Track improvements will not go outside of the existing footprint of the stone masonry retaining walls. The existing utility services to the Maritime Square and Ironworks buildings will not be impacted.

While work is being performed on the West Abutment, the southbound lane of North Water Street will need to be closed. A temporary traffic signal can be installed to allow alternating traffic or southbound lane can be closed with traffic rerouted via Marshall Street-North Main Street-Washington Street.

None of the utility mains within the North Water Street foot print will be impacted by construction.

Pedestrian Access on the east side of North Water Street will be maintained. The sidewalk on the west side may need to be closed when there is work at the west abutment. A pedestrian maintenance and protection of traffic plan will be developed to maintain pedestrian access to the area.

Access to the Loading Dock will be maintained or provisions made for an alternate delivery and refuse removal location.

There will be impacts to the electric transformer and associated service meters, conduits and underbridge lighting located at existing Pier 1.

The proposed substructure design will impact the underground submarine cable.

The outlet for the drainage from the Maritime Square Building and Loading Dock Area will need to be rerouted near its terminus. This will require a new outlet location and protection.

With the parallel alignment with the closer track center spacing, a shorter length retaining wall will be required on the south side only on the east side of the Norwalk River.

Option 4S – Non Parallel Alignment Through Truss Rolling Lift Bascule

West of North Water Street, the proposed Bridge and Track improvements will not go outside of the existing footprint of the stone masonry retaining walls. The existing utility services to the Maritime Square and Ironworks buildings will not be impacted.

None of the utility mains within the North Water Street foot print will be impacted by construction.

Pedestrian Access on the east side of North Water Street will be maintained. The sidewalk on the west side may need to be closed when there is work at the west abutment. A pedestrian maintenance and protection of traffic plan will be developed to maintain pedestrian access to the area.

Access to the Loading Dock will be maintained or provisions made for an alternate delivery and refuse removal location.

There will be impacts to the electric transformer and associated service meters, conduits and underbridge lighting located at existing Pier 1.

The proposed substructure design will impact the underground submarine cable.

Due to the non-parallel alignment, retaining walls will be required on the north and south sides of the railroad tracks on the east side of the Norwalk River.

Option 8A – Parallel Alignment Through Truss Vertical Lift (180' span)

The existing west abutment will become a pier with a new abutment installed to the west. A new retaining wall will be required on the south side to protect the existing stone masonry retaining wall. West of North Water Street, the proposed Bridge and Track improvements will not go outside of the existing footprint of the stone masonry retaining walls. The existing utility services to the Maritime Square and Ironworks buildings will not be impacted.

While work is being performed on the West Abutment, the southbound lane of North Water Street will need to be closed. A temporary traffic signal can be installed to allow alternating traffic or southbound lane can be closed with traffic rerouted via Marshall Street-North Main Street-Washington Street.

None of the utility mains within the North Water Street foot print will be impacted by construction.

Pedestrian Access on the east side of North Water Street will be maintained. The sidewalk on the west side may need to be closed when there is work at the west abutment. A pedestrian maintenance and protection of traffic plan will be developed to maintain pedestrian access to the area.

Access to the Loading Dock will be maintained or provisions made for an alternate delivery and refuse removal location.

There will be impacts to the electric transformer and associated service meters, conduits and underbridge lighting located at existing Pier 1.

The proposed substructure design will impact the underground submarine cable.

The outlet for the drainage from the Maritime Square Building and Loading Dock Area will need to be moved. The drainage will be rerouted south along North Water Street in the footprint of the existing 12" clay storm sewer approximately 200 feet south of the bridge before heading due east discharging into the Norwalk River. This new location will require outlet protection. The Imax Theater roof drainage will also be impacted and will need to be added to this rerouted system for a stable discharge point.

With the parallel alignment, east of the eastern abutment, a retaining wall will be required on the south side only.

Option 11C – Parallel Alignment Through Truss Vertical Lift (Tower Drive) (250' span)

The existing west abutment will become a pier with a new abutment installed to the west. A new retaining wall will be required on the south side to protect the existing stone masonry retaining wall. West of North Water Street, the proposed Bridge and Track improvements will not go outside of the existing footprint of the stone masonry retaining walls. The existing utility services to the Maritime Square and Ironworks buildings will not be impacted.

While work is being performed on the West Abutment, the southbound lane of North Water Street will need to be closed. A temporary traffic signal can be installed to allow alternating traffic or southbound lane can be closed with traffic rerouted via Marshall Street-North Main Street-Washington Street.

None of the utility mains within the North Water Street foot print will be impacted by construction.

Pedestrian Access on the east side of North Water Street will be maintained. The sidewalk on the west side may need to be closed when there is work at the west abutment. A pedestrian maintenance and protection of traffic plan will be developed to maintain pedestrian access to the area.

Access to the Loading Dock will be maintained or provisions made for an alternate delivery and refuse removal location.

There will be impacts to the electric transformer and associated service meters, conduits and underbridge lighting located at existing Pier 1.

The proposed substructure design will impact the underground submarine cable.

The outlet for the drainage from the Maritime Square Building and Loading Dock Area will need to be moved. The drainage will be rerouted south along North Water Street in the footprint of the existing 12" clay storm sewer approximately 200 feet south of the bridge before heading due east discharging into the Norwalk River. This new

location will require outlet protection. The Imax Theater roof drainage will also be impacted and will need to be added to this rerouted system for a stable discharge point.

With the parallel alignment, east of the eastern abutment, a retaining wall will be required on the south side only.

