**HEAVY MOVABLE STRUCTURES, INC.**
**THIRTEENTH BIENNIAL SYMPOSIUM**

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# Fore River Bridge Replacement Study


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# Introduction

The bridge site is located at the mouth of the Weymouth Fore River, which divides the City of Quincy from the Town of Weymouth, on the South Shore of Massachusetts. The bridge carries State Route 3A, and is located about 9 miles south of Boston's city center. Route 3A carries over 30,000 vehicles on a daily basis. Immediately inboard of the bridge is the site of the old Fore River Shipyard, which at one time was one of the busiest shipyards in the United States.

The old Fore River Bridge, a bascule bridge constructed in 1936, was found to be seriously deteriorated in the late 1990s. In 2002, the historic bridge was replaced by a $60 million temporary movable bridge with a fifteen-year life span.

The Massachusetts Department of Transportation (MassDOT) has studied the site to identify the most appropriate permanent solution for replacing the temporary bridge. In 2008, MassDOT tasked the STV design team with investigating both a vertical lift and bascule type bridge, and with selecting the preferred bridge alternative. Once the selection has been accepted by both MassDOT and FHWA, the design team is tasked with advancing the design to the 30% level of completion, submitting all appropriate regulatory permits, and with developing procurement documents so the bridge may be bid as a 'Design-Build' contract. The value of the Design-Build Contract is expected to be $260 million.

# Site History

The roadway that is now Route 3A has been a major route to the South Shore, ever since the Hingham and Quincy Bridge and Turnpike Corporation was formed in 1808. A steel, through truss, swing bridge was built across the Fore River 1902. However due to the growth of the Fore River Shipyard, which was established in Quincy in 1901, and the increase in volume of roadway traffic, the swing bridge proved to be a bottleneck. The swing bridge was replaced in 1936 by a bascule bridge, which provided a channel width of 175 feet, and a vertical channel clearance of 33' at the fender line with the bridge in the closed position. The double leaf bascule span was supported by deck truss girders. There were also a total of seven approach spans and two approach ramps which, along with the moveable span, had a total length of 2,216 feet. The bridge carried four lanes of traffic, and two sidewalks. The pier structures were faced in granite and trimmed with copper detailing, and had an architectural treatment consistent with the Art-Deco style. The bridge won an Honorable Mention in 1936 from the American Institute of Steel Engineers.


***Photo 1 – Fore River Shipyard in 1918, Swing Bridge in background.***

The Fore River Shipyard moved from East Braintree to Quincy in 1901. The volume of shipping manufacture steadily increased and reached its zenith during World War II, at which time over 50,000 workers were employed. Submarines and battleships were built for the US Navy. After the war, the volume of manufacture went into decline. In the 1970s, the shipyard built LNG tankers. The last ship was built in 1982. There was an attempt in the 1990s to revive ship building at the site, which proved to be unsuccessful. Today the shipyard site is used for various industrial, commercial and storage uses. The old shipyard site, and the surrounding area is currently classified as a 'Designated Port Area' by the Massachusetts office of Coastal Zone Management (CZM).

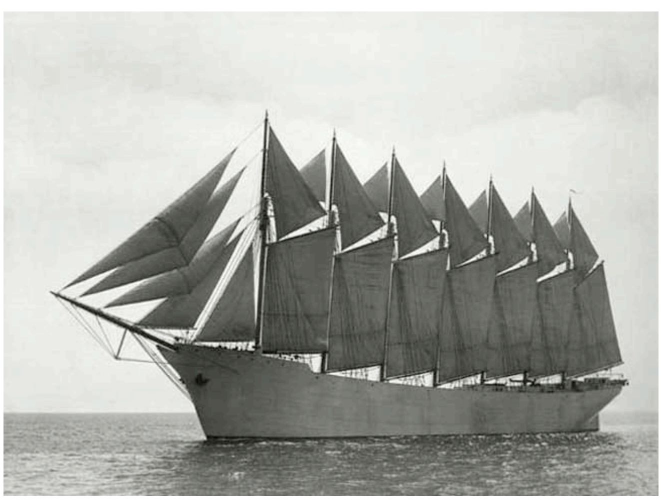


***Photo 2 - Schooner 'Thomas W. Lawson' 1902, the largest schooner and the largest pure sailing vessel ever built, product of the Fore River Shipyard.***

***Photo 3 – USS Massachusetts, built in 1942, at the Fore River Shipyard***

Despite the loss of the shipyard, the Fore River navigation channel is still heavily used by a variety of vessels. In 2002 the bascule bridge had over 600 bridge openings. Vessels range from pleasure boats with masts of over 30 feet, to Panamax class oil tankers supplying the Citgo storage facility. The facility, which is located on the in-board side of the bridge, is a major distribution center for heating oil, gasoline and diesel fuel for the New England area.

