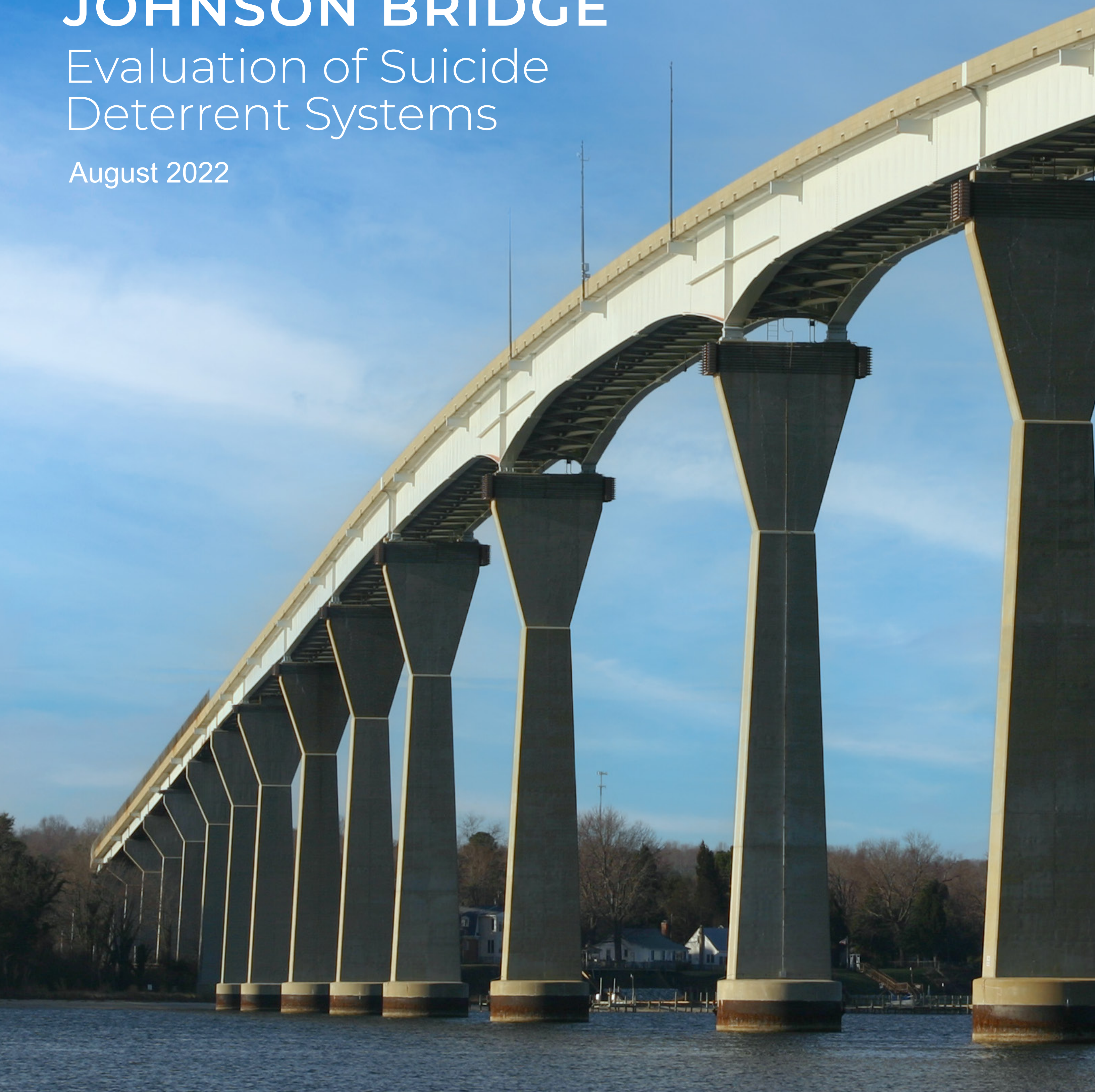
MARYLAND DEPARTMENT OF TRANSPORTATION

STATE HIGHWAY ADMINISTRATION

GOVERNOR THOMAS JOHNSON BRIDGE

Evaluation of Suicide Deterrent Systems

August 2022



Executive Summary

The Governor Thomas Johnson Bridge is a 1.4-mile-long bridge on MD 4 (Patuxent Beach Road) over the Patuxent River and Town Creek, near Solomons, Maryland. The Maryland Department of Transportation State Highway Administration (MDOT SHA) owns and maintains the bridge. The bridge rises approximately 160 feet above the water to accommodate a 140-foot-high US Coast Guard navigation channel within its main span.