5.8.9 Vessel Collision Loading Pier Protection

To supplement the AREMA pier protection guidelines, a vessel impact risk analysis was carried out in accordance with the AASHTO LRFD provisions for bridges crossing navigable waterways, as outlined in the AASHTO Guide Specifications and Commentary for Vessel Collision Design of Highway Bridges, 2nd Edition (w/ 2010 interim revisions). The procedure used to compute the Method II (probabilistic analysis) design impact force for new piers was back-calculated based on the required resistance strength needed to meet the design acceptance criteria. The vessel classes and trip data from the previous vessel impact study (2009) have been used for the analysis. Conservatively, a 5% annual increase rate of vessel transit was assumed for all vessel classes. Based on consultation with waterway users, even if a significant horizontal navigation clearance is provided by the new movable spans, it is anticipated that barge tows will not increase in size due to physical constraints on the waterway north of the Walk Bridge and at the Stroffolino Bridge.

For Options 4S, 8A and 11C, it was assumed that the centerline of the channel coincides with the centerline of the proposed movable span. Since the proposed Pier 2 (west vertical lift span or bascule rest pier) is not in the water it was assumed that the design barge will never collide with this pier. The analysis has been performed for a single transit path consideration for all vessel classes in the navigational channel through the proposed bridge. To satisfy the minimum allowable return period of collapse (10,000 years) the required ultimate lateral capacity, conservatively used for the design lateral load demand, for the new Pier 3 (east vertical lift span) was estimated at 2,029 kips for both Options 4S and 8A (L_{span} = 180 ft. & $W_{channel}$ = 120 ft.) and Option 11C (L_{span} = 250 ft & $W_{channel}$ = 180 ft.).

For Options 2G and 3A, it was assumed that the west edge of the new navigational channel matches with the far west edge of the existing channel. Under this geographic assumption just a small portion of the bascule pier (or rest pier) is in the water and the geometric probability of collision for the proposed bascule pier is relatively low. However, the approach pier at the bascule span toe side is, relatively, more vulnerable. The required ultimate lateral capacity for the approach piers for the proposed 120 ft. bascule span with the different navigation channel width consideration ($W_{channel}$ = 80 ft. or 90 ft.) was estimated at 2,032 kips.

Upon determination of the design vessel, the main pier in the water was analyzed for vessel impact loads. Pier protection alternatives have also been evaluated at the new piers for the design vessel class. Recommendations for the pier protection include installing a new dolphin system, installing a new pile supported fender and utilizing super cones. The design vessel collision energy was estimated at 1,223 kip-ft. for Options 4S, 8A and 11C and 1,263 kip-ft. for Options 2G and 3A.

To protect the new bridge substructure and enhance the resiliency of the overall system, three methods of pier protection have been identified:

- Option 1: New dolphin system (Vessel Collision Kinetic Energy fully absorbed by the dolphin system) This option utilizes 1 – 20 ft dia. cofferdam type dolphins at each nose of the main pier in the water.
- Option 2: New pile supported composite fender system (Vessel Collision Kinetic Energy fully absorbed by the new fender) This option utilizes approximately 30 – 1ft diameter fiberglass reinforced plastic piles and 12” x 12” fiberglass reinforced composite lumber wales, chocks and blockings (Photo 5-5).

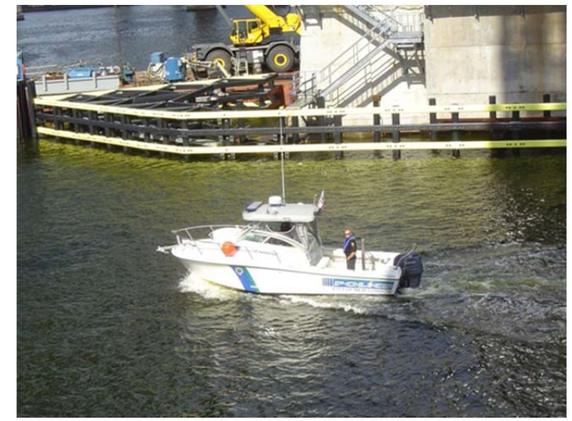

Photo 5 -5 – Use of composite fender system for a railroad movable bridge pier

- *Option 3: Super cones (Vessel Collision Kinetic Energy absorbed by the new pier and super cones)* Similar to the vessel collision design philosophy adopted for recently commissioned movable bridges in which the new pier and its foundation can be the primary load resisting members for the design vessel collision. The super cone system with fender panel is a secondary fender mainly to minimize damage to the pier and the vessel in the event of an abrasion or collision (Photo 5-6).

Photo 5 - 6 – Example of energy absorption pier protection of railroad movable bridge pier

Even though the super cones do not have sufficient energy absorbing capacity for the design vessel class collision, this system can be used to redirect the colliding vessels and/or dissipate portion of collision energy. The locations of the lift span piers for Option 11C make this replacement option a viable candidate to incorporate Super Cone fender

systems. Because of the location of the lift span piers for Option 11C, a super cone system is included in the span details and cost estimates.

5.8.10 Structural Steel Protective Coating Systems

Protective coatings on steel bridge elements are essential to prevent corrosion and loss of structural load carrying capacity over time, thereby prolonging the service life of the structure. Additionally, protective coatings can be used to develop the visual characteristics and aesthetic appeal for bridge structures. Several strategies exist for preventing or retarding the corrosion of steel bridges, including the use of corrosion resistant materials (e.g., weathering steel) and the application of protective coatings (e.g., painting or metalizing). From the point of view of corrosion performance, an advantage of using weathering steel in bridges is that, under normal conditions, it may be left unpainted, leading to reduced lifecycle costs. However, due to the brackish characteristics of the Norwalk River, the use of weathering steel for the Walk Bridge Replacement is not recommended. With that, consideration is given to both painted and metalized protective systems.

Fabrication shop-applied paint systems are generally considered to be the preferred method of providing corrosion resistance of steel bridges by many bridge owners. These paint systems not only provide the desired level of corrosive protection for the steel elements, but also provide an opportunity to establish the visual appearance of the bridge through the use of a wide array of paint colors. Despite routine maintenance and inspection, an original bridge paint system can expect to be renewed every 25 to 30 years in order to preserve both the corrosive protection provided by the system as well as the aesthetics of the structure. Cost, schedule and environmental permitting requirements generally make movable bridge maintenance painting a significant capital expenditure as part of a structure's overall lifecycle costs.