In 1999, a major rehabilitation of the bascule bridge superstructure was initiated. However, as the work progressed, serious deterioration of the concrete pier structures was identified. In particular, the concrete components of the superstructure and piers suffered from extensive and irreparable defects caused by alkali-silica reactivity (ASR). In 2000, the decision was made to completely replace the bridge. A temporary, ACROW type, twin leaf vertical lift movable bridge had been scheduled to be erected across the Fore River immediately in-board of the bascule bridge in order to facilitate the superstructure rehabilitation. The plans and specifications for the temporary bridge were re-worked to assure a minimum 15 year life span. Construction of the temporary bridge was completed in 2002, providing a 175’ channel width and 175 feet vertical clearance when in the open position. The 1936 bascule bridge was demolished in 2004, along with the approach spans on both the Quincy and Weymouth sides. At the direction of the US Coast Guard, the foundations of the bascule pier were completely demolished two years later. Only the approach ramps and the approach span foundations now remain.

***Photo 4 - Fore River 1936 Bridge***

***Photo 5 Fore River Temporary Bridge***

# 2002 Replacement Study

Once the decision was made to demolish the bascule bridge, MassDOT commissioned a Replacement Study, which was conducted by Vollmer Associates, LLP, and published in January 2002. Alternatives for replacing the deteriorated 1936 Bridge that were investigated included:

- Vertical lift bridge providing a 300’ navigation channel, and 40’ vertical channel clearance,
- Bascule bridge providing a 300’ navigation channel, and 40’ vertical channel clearance,
- Vertical lift bridge providing a 300’ navigation channel, and 70’ vertical channel clearance,
- Bascule bridge providing a 300’ navigation channel, and 70’ vertical channel clearance,
- Fixed bridge with a 350 foot main span,
- Fixed bridge with a 750 foot main span (no piers in the river),
- A tunnel, and
- Alternative alignments for Route 3A across the Fore River.

The 300 foot channel width was investigated for all bridges because the defined Federal navigation channel width on both the in-bound and out-bound approaches to the bridge is 300 feet or greater.

The study ultimately concluded that a movable bridge on the existing alignment of Route 3A presented the best solution. The study further stated that a 350-foot bascule span would present a significant structural design challenge. Increasing the vertical clearance to 70 feet in the closed position would "eliminate approximately 50% of the bridge openings", but that benefit is offset by the additional cost, and disruption to the Quincy and Weymouth neighorhoods.

# 2010 Bridge Type Study

In 2008 MassDOT contracted STV Incorporated to perform a detailed investigation into whether a vertical lift bridge or a bascule bridge should be selected for the site. The recommended alternative is identified through the Bridge Type Study, and is to be submitted to the FHWA for concurrence through an Environmental Assessment. To support the Environmental Assessment, a noise analysis, an air quality analysis, and a traffic analysis are being performed. A Geotechnical Report and a Hydraulics Study are also being performed to better define the project constraints.

Through an interactive process with the United States Coast Guard and the mariners who frequent the channel, MassDOT and the design team establisheded criteria for the navigation channel width. The Coast Guard and mariners would not accept the 175 foot width provided by the 1936 Bridge and currently provided by the Temporary Bridge. However, MassDOT successfully argued that furnishing a navigataion channel of 300 feet was needlessly expensive. The outcome was that the Coast Guard would accept 225 feet as an absolute minimum, which can be accommodated by a bascule bridge, but that the preference was for 250 feet which can be furnished by a vertical lift bridge. As a consequence the Type Study went forward with to options namely a bascule bridge with a 225 foot navigation channel, and a vertical lift bridge with a 250 foot channel.

At the time of writing, STV has completed the Bridge Type Study and has recommended that a Vertical Lift Bridge be selected for the site. The selected type is currently under review with the FHWA. Provided here is a summary of the advantages and disadvantages identified for both the vertical lift and the bascule bridge types at this site.

The conclusion of the Type Study was that STV recommended the Vertical Lift option for the movable span. The proposed vertical lift span of 320 feet is well within the standards of application for vertical lift bridges. Conversely, the proposed Bascule Structure would represent the largest and heaviest bascule structure in the United States. The advantages and disadvantages of the two bridge types are summarized below.