As of March 15, 2022, four suicide attempts have occurred since the beginning of the year. MDOT SHA has undertaken steps to reduce the number of suicides by installing signage on the bridge that connects individuals to a crisis hotline. The purpose of this report is to assess feasible alternatives for additional suicide deterrent systems on the bridge.

Two types of suicide deterrent systems are typically used on bridges, physical and non-physical. Physical suicide deterrent systems include measures such as tall barriers and netting designed to physically impede the ability of an individual to jump. In contrast, non-physical deterrent systems include measures such as patrols, signage, and callboxes that connect persons to crisis and suicide hotlines. In general, most known physical suicide deterrent systems on major bridges are tall barriers. One exception to this is the Golden Gate Bridge, where a 20-foot-wide horizontal net located approximately 20 feet below the roadway surface is currently being installed.

Eight conceptual alternatives were identified for preliminary evaluation, considering both physical and non-physical systems. Three alternatives represented a range of tall barriers, two represented a range of netting, and three represented options for on-site security monitoring, remote video monitoring, or callboxes combined with signage. The non-physical alternatives were not pursued further since MDOT currently uses a combination of the non-physical deterrent systems. MDOT continuously works with our partners to review operational, training, and safety protocols and procedures.

The physical alternatives consisted of three barrier and two netting alternatives, identified numerically one through five. The numerical identification is not indicative of any preference or value. These alternatives were examined against 13 factors addressing safety, structural, operations and maintenance, and regulations. Estimated construction costs and schedules to implement the systems were developed, including considerations for temporary maintenance of traffic, sequence of construction, and temporary work zone protection during construction. Maintenance of traffic involves the location and configuration of traffic on the bridge and approach roadways during construction. Refer to Appendix B for a comparison of the alternatives against each of the factors considered.

Based on a review of numerous barrier deterrent systems and standard bridge protective fencing, the heights of the barriers vary but a minimum height of 8 feet is commonly used above the roadway surface or any perceived foothold. Additionally, the barriers are typically developed with anti-climb features and materials that impede the ability of the deterrent system to be scaled. The proposed barrier alternatives explore locations on and behind the existing bridge parapet and generally range in height from 8 feet, 0 inches to 10 feet, 8 inches from the roadway surface based on the location of a perceived foothold. The alternatives consider anti-climb features such as an angled return at the top of the barrier and the use of woven wire mesh to hinder climbing.

Less information is available on netting deterrent systems. The netting alternatives consider locations near the roadway level and further below near the bottom of the bridge beams. The depth of the bridge from the top of the roadway to the bottom of the beam varies along its length from 4 feet, 6 inches in the approach spans to 21 feet, 9 inches in the main span over the navigation channel. Within the main span, the netting was preliminarily evaluated at approximately 15 feet below the top of the bridge parapet. The width of the net varies based on depth, with a width up to 15 feet in the main span. Some research recommends that netting be located significantly below the pedestrian level to deter jumping, suggesting a minimum depth of approximately 13 feet based on a statistical evaluation of a subset of data (Hemmer, Meier, and Reisch, 2017). This depth is not achievable in most spans across the bridge based on the geometry of the bridge and the attempt to keep netting above the bottom of the beam.

A bridge analysis was performed to evaluate the effects of the added weight and wind effects from the proposed alternatives. Critical sections of the bridge were assessed, including the concrete and steel beams and the tallest pier. The purpose of the initial assessment was to screen the effects of the alternatives to evaluate the feasibility of adding a barrier or netting system to the bridge. Preliminary evaluations indicate that although the addition of a

suicide deterrent system is feasible, it may require strengthening of some pier columns. Further analysis would be necessary to assess the additional cost, full design, and timeline.