Metalizing provides an alternative approach to corrosion protection over traditional paint systems. Metallizing is a common term used to describe thermal sprayed metal coatings. These coatings have a dull gray appearance with a roughened texture as applied, but may be sealed and top-coated with most conventional paint systems if a different appearance or color is desired. When applied properly, these coatings have shown excellent long term performance when compared to more conventional paint systems, especially in more severe coastal and salt-rich environments. However, recent cost estimates place metallizing as nearly twice the cost of conventional painting on a square foot basis. Despite this, metallizing should be considered as the recommended alternative is refined and a comprehensive life-cycle cost analysis of coating options is completed. Additional considerations for selecting a metalized system include fabrication shop capabilities, fabrication schedule and steel delivery to the project site at the time of construction.

For cost estimating and life-cycle cost computations, a conventional (either a 2- or 3-coat paint system) has been incorporated into the cost estimating and life-cycle cost computations for all replacement options.

5.8.11 Right-of-Way and Construction Access

Right-of-Way

In all bridge replacement scenarios, the existing bridge will be replaced on an alignment that essentially matches the alignment of the existing bridge. Depending on the replacement option, there are variances between the track alignment on both the east and west track approach. For "parallel" track alignment options - - Options 3A, 8A and 11C - - no right-of-way needs are anticipated for the bridge and track configurations themselves. Based on an assessment of the parcels in the vicinity of the alignments for each of the alternatives, there are 2 areas requiring additional investigation for potential aerial easements.

For "non-parallel" alignment options - - Options 2G and 4S - - potential right-of-way needs have been identified for retaining wall placement and construction on the east track approaches.

Additionally, for options having a control house located on the east side of the river - - Options 2G, 4S and 11C, permanent property needs have been identified on the east side of the river that will accommodate parking, access, and generator building placement.

A summary of the permanent right-of-way needs is included in Appendix P.

Construction Access

The Walk Bridge replacement is a significant construction undertaking, requiring construction laydown areas to store materials and stage certain construction operations. Additionally, having water-access in close proximity to the bridge location is desired to efficiently advance the construction. Using GIS-based information available in the public domain, property parcels were identified and screened for their potential use as construction laydown areas. Information on these parcels, including available areas, is included in Appendix P.

6 Additional Considerations

6.1 Environmental Resources and Considerations

Section 6.1 provides a summary of existing environmental resources and conditions in the vicinity of Walk Bridge. Appendix Q provides an environmental resources photo log of the project site and figures of existing environmental conditions.

6.1.1 Tidal Wetlands

Wetlands are defined in 40 CFR Part 230 as areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. The project corridor was investigated in October 2014 to delineate inland and tidal wetlands. Tidal wetlands were found in the vicinity of Walk Bridge. No inland wetlands were found in the project corridor. Figure Q-3 provides a sketch of existing tidal wetlands in the project vicinity based upon field investigation.

6.1.2 Intertidal Habitat

Intertidal habitat, including mudflats, sand, and cobble, exists at the site of Walk Bridge. Mudflats are defined in 40 CFR Part 230 as broad flat areas located along the sea coast and in coastal rivers to the head of tidal influence and in inland lakes, ponds, and riverine systems. Coastal mud flats are exposed at extremely low tides and inundated at high tides with the water table at or near the surface of the substrate. The substrate of mud flats contains organic material and particles smaller in size than sand. They are either unvegetated or vegetated only by algal mats.

6.1.3 Benthic Resources

Site walkovers conducted in September and October 2014 indicate that a dense shellfish mat (bed) is located adjacent to and in the immediate vicinity of the bridge's eastern abutment. The shellfish bed is dominated by ribbed mussels, as shown in the project environmental resources photo log.

Figure Q-4 provides a map of state-designated natural shellfish beds and the observed dense shellfish concentration. The natural shellfish bed in the City of Norwalk is currently a prohibited shellfish growing area, and is closed for the harvesting of shellfish, except for licensed aquaculture operations.

6.1.4 Essential Fish Habitat

As previously cited, the Norwalk River at the site of Walk Bridge is an EFH for multiple species. Species include the following: Atlantic Butterfish (juvenile and adult); Black Sea Bass (juvenile); Bluefish (juvenile and adult); Little Skate (adult); and Longfin Inshore Squid (eggs, juvenile, and adult).

6.1.5 Floodplain

Per the Federal Emergency Management Agency (FEMA) Federal Insurance Rate Map (FIRM), revised July 8, 2013, the Walk Bridge is located within Zone AE, defined as areas subject to inundation by the 1-percent-annual-chance flood event, often referred to as the 100-year flood. Figure Q-5 provides a map showing special flood hazard areas in the vicinity of Walk Bridge, per the current FEMA FIRM.

6.1.6 Potential Unsuitable Sediment

In January 2014, the USACE completed a multi-phase maintenance dredging project at Norwalk Harbor, from the mouth of the harbor north to the Washington Street Bridge, located just south of Walk Bridge. A portion of the dredged material was deemed unsuitable and required disposal in confined aquatic disposal (CAD) cells and subsequent capping.[13] It is anticipated that material excavated for the construction of the replacement bridge could be deemed unsuitable/impacted and require special disposal methods.

6.1.7 Noise Sensitive Receptors

Noise sensitive receptors include nonprofit institutional or public use structures, or residential land uses. Noise sensitive receptors are located in the immediate vicinity of Walk Bridge. Near the western abutment of the bridge, noise sensitive receptors include the Maritime Aquarium of Norwalk and IMAX Theatre and private condominiums. Near the eastern abutment of the bridge, noise sensitive receptors include the public rowing facility adjacent to Coastwise Boatworks/SoNoWharf and residential land uses.