## Vertical Lift Advantages

Ease of Navigation:

- Based on a 10% design level, both bridge types have approximately the same cost of construction, which is $136 million. However, the Vertical Lift, which provides an additional 25 feet of horizontal navigation clearance, represents the better value in terms of optimizing the ease of navigation.
- The Fore River estuary is classified as a "Designated Port Area" by the Massachusetts Office of Coastal Zone Management (CZM). Because of this designation, the proposed bridge cannot hinder the present use, and future development of the port facilities. With the widening of the Panama Canal, larger vessels, both tankers and freighters, will be using port facilities along the US east coast. The Fore River Bridge site is located at a sharp bend in the

navigation channel. In addition, vessels navigating the site must contend with significant tidal currents because of the constriction in the river at the bridge site. The 250 foot navigation channel will better accommodate these larger vessels at this challenging navigation location.
- A critical hurdle for the project to clear is the acceptance by the US Coast Guard. By providing a 250 foot navigation channel width, the project optimizes the potential of achieving an approved permit from the Coast Guard, in a timely manner. While not discounting the 225' channel, the Mariners have expressed a clear preference for the 250 foot channel. The potential for delay to the project in the Coast Guard approval process, or even rejection of the application, are significant with the Bascule option.
- Coast Guard regulation 117.621 states that during commuting times the bridge is only to open on signal for vessels greater than 10,000 gross tons. Consequently, sloops and other small vessels that require bridge openings to navigate the channel are restricted to passing through the channel at non-commuting times. The vertical lift, which maximizes vertical clearance when the movable span is in the closed position, minimizes this restriction.
- As the lift piers are set back behind the 320 foot lift span, there is no danger of a collision with the bridge structure should a Panamax vessel strike the fender system at an angle of up to 15 degrees.

Ease of Vehicular Transit:
- The Vertical Lift provides an additional 17 feet of vertical clearance at the fender line when the movable span is in the closed position; that is, when the span is open to roadway traffic. Consequently, the number of annual bridge openings is estimated to be 475, roughly 25% lower than the 633 openings that would be anticipated for the bascule bridge. This equates to fewer delays for vehicles using the bridge, and less frequent traffic queues in the "touch-down" neighborhoods.
- The resulting improved vehicular traffic movement reduces many ancillary impacts including air pollution, vehicle engine noise, wasted time sitting in traffic when the bridge is open, and detours for maintenance.

Structural Considerations:
- The Vertical Lift requires smaller and less costly foundations since elaborate cofferdams and associated tremie seal placements are not required. The result is a reduction to the permanent impact area within the bed of the Fore River channel, while also reducing the amount of sediment disturbance during construction.
- The Vertical Lift has better seismic performance because the structure is "softer" or more flexible than the Bascule.
- The Vertical Lift represents a lesser impact on the hydraulic characteristics of the Fore River since the pier structures are smaller and do not occupy as much of the cross-sectional area of the river. For the 100 year scour event, the Vertical Lift has 13 feet depth of scour, while the Bascule has 33 feet depth of scour.
- The operations of a Vertical Lift bridge are less affected by high winds when compared to a Bascule bridge of this magnitude. Consequently, the operation of the vertical lift is less likely to be disrupted during high winds than the bascule.

Machinery Components:

- The Vertical lift requires only two sets of machinery, instead of the four sets needed for the Bascule.
- Vertical Lift machinery sizes are well within the parameters of both the American Gear Manufacturers Association (AGMA) and AASHTO Standards.
- Adequate access around the machinery for inspection and maintenance can be assured.
- The Vertical Lift has smaller machinery and, as a consequence, has lower electrical requirements, operational costs, and less impact on the environment.
- The Vertical Lift requires fewer electrical cabinets.

Constructability:

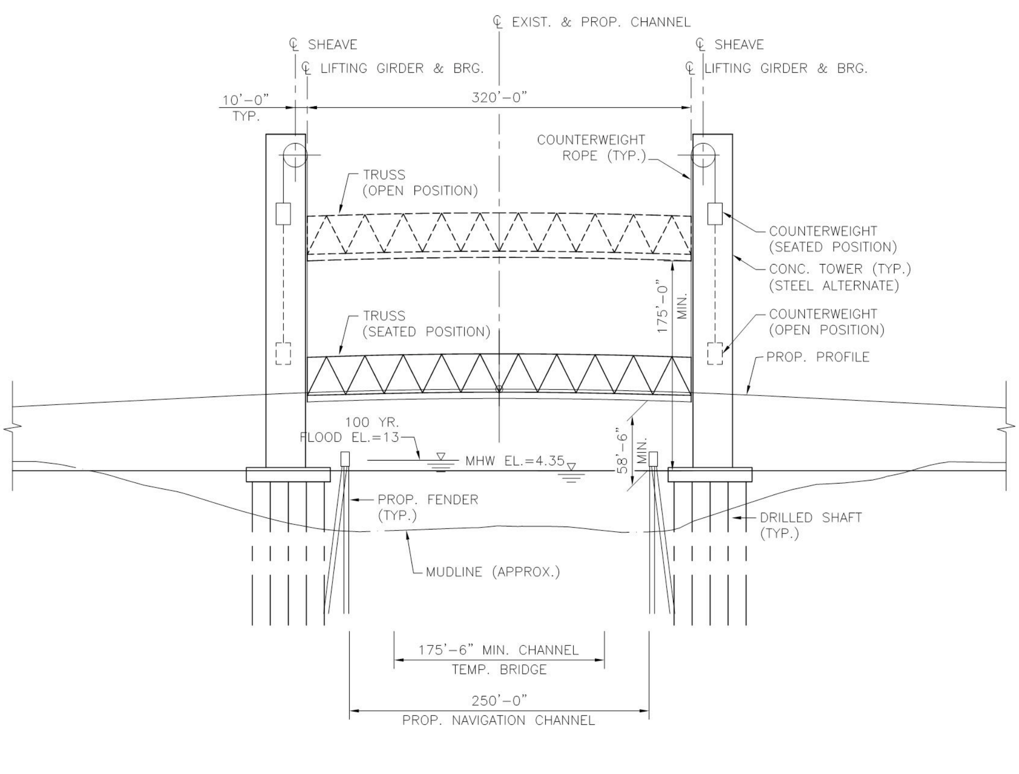
- The Vertical Lift span can be constructed off-site, floated into place, and installed with minimal disruption to the navigation traffic. The construction can more easily be accelerated for the vertical lift.

## Vertical Lift Disadvantages

Aesthetics:

- The Vertical Lift results in a taller structure which generates a greater visual impact.
- The Vertical Lift structure is not consistent with the architectural form of the original bridge.
- In terms of aesthetics, this is not the preferred bridge type for the nearby communities.

***Figure 1– Proposed Vertical lift Elevation***



## Bascule Advantages

Aesthetics:

- The Bascule structure is consistent with the previous bridge type.
- The Bascule is aesthetically preferred by the nearby communities.

## Bascule Disadvantages

Ease of Navigation:

- The horizontal clearance is not as wide as the vertical lift option resulting in a more constricted passageway for vessels. A larger number of vessels under 10,000 gross tons will be restricted from using the channel during commuting times.
- The possibility of a vessel striking the bridge superstructure exists when the bascule span is in the open position and the angle of impact is less than 15 degrees.

Ease of Vehicular Transit:

- More openings are anticipated, leading to more disruption of roadway traffic.
- The transverse joint in the roadway at the intersection of the Bascule leaves will generate a slight “bounce” or discontinuity for motorists passing over the bridge. The “bounce” effect can be counteracted with shear locks, but will not be eliminated.

Structural Considerations:

- The proposed bascule structure—having a solid deck, a span length of 315 feet from trunnion to trunnion, and a span width of 74 feet—would be extremely large for a bascule-type structure. If constructed, this bascule bridge would represent the largest, heaviest bascule structure in the United States.
- The larger pier structures for the Bascule, necessary to accommodate the counterweight as it drops below the deck, will likely require elaborate cofferdam and tremie systems resulting in greater permanent impacts to the bed of the Fore River.
- The massive and stiff pier structures for the Bascule will have less favorable behavior under seismic load and will require very large foundation systems. The larger foundations will result in a more significant marine habitat/river bed impact.
- The larger pier structures will generate a greater impact on the hydraulic characteristics of the Fore River including a potential for greater scour depth.
- The Bascule pits will need sump pumps and will tend to collect debris from roadway joint run-off.

Machinery Components:

- The four sets of machinery will be very large and will require the use of high performance materials in order to conform to the parameters of AGMA and AASHTO.
- Procurement, maintenance, and eventual replacement of these non-standard machinery components will present significant challenges (see note 1).