One of the more significant effects of adding a suicide deterrent system to the bridge is the effect on the routine condition inspection of the bridge. The National Bridge Inspection Standards (NBIS) requires routine inspection of the bridge on a 24-month basis. Additionally, the main span of the bridge over the navigation channel, and the four spans on each side, consist of a two-girder system, which is fracture critical. A fractural critical member is a steel member in tension, or with a tension element, whose failure would probably cause a portion of or the entire bridge to collapse. In accordance with NBIS requirements, MDOT SHA performs a hands-on inspection, within arm's reach, of the fracture critical members on a 12-month basis. The bridge inspection requires special access equipment located on top of the roadway that reaches around the edge of the bridge and under the bridge. The addition of barriers and netting affects access to the areas under the bridge. The netting alternatives significantly affect, if not prohibit, the beams from being inspected from the top of the roadway in all spans. In contrast, the barrier alternatives significantly affect, if not prohibit, the inspection of the beams from the top of the roadway within the fracture critical spans only. For the barrier alternatives, options such as designing removable sections of the barrier could be evaluated to mitigate the effect within the fracture critical spans, which would increase the cost and delivery time, possibly significantly.

In terms of cost and schedule to implement, one of the major contributing factors is the consideration for temporary maintenance of traffic during construction. Since the bridge only has two lanes of traffic, and one lane will be required for construction, the cost and schedule have been preliminarily based on nighttime, single-lane closures during the week without seasonal restrictions. The nighttime closures are based on the current traffic requirements for the routine condition inspection of the bridge. The estimated construction cost in 2022 dollars is between $8.5 million and $13.3 million. The estimated time to implement the project is between 26 and 34 months, which includes the time for planning and preliminary engineering, final design, and construction. Planning and preliminary engineering include the National Environmental Policy Act (NEPA) and National Historic Preservation Act Section 106 processes. Additional economies and a shorter period of construction can be realized if sustained daytime lane closures and/or weekend work is permitted. If the seasonal restriction of November 1 to March 31, normally imposed on the routine condition inspections of the bridge, is imposed on this project, it will likely take an additional 10 to 12 months for construction to be completed.

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Acronyms and Abbreviations

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
BHA	Behavioral Health Administration
CE	Categorical Exclusion
CFR	Code of Federal Regulations
CWA	Clean Water Act
DNR	Department of Natural Resources
EA	Environmental Assessment
EIS	Environmental Impact Statement
ESC	erosion and sediment control
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FONSI	Finding of No Significant Impact
ft	feet
kip	1,000 pound-force
lb	1 pound-force
LF	linear foot
MASH	Manual for Assessing Safety Hardware
MBTA	Migratory Bird Protection Act
MD	Maryland
MDE	Maryland Department of the Environment
MDH	Maryland Department of Health
MDOT	Maryland Department of Transportation
MEPA	Maryland Environmental Policy Act
MOT	maintenance of traffic
MOTAA	Maintenance of Traffic Alternatives Analysis
MOU	Memorandum of Understanding
mph	miles per hour
NBIS	National Bridge Inspection Standards
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NHS	National Highway System
NOAA	National Oceanic and Atmospheric Administration
NRHP	National Register of Historic Places
NTP	Notice to Proceed
PA	Programmatic Agreement
PATON	Private Aids to Navigation
PCE	Programmatic Categorical Exclusion
RHA	River and Harbors Act
psf	pounds per square foot
ROD	Record of Decision
SDS	suicide deterrent system
SHA	State Highway Administration
SPRAT	Society of Professional Rope Access Technicians
State	State of Maryland
SF	square feet
US	United States
USACE	US Army Corp of Engineers
USCG	US Coast Guard
USFWS	US Fish and Wildlife Services
vpd	vehicles per day
WQC	Water Quality Certification
ZOI	Zone of Intrusion

Introduction

The Governor Thomas Johnson Bridge is a 1.4-mile-long bridge on MD 4 (Patuxent Beach Road) over the Patuxent River and Town Creek, near Solomons, Maryland. The bridge is one of two crossings over the Patuxent River in Southern Maryland and connects Calvert and St. Mary's Counties. Built in 1977, the bridge is owned and maintained by the Maryland Department of Transportation State Highway Administration (MDOT SHA). The bridge carries two lanes of traffic, with minimal shoulders, and no sidewalks or dedicated bicycle lanes.

The bridge rises approximately 160 feet above the water to accommodate a 140-foot-high US Coast Guard (USCG) navigation channel within its main span. In recent years there has been an increased number of suicides and suicide attempts on the bridge. As of March 15, 2022, four suicide attempts have occurred since the beginning of the year.