[13] USACE, New England District, Public Affairs Office, "Update Report for Connecticut," current as of June 30, 2014.

7 Construction Schedules, Construction Cost, Lifecycle Costs

7.1 Construction Schedules

Construction schedules were developed for each replacement alternative based on each options detailed construction sequence. The construction schedules take into account key operations and the anticipated duration for their completion. Where possible, elements of accelerated bridge construction are reflected in the schedule. Long lead items and site preparation are also included in the overall schedules.

Construction Schedules for each replacement option are included in Appendix H.

It is recognized that there are periods throughout the year when open water construction will be limited or restricted based on regulatory requirements. As the actual start date of construction is unknown at this time, it is difficult to incorporate these in-water restrictions directly into the overall construction schedule. Rather, construction operations that are candidates for the known restrictions have additional construction time incorporated in their respective durations to account for any regulatory-related work stoppages or delays. As additional information is collected regarding the known date for the start of construction, construction schedules will require updating to reflect any seasonal construction restrictions.

A summary of the overall construction duration for each bridge replacement option is provided below in Table 7-1. There are 2 values presented for construction duration. The first value describes the overall project completion timeline, including the removal of existing bridge substructure and demobilization from the project site. The second value is associated with the timeline for the new movable spans to both be placed in service.

Construction Duration	Replacement Option				
	2G	3A	4S	8A	11C
Total Construction Duration (months)	36	32	32	38	42
New Movable Spans in Service (months)	36	30	30	34	38
In-water Work Duration (weeks)	80	70	33	40	40

Table 7 - 1 – Overall Project Durations, by Replacement Option

The maintenance of both rail and marine traffic is a key element to the overall success of the project. In the presentation of each construction schedules in Appendix H, impacts to rail and navigation traffic are quantified in order to develop comparisons between the alternatives. As construction advances as outlined in the option-specific construction sequences, there are various points along the way when certain tracks are taken out of service as well as the channel is restricted for navigation traffic. Tables 7-2 and 7-3 outline the impacts to rail and marine traffic, respectively.

Rail Closure	Replacement Option (Duration of Rail Impacts)				
	2G	3A	4S	8A	11C
All Tracks Closed (hours)		24	24	24	24
Tracks 1 and 3 Closed (weeks)	3	13	16	27	40
	11	17			
Track 3 only Closed (weeks)			49		
Tracks 2 and 4 Closed (weeks)	67	12	16	9	8
		32		34	36

Table 7 - 2 – Estimated Duration of Rail Outages, by Replacement Option

For rail closures shown in the table, each line of entry represents a continuous duration of impacted rail (complete rail closures). Additional and separate durations, if any, are shown on subsequent lines in the summary shown in Table 7-2. For example, Option 2G has one solid 3 week period when Tracks 1 and 3 are out of service. Additionally, this option has a second period of 11 weeks when Tracks 1 and 3 are out of service. It should be noted that the rail outage durations shown are for periods of time when a track is completely taken out of service for an extended period of time beyond routine work windows.

Channel Impacts		Replacement Option (During Channel Impacts)				
		2G	3A	4S	8A	11C
Channel Closed (days)	Duration #1	1	1	1	1	1
	Duration #2	1	1	1	1	1
	Duration #3	1	1	1	1	1
	Duration #4	1	1	1		
Vertical Restriction (weeks)	Duration #1	7	3	3	74	38
	Duration #2	64	31	64	16	
	Duration #3		16	1		
Horizontal Restriction (weeks)	Duration #1	16	3	4	12	16
	Duration #2	49	31	65	71	
	Duration #3		16	17	26	
	Duration #4			15	16	

Table 7 - 3 – Estimated Duration of Navigation Impacts during Construction, by Replacement Option

In order to quantify impacts to marine traffic, the following definitions are used:

- "Channel Closed" refers to a complete blockage of the channel due to removal of swing span and/or installation of movable span.
- "Vertical Channel Restriction" is caused by swing span being closed or temporary fixed span are in place over the navigable channel, including the run-around structure.

- "Horizontal Channel Restriction" is based on piers placed within waterway and the removal of existing piers within waterway. This does not include routine construction barges/equipment that may be in waterway during the course of construction.

7.2 Construction Costs and Overall Project Costs

Construction Cost Estimates and Overall Projects Cost Estimates were developed for each of the replacement options. The cost estimates are organized by logical construction items, and considered comprehensive for the level of design that has been completed for the scope of this study. Detailed cost breakdowns of the replacement options are included in Appendix I.

A summary of costs for the viable alternatives is shown in Table 7 - 4.

OPTION	ESTIMATED BASE BID COST (2014)	ESTIMATED CONSTRUCTION COST (2018)	TOTAL CONSTRUCTION COSTS	TOTAL PROGRAM COSTS
OPTION 2G - - 120' Through Plate Girder Trunnion Bascule	$ 225,927,000	$ 254,283,000	$ 427,197,000	$ 462,713,000
OPTION 3A - - 120' Deck Plate Girder Rolling Bascule	$ 177,318,900	$ 199,574,900	$ 335,286,900	$ 364,236,900
OPTION 4S - - 204' Through Truss Rolling Bascule	$ 202,642,000	$ 228,076,000	$ 383,169,000	$ 415,540,000
OPTION 8A - - 180' Through Truss Vertical Lift Span (Span Drive)	$ 279,092,000	$ 314,121,000	$ 527,726,000	$ 570,423,000
OPTION 11C - - 250' Through Truss Vertical Lift Span (Tower Drive)	$ 304,281,000	$ 342,471,000	$ 575,354,000	$ 621,453,000

Table 7 - 4 – Estimated Construction and Overall Project Costs, by Replacement Option

Initially, probable base bid costs were developed in current (2014) dollars, which include 10% mobilization and 25% design contingency, commensurate with the level of design refinement.