- The size of the machinery needed for this bascule generates great difficulty in fitting all components within the pier structure pits. Fitting all equipment within the pits while providing minimal access for inspection and maintenance will be problematic (see note 1).
- The Bascule leafs, in order to carry roadway traffic, will have a high dependency on lock machinery that will require continual maintenance regardless of how conservatively it is designed.
- As the raising and lowering of the bascule leaves is affected by high winds, additional motors with higher horsepower are required for the bridge to function properly.

Constructability:

- The construction of the bascule leafs, typically constructed in the horizontal position across the channel, will likely have a significant impact on the navigation channel. The construction is, in general, more complex than the vertical lift and is expected to cause more frequent construction challenges, potentially leading to additional delays and claims.

Aesthetics:

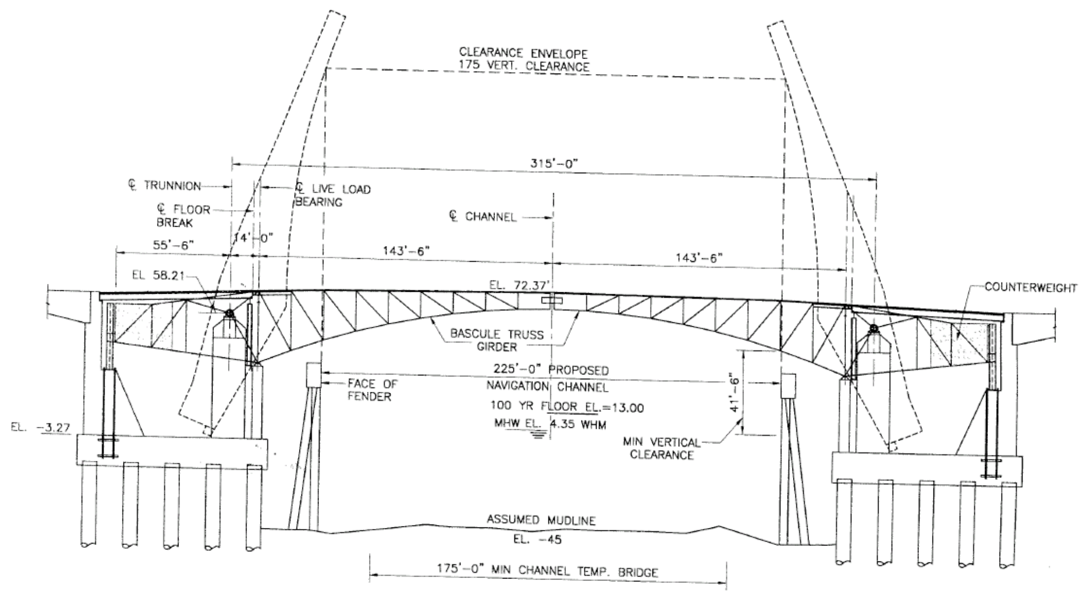
- The proposed Bascule Bridge, with its enclosed counterweight pits will be considerably more massive than the 1936 Bascule structure. Although still a Bascule, the proposed Bascule will not be similar in appearance.

Life Cycle/Maintenance Cost:

- The proposed Bascule Bridge option presents difficulties in maintenance associated with access to the closed pit pier (see Note 1 below). When large components need to be replaced, access to the pits will need to be from the channel side and from the water. During this replacement work, the bridge will need to be set in the open position, causing significant disruptions in roadway traffic.
- As more motors/machinery will be required to drive the movement of the bridge, additional maintenance will in turn be necessary.

*Note 1:*
*From a mechanical standpoint, the enclosed gear reducers and other components required by the bascule option are very large and will be difficult to fit in the space available while providing even a minimum level of access for maintenance. The semi-circular rack gear needs to utilize internal gear teeth with the superstructure configuration proposed. Internal gears of this size are unusual, and most suppliers do not have much experience producing them. The full length of the rack gears will most likely be impractical to access given structural constraints, making maintenance and inspection problematic. From an inspection standpoint, the open gears will be too large for traditional chordal tooth measurements as commercially available calipers are too small, and the size of the gears and potential restricted access may make span measurements difficult. The rack gears, being internal, cannot have meaningful wear measurements made on them.*

***Figure 2 – Proposed Bascule Longitudinal Section***





References: Fore River Bridge Type Study, STV Incorporated, September 2010

HAER MA-36 - Fore River Bridge, Route 3A, spanning Fore River, Weymouth, Norfolk County, MA

Forerivershipyard.com

The Fore River Bridge Replacement Study, Vollmer Associates, LLP, January 2002

Photos –wikipedia.com