MDOT has undertaken steps to deter suicides on bridges by installing signage connecting individuals to a crisis hotline. The message on these signs was developed in coordination with the Maryland Department of Health (MDH) Behavioral Health Administration. The MDOT also continuously monitors traffic cameras at or near bridges for stopped vehicles or presence of individuals to quickly dispatch the appropriate first responders to the scene. The purpose of this evaluation is to assess feasible alternatives for other suicide deterrent systems (SDS) on the bridge.

Purpose and Need

The Governor Thomas Johnson Bridge is a significant feature within the region. The purpose of the evaluation is to assess feasible alternatives for suicide deterrent systems that will impede individuals from jumping off the bridge.

Scope of Work

The evaluation includes the assessment of feasible alternatives for suicide deterrent systems on the bridge. The primary tasks include:

- Identifying feasible alternatives.
- Assessing how alternatives are influenced by recent bridge condition inspections, existing bridge details, American Association of State Highway and Transportation Officials (AASHTO) codes, and Manual for Assessing Safety Hardware (MASH) criteria.
- Evaluating alternatives over a range of topics including effects on the bridge; costs to construct; time to implement; maintenance of traffic during construction; permit and/or agency coordination; bridge maintenance and inspection; and other considerations.

The evaluation is based on conceptual-level development of the alternatives. Construction costs and schedules are representative of the preliminary stage of development.

Project Site and Bridge Characteristics

The Governor Thomas Johnson Bridge is one of two crossings over the Patuxent River in Southern Maryland (Figure 1). The bridge is on MD 4 (Patuxent Beach Road) between Solomons and California, connecting Calvert County to the north with St. Mary's County to the south. The Patuxent River Naval Air Station is just downriver. The other bridge crossing is approximately 20 miles further upriver, where MD 231 (Prince Frederick Road) connects Calvert and Charles Counties near Benedict. See Figure 3 for a site and regional map.

Figure 1. Governor Thomas Johnson Bridge

From the north, MD 2 and MD 4 run together as a four-lane divided roadway, with two lanes in each direction. However, just north of the bridge, MD 2 exits to Solomons, while MD 4 continues over the bridge as a two-lane roadway, with one lane in each direction. MD 4 is classified as a Principal Arterial (Other) in this area and is on the National Highway System (NHS). In 2020, the Annual Average Daily Traffic (AADT) was approximately 23,600 vehicles per day (vpd) with 6.3 percent trucks. The AADT was down from 28,200 vpd in 2019. The posted speed limit is 45 mph on the approach roadways to the bridge. In review of available accident data between January 1, 2015 through December 21, 2021, there were 29 crashes on or near the bridge. Sixteen of the 29 crashes were classified as "same direction rear end." Six crashes were single vehicle, where three involved a vehicle striking a "curb," one involved a vehicle striking a "bridge or overpass," and two were not discernable (Maryland State Police).

The Governor Thomas Johnson Bridge is approximately 1.4 miles long (7,200 feet) and crosses over the Patuxent River and Town Creek. There are two lanes of traffic on the bridge, one each direction, with minimal shoulders and no sidewalks or dedicated bicycle lanes. There are signs on the approaches to the bridge warning of cross winds and that crossing is unadvisable for bikes and mopeds. According to the MDOT 2040 Maryland Bicycle and Pedestrian Master Plan 2019 Update, the bridge is not on a designated bicycle route. The bridge currently has a 2-foot, 8-inch tall, concrete parapet on both edges of the bridge deck, with a 5-foot-tall chain link fence constructed on top of the parapet in some spans (Figure 2).

The bridge is designated in the MDOT SHA inventory as Bridge No. 040019001. The bridge is comprised of prestressed concrete beams, steel beams, and two-girder fracture critical beams, the latter of which span the main navigation channel and the four spans on each side. According to the National Bridge Inspection Standards (NBIS), a fractural critical member is a steel member in tension, or with a tension element, whose failure would probably cause a portion of or the entire bridge to collapse. MDOT SHA performs a hands-on inspection, within arm's reach, of the fracture critical members on a 12-month basis.