An inflation escalation of 3% annually to the midpoint of construction, assumed to be year 2018, was applied to the 2014 base bid costs.

The total construction costs in 2018 dollars were estimated by incorporating the following:

- Metro-North force account work estimated at 40% of the base 2018 costs
- Construction contingencies at 10%
- Construction incidentals at 10%

Finally, the overall project costs were estimated using the Total Construction Costs (including MNR force accounts, contingencies and incidentals) and incorporating the following:

- Design and Environmental permitting at 10%
- Right of Way costs at 1%
- Railroad Operating Costs at 0.5%
- Waterway User Costs at 0.5%

An additional fee of $5,000,000 is included for the relocation of the overhead transmission lines.

The cost estimate development is based on several sources, including the conceptual plans and suggested construction sequences, recent bid tabs from major fixed and movable bridge projects that are similar to the replacement of the Walk Bridge as well as similar sized regional projects. Additionally, input from HNTB's cost estimating professionals was incorporated to capture current market pricing trends.

While HNTB has no control over market fluctuations of material costs or labor, the cost estimates are based on the most current information available, including known industry trends. An appropriate contingency has been added to each cost estimate to account for uncertainties in the estimate based on the level of engineering completed at the time of the cost development.

7.3 Life Cycle Costs

The life cycle cost analysis was carried out as a means to perform an economic evaluation of different bridge alternatives. Life cycle costs provide a comparison of the ownership costs of the different alternatives having the consistent quality and functionality. This evaluation was based largely on assumptions. Though actual numbers may not be realized in future, it gives a fair comparison of the ownership costs among the different alternatives. The five bridge options were compared to each other based on operation, maintenance and operation costs. The alternative with the lowest annualized present value cost is the replacement option that will project to be the least expensive to operate and maintain over the life of the structure.

The life cycle cost analysis was based on operation, maintenance and repair/replacement costs, and does not account for the initial cost of construction. The following assumptions were made while calculating the cost:

- Operator cost - - Operator salary was assumed to be $50,000 per year with an overhead multiplier as 1.6 and 3 shifts per day for all the five bridge alternatives.
- Annual inspection, maintenance and supply cost - - an annual structural maintenance cost of $25,000 with $10,000 for supplies was assumed for all the bridge alternatives. The annual structural maintenance cost was assumed to be minor and assumed to be same for all the five bridge alternatives. Similarly, an annual maintenance cost of $25,000 was assumed for electrical maintenance for all the five bridge alternatives. Annual mechanical equipment maintenance cost was assumed to be varied for different alternatives.
- Structural repair/replacement cost - - a mid-major structural repair work was assumed to be needed in every 25 years followed by a major replacement work every 30 years. Minor structural repair work was assumed to be required every 15 years. These maintenance intervals were assumed to be the same for the different alternatives; however, the maintenance costs varied depending on the type of movable span, total length of the bridge, number of new substructure elements, number of re-used substructure elements and type of fender system used.
- Electrical repair/replacement cost - - PLC and drive upgrades were assumed to be replaced every 15 years. A major electrical system replacement work was assumed to be needed in every 30 years.
- Mechanical repair/replacement cost - - a major mechanical equipment repair and replacement work was assumed to be needed in every 25 years. Up-haul and downhaul ropes of the span driven vertical lift span (Option 8A) were assumed to be needed every 5 years.
- Annual inflation - - Annual inflation rate (AIR) is assumed to be 4%.
- Discount rate - - in order to be able to add and compare costs that are incurred at different times during the life cycle of the project, the costs were made time-equivalent. In order to that, the costs were converted to present values by discounting those to a common base year of 2014. The discount rate (DR) is assumed to be 5% for all the five alternatives.

The operation, maintenance and repair/replacement costs were first quantified as the cost that would occur in year 2014.The inflated cost (IC) was then calculated as:

$$IC = COST\ (1+ AIR)^{N-1},\ N = \text{number of year in consideration from the base year 2014}$$

Inflated cost was then discounted to a present worth (PW) cost as follows:

$$PW = IC/(1+DR)^{N-1}$$

Present worth life cycle costs (PWLC) were then calculated as the sum of the present worth from the beginning of base year 2014 till year in consideration. Present worth Life cycle costs were calculated for 25, 50 and 100 years. In order to compare the life cycle cost effectiveness of different alternatives, the present worth life cycle costs were then converted to an annualized value (A). Annualized values are essentially the series of cash flows required to be invested per year in order to maintain the quality and functionality of the bridge for the time period under consideration. The lower the annualized values, the more favorable the bridge alternative is from an operation, maintenance and repair/replacement perspective. The annualized values (AV) were calculated by multiplying the present worth life cycle cost (PWLC) by an annuity factor (PA):

$$PA = DR / [1-(1+DR)^{-n}],\ n = \text{time interval in consideration}$$

$$AV = PWLC \times PA$$

Summary:

- Refer to Figure 7-1 for a comparative analysis of life cycle costs for the bridge replacement options.
- In general, bridge alternatives with the bascule span as movable span are more attractive than the bridge alternatives with vertical lift spans as movable spans from a life cycle cost analysis.
- As shown in Figure 7-1, annualized values for Option 3A (deck plate girder rolling bascule) are the lowest. This can be attributed to the lower replacement cost for PLC and drive upgrades that will occur every 15 years for the movable span as well as the lower yearly maintenance cost. The 25 years mechanical repair/replacement cost for Option 3A will be higher than Option 4S; however, option 4S will have a higher yearly maintenance cost than option 3A.
- Option 3A will also have a lower structural inspection, maintenance and repair cost than Option 2G because of the needs of extensive inspection; repair and potential replacement of the existing west abutment that would be re-used in Option 2G.

Detailed Life Cycle Cost tabulations are included in Appendix J.

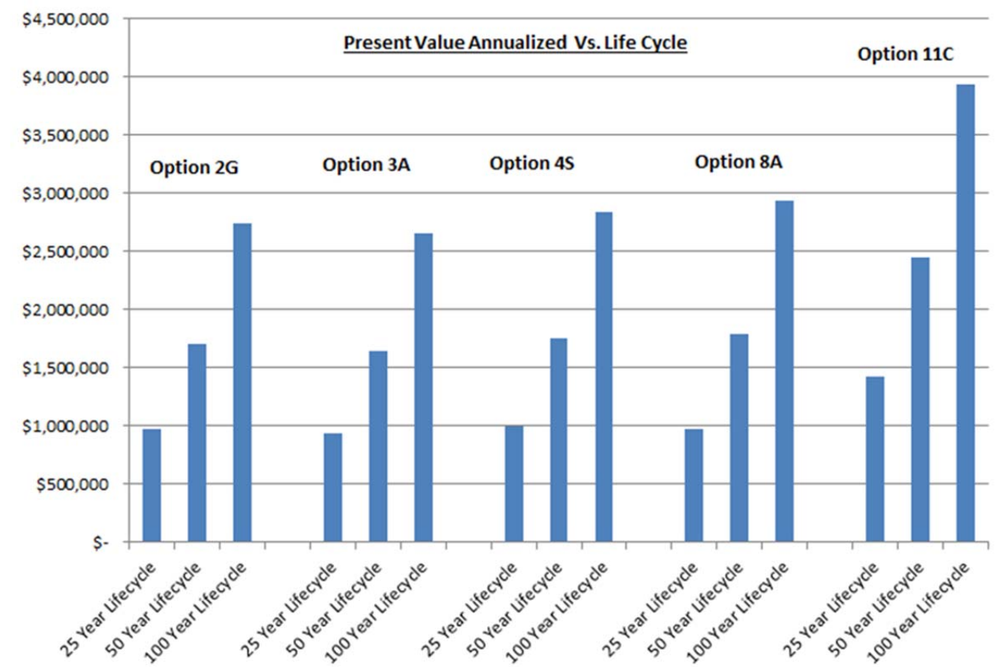

Figure 7 - 1 – Estimated Life Cycle Costs of Replacement Options

8 Comparative Analysis of Replacement Alternatives – Discussion and Recommendation

8.1 Environmental Analysis

8.1.1 Overview of the Environmental Screening Process

Table 8-1 presents the seven environmental resource impact factors used to conduct an environmental screening of the Walk Bridge replacement alternatives. Impacts to resources were quantified based upon the conceptual (15 percent) design footprints of the five bridge replacement alternatives. As an example of the method used to evaluate conceptual alternatives, Figure 8 - 1 presents the conceptual design plan view, footprint, and overlay on intertidal resources for Alternative 4S at the Norwalk River. The evaluations were completed using geographic information system (GIS) computer methods, and include all components of each alternative, comprised of the replacement bridge and railroad approaches. Similar footprints and footprint overlays on with mapped resources were developed for the other four bridge replacement alternatives.

Table 8 - 1 – Environmental Resource Screening Factors, Walk Bridge Replacement Alternatives

Environmental Factor	Evaluation Metric	Measure of Impact	Evaluation Ratings
Tidal wetlands [a]	Area of direct impact and/or indirect impact to tidal wetlands	square feet (sf)	1= most indirect & direct impact; 2= both indirect & direct impacts; 3= some indirect/no direct impact; 4 = some indirect /no direct impact; 5= no direct or indirect impact
Intertidal Habitat [b]	Area of direct permanent and direct temporary impact to intertidal habitat	sf	1= most direct & indirect impacts; 2=both minor direct & indirect impacts; 3=minor direct impacts; 4 = temporary impacts only; 5= no direct permanent or temporary impact
Benthic resources	Area of impact to State-designated natural shellfish beds	sf	1= greatest impact; ranging to 5=least impact
	Area of impact to field-observed shellfish concentration		
Essential Fish Habitat	Area of impact to river bottom	sf	1=largest footprint & longest duration in waterway; ranging to 5=smallest footprint & shortest duration in waterway
	Duration of in-water work [c]	weeks	1=longest duration in waterway; ranging to 5 = shortest duration in waterway
Floodplain	Area of fill within the 100-year floodplain	sf	1 = largest area of fill; ranging to 5=smallest area of fill
Potential unsuitable sediment	Volume of excavated material associated with construction of piers (within containment)	cy	1=greatest volume of excavated material; ranging to 5=least volume of excavated material
Noise sensitive receptors	Duration of construction period (through project construction)	months	1=shortest construction period; ranging to 5= longest construction period

a. Tidal wetlands are defined as vegetated wetlands below the high tide line.
b. Intertidal is defined as the area between the mean high water and mean low water.
c. The duration of in-water work includes removal of existing bridge substructure and construction of new bridge substructure.