Figure 2. Existing Bridge Parapet

The Governor Thomas Johnson Bridge rises approximately 160 feet above the water to accommodate a 140-foot high and 300-foot wide USCG navigation channel within the main span of the bridge. According to the as-built drawings, there are also two 50-foot channels within the approach spans over Town Creek. These channels are not maintained or surveyed by the federal government; therefore, they are not included on the USCG navigation charts. The bridge was built in 1977 and is approaching 50 years old, which is the threshold for consideration for the National Register of Historic Places (NRHP). In reference to Section 106 of the National Historic Preservation Act (NHPA), a determination of eligibility has not been completed to date for the bridge.

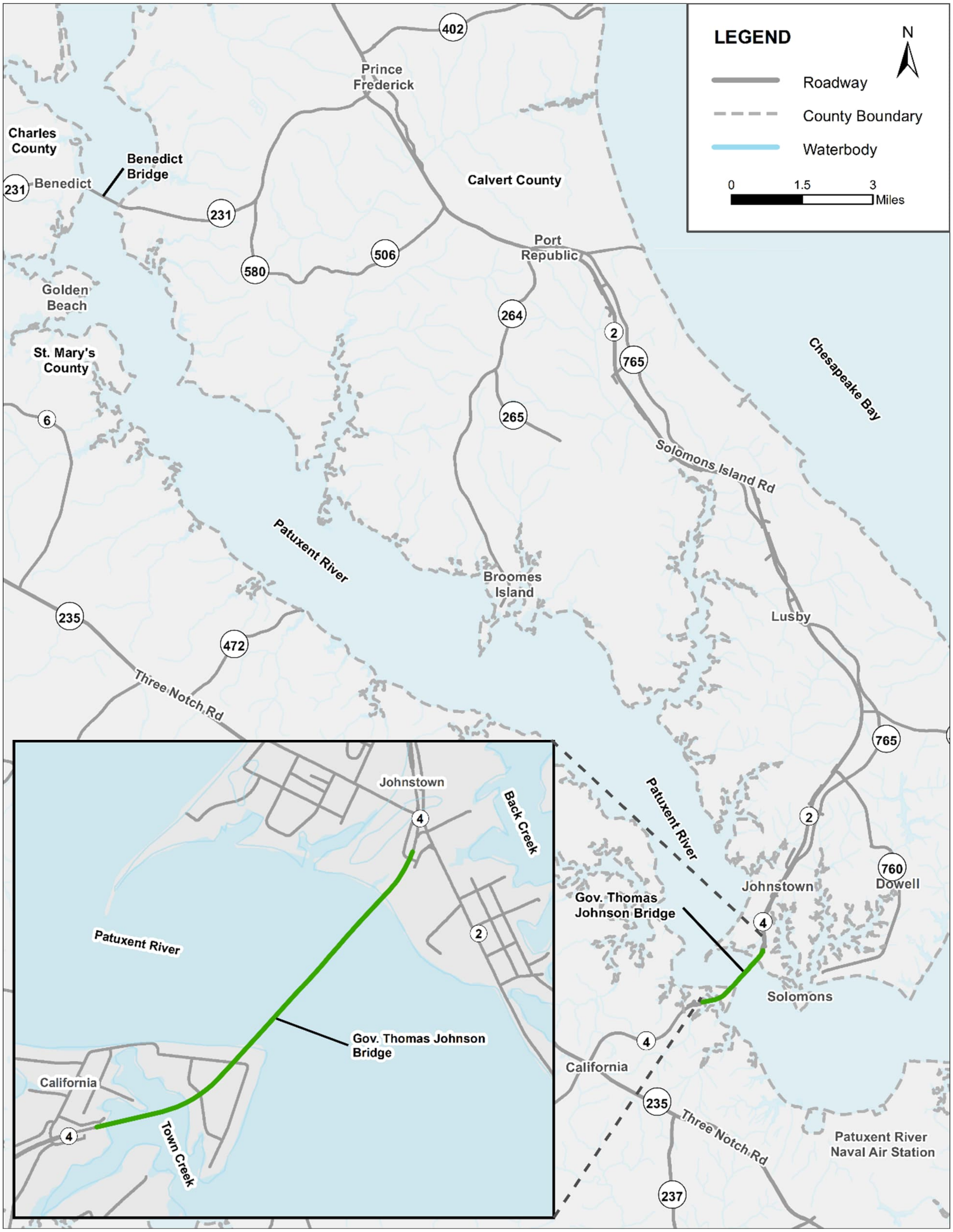


Figure 3. Site and Regional Map

Suicide Deterrent Systems

Two types of suicide deterrent systems are typically used on bridges, physical and non-physical. Physical suicide deterrent systems include measures such as tall barriers and netting designed to physically impede the ability of an individual to jump. In contrast, non-physical deterrent systems include measures such as patrols, signage, and callboxes that connect persons to crisis and suicide hotlines.