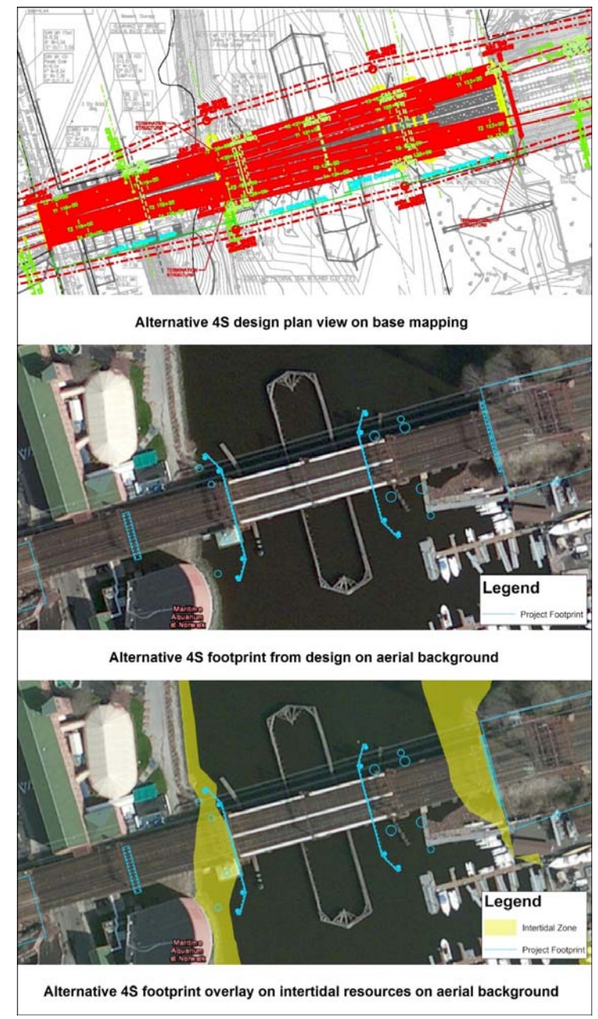

Figure 8 - 1 – Example Conceptual Design Plan View, Footprint and Overlay on Resources

In addition to the environmental screening factors identified in Table 8-1, other environmental criteria were identified and evaluated. There are several environmental criteria common to all options that would apply irrespective of the selected bridge replacement alternative. At this conceptual design stage, and relative to these additional environmental criteria, differences among bridge replacement alternatives would be indistinguishable. These criteria include:

- Coastal Zone. Walk Bridge is located within the Coastal Zone of Connecticut. Consistency with Connecticut coastal zone policies will be included in federal and state permit applications.
- Environmental Justice. Environmental Justice communities are located immediately adjacent to Walk Bridge, to the northwest, southwest, and southeast of the rail corridor.[14]
- Threatened and Endangered Species Habitat. As previously cited, the Natural Diversity Data Base Map (June 2014) indicates that Walk Bridge is located in an area with state and federal listed species and significant natural communities. Additional review will be requested to determine specific boundaries of resource areas and locations of species.
- Environmental Risk Sites. A preliminary database search indicates that there are environmental risk sites, as listed in federal and/or state databases, located within or proximate to the project footprint.[15] Additional review will be conducted as necessary to assess the potential to encounter environmental risk sites during project construction.
- Land Use Planning and Zoning. The Walk Bridge replacement project is consistent with existing land use planning and zoning. The need for the replacement project has been documented in federal and state transportation planning documents.[16]

The following environmental criteria are not applicable to the project site and immediate vicinity, and were not included in the environmental impact screening:

- Aquifer Protection Areas. This criterion is not applicable. Walk Bridge is not located in an aquifer protection area, as designated by Connecticut DEEP.
- Wells and Public Water Supplies. This criterion is not applicable. Walk Bridge is not located in an area of contribution to a public water supply.
- Prime and Unique Farmlands. Walk Bridge is not located in an area that includes prime, statewide important, or locally important farmland soils. Locally important farmland soils have not been designated by the City of Norwalk.

[14] Connecticut Department of Energy and Environmental Protection, "Environmental Justice Communities, Norwalk, CT," January 2009.
[15] Environmental Data Resources, Inc. Walk Bridge Replacement, EDR DataMap Corridor Study, November 26, 2014.
[16] Federal and state transportation planning documents include: *Northeast Corridor Infrastructure Master Plan* (NEC Master Plan Working Group, May 2010); and *Connecticut State Rail Plan, 2012-2016* (Connecticut Department of Transportation, Bureau of Public Transportation, Office of Rail).

8.1.2 Results of the Environmental Screening of Alternatives

Tables 8-2 through 8-6 present the results of the environmental screening of the Walk Bridge replacement alternatives. For each of the evaluation criteria presented in Table 8-1, the five bridge replacement alternatives were ranked from 1 to 5, with 1 being the alternative with the most measurable or likely impact, considered the least favorable alternative; and 5 being the alternative with the least measurable or likely impact, considered the most favorable alternative. Since the seven environmental factors were given equal weighting, the individual rankings were multiplied by a similar factor (10) to derive the total environmental "score" for each alternative.[17]

Table 8 - 2 – Environmental Factor Ranking of Alternative 2G

Environmental Factor	Potential Impact	Ranking	Factor	Subtotal
Tidal wetlands	661 sf of direct permanent impact; indirect impacts in 2 locations	1	10	10
Intertidal habitat	893 sf permanent direct impact; 755 sf temporary direct impact	1	10	10
Benthic resources	2,639 sf of permanent impact and 1,975 sf of temporary impact to state-designated shellfish beds	1	5	5
	92 sf of permanent impact to field-observed shellfish concentration	3	5	15
Essential Fish Habitat	1,746 sf of permanent impact and 1,220 sf of temporary impact to river bottom	1	5	5
	80 weeks of in-water work	1	5	5
Floodplain	4,787 sf of permanent impact and 2,363 sf of temporary impact within 100-year floodplain	1	10	10
Potential unsuitable sediment	6, 506 cy of sediment removal	1	10	10
Noise sensitive receptors	32-month construction period	3	10	30

Note: A ranking of 1 = greatest potential impact/least favorable alternative; a ranking of 5 = least potential impact/most favorable alternative.

Table 8 - 3 – Environmental Factor Ranking of Alternative 3A

Environmental Factor	Potential Impact	Ranking	Factor	Subtotal
Tidal wetlands	363 sf of direct impact; indirect impacts in 3 locations	5	10	50
Intertidal habitat	1,033 sf of permanent direct impact	2	10	20
Benthic resources	2,263 sf of impact to state-designated natural shellfish bed	3	5	15
	21 sf of impact to observed shellfish concentration	4	5	20
Essential Fish Habitat	1,230 sf of impact to river bottom	3	5	15
	70 weeks of in-water work	2	5	10
Floodplain	3,758 sf of impact within 100-year floodplain	4	10	40
Potential unsuitable	5,865 cy of sediment removal	2	10	20

[17] For environmental factors with two measures of impact, such as benthic resources and EFH, each impact ranking was multiplied by 5 to provide equal weighting with the other environmental factors.

Environmental Factor	Potential Impact	Ranking	Factor	Subtotal
sediment				
Noise sensitive receptors	28-month construction period	5*	10	50

Note: A ranking of 1 = greatest potential impact/least favorable alternative; a ranking of 5 = least potential impact/most favorable alternative.
* Tie with Alternative 4S

Table 8 - 4 – Environmental Factor Ranking of Alternative 4S

Environmental Factor	Potential Impact	Ranking	Factor	Subtotal
Tidal wetlands	388 sf of direct impact; indirect impacts in 2 locations	4	10	40
Intertidal habitat	496 sf of permanent direct impact	5	10	50
Benthic resources	1,532 sf of impact to state-designated shellfish bed	5	5	25
	No impact to observed shellfish concentration	5	5	25
Essential Fish Habitat	1,036 sf of impact to river bottom	4	5	20
	33 weeks of in-water work	5	5	25
Floodplain	2,823 sf of impact within 100-year floodplain	5	10	50
Potential unsuitable sediment	3,530 cy of sediment removal	5	10	50
Noise sensitive receptors	28-month construction period	5*	10	50

Note: A ranking of 1 = greatest potential impact/least favorable alternative; a ranking of 5 = least potential impact/most favorable alternative.
*Tie with Alternative 3A

Table 8 - 5 – Environmental Factor Ranking of Alternative 8A

Environmental Factor	Potential Impact	Ranking	Factor	Subtotal
Tidal wetlands	448 sf of direct impact; indirect impacts in 3 locations	2	10	20
Intertidal habitat	947 sf of direct impact	4	10	40
Benthic resources	2,526 sf of impact to state-designated shellfish bed	2	5	10
	126 sf of impact to observed shellfish concentration	1	5	5
Essential Fish Habitat	1,579 sf of impact to river bottom	2	5	10
	40 weeks of in-water work	4*	5	20
Floodplain	4,398 sf of impact within 100-year floodplain	2	10	20
Potential unsuitable sediment	4,034 cy of sediment removal	4	10	40
Noise sensitive receptors	36-month construction period	2	10	20

Note: A ranking of 1 = greatest potential impact/least favorable alternative; a ranking of 5 = least potential impact/most favorable alternative.
* Tie with Alternative 11C

Table 8 - 6 – Environmental Factor Ranking of Alternative 11C

Environmental Factor	Potential Impact	Ranking	Factor	Subtotal
Tidal wetlands	440 sf of direct impact; indirect impact in 3 locations	3	10	30
Intertidal habitat	1,009 sf of direct impact	3	10	30
Benthic resources	1,784 sf of impact to state-designated shellfish bed	4	5	20
	117 sf of impact to observed shellfish concentration	2	5	10
Essential Fish Habitat	775 sf of impact to river bottom	5	5	25
	40 weeks of in-water work	4*	5	20
Floodplain	3,786 sf of impacts within 100-year floodplain	3	10	30
Potential unsuitable sediment	4,467 cy of sediment removal	3	10	30
Noise sensitive receptors	38-month construction period	1	10	10

Note: A ranking of 1 = greatest potential impact/least favorable alternative; a ranking of 5 = least potential impact/most favorable alternative.
* Tie with Alternative 8A

8.1.3 Summary

Table 8-7 presents the summary of results of the environmental screening for the Walk Bridge replacement alternatives. The compilation of the environmental screening subtotals was used to rate the relative level of permitting complexity for each alternative, which is based upon the premise that greater impacts would involve more documentation and would increase permitting complexity. For the purposes of this screening, it is assumed that permitting complexity would increase with increased number of weeks of in-water work; increased size of footprint within resource areas; increased volume of dredged sediment; and increased construction duration. The lowest scoring alternative would be likely to have a more complex permitting process (least favorable alternative), and the highest scoring alternative would be likely to have a less complex permitting process (most favorable alternative).

Table 8 - 7. Summary of Bridge Replacement Alternatives Environmental Rankings

Environmental Factor	Alternative 2G	Alternative 3A	Alternative 4S	Alternative 8A	Alternative 11C
Tidal wetlands	10	50	40	20	30
Intertidal habitat	10	20	50	40	30
Benthic resources	20	35	50	15	30
Essential Fish Habitat	10	25	45	30	45
Floodplain	10	40	50	20	30
Potential unsuitable sediment	10	20	50	40	30
Noise sensitive receptors	30	50	50	20	10
Composite Score	**100**	**240**	**335**	**185**	**205**

Environmental Factor	Alternative 2G	Alternative 3A	Alternative 4S	Alternative 8A	Alternative 11C
Environmental Ranking	**1**	**4**	**5**	**2**	**3**

Based on the results of the environmental screening, Alternative 4S, with a composite score of 335, would be the most favorable alternative from an environmental perspective; it would likely have the least environmental impacts and potentially the least complex permitting process. Alternative 3A, with a composite score of 240, would be the second most favorable alternative; followed by Alternative 11C, with a composite score of 205; and Alternative 8A, with a composite score of 185. Alternative 2G, with a composite score of 100, would likely have the greatest environmental impacts and the most complex permitting process, and would therefore be the least favorable alternative from an environmental perspective.

The result of the environmental screening of the bridge replacement alternatives is a contributory factor in the overall screening criteria for determining the preferred alternative.

9 Summary

9.1 Recommended Option

9.2 Cost

9.3 Schedule

9.4 Effects on Track and Channel Operations