In general, most known physical suicide deterrent systems on major bridges in the United States and in other countries such as Canada, the United Kingdom, Norway, and New Zealand, are tall barriers. However, one exception to this is the Golden Gate Bridge, where a 20-foot-wide steel net located approximately 20 feet below the roadway surface is currently being constructed. The use of netting borrows from success in the use of nets to prevent suicides around the Munster Terrace cathedral in Bern, Switzerland.

Factors for Evaluating Suicide Deterrent Systems

The AASHTO bridge design codes do not include specific criteria for suicide deterrent systems. Design codes and guidelines contain information on vehicular, pedestrian and bicycle barriers in context of geometry and design loads, but nothing specific to barriers and netting used to prevent or impede suicides. The following factors were developed to evaluate the proposed suicide deterrent systems (Table 1), several of which have been used on another recent evaluation for similar systems on a notable bridge for the Federal Highway Administration (FHWA). The factors generally apply to the following broader categories: safety, structural, operations and maintenance, and regulation. The factors were used as a guide in the evaluation of the alternatives.

In reference to safety, the purpose and need of this study is to identify feasible alternatives to impede an individual's ability to jump off of the bridge (Factor A). The addition of the SDS should not adversely affect the safety or become an additional hazard to roadway users (Factor B). In other words, the barrier itself should not potentially cause harm to routine users of the bridge. Similarly, the selected SDS should not create undue risk to a person coming in contact with the system (Factor C). The SDS materials and components should not cause a person to come to undue bodily harm by attempting to climb or jump onto the deterrent system.

The SDS should minimize the effect on the existing bridge parapet's Zone of Intrusion (ZOI) for safety and maintenance reasons (Factor D). The ZOI is defined by the AASHTO Roadside Design Guide in context of a vehicle collision with the barrier (parapet). The ZOI defines an area around the barrier where a vehicle or any major part of the barrier system may extend during a collision. With regards to warrants for crash testing in accordance with MASH criteria (Factor E), the AASHTO MASH criteria require the examination of modifications to existing barriers (parapets) for warrants for full-scale crash testing. Crash testing requires full-scale mock-up of the proposed barrier and physical crash testing to evaluate the overall performance of the barrier during a crash. In some instances, depending on the overall layout and geometry, this may include both the bridge parapet and SDS. Crash testing, if warranted, will extend the final design schedule and time to implement the project. Therefore, SDS alternatives that do not warrant crash testing can be implemented sooner.

The structural category evaluates one overarching factor, does the SDS have a negative effect on the bridge's load carrying capacity (Factor F). The intent of this factor is to ensure that any additional loading from the installation of an SDS does not have a negative effect that cannot be mitigated on the bridges ability to carry traffic safely and effectively. This includes the evaluation of the bridge's structural and safety features (e.g. parapets).

The operations and maintenance category considers factors to evaluate how the installation of the SDS will affect the required routine inspection and routine maintenance of the bridge (Factors G, H, & I). Routine inspection and maintenance of the SDS is also evaluated, considering how easily the deterrent system can be inspected and maintained as part of the overall maintenance and inspection of the bridge (Factor J).

Regulation assesses effects on the USCG clearance envelope (Factor K) and NHPA Section 106 (Factor L) and National Environmental Policy Act (NEPA) requirements (Factor M). The effects of the SDS on regulations evaluate the duration of time required to implement the project. The more the effect the SDS has on regulatory requirements, the longer it may take to implement the project.

Table 1. Factors Used in the Evaluation of the Suicide Deterrent Systems

Category		Factor
Safety	A	Impede an individual's ability to jump off the bridge
	B	Not cause safety or nuisance hazard to roadway users
	C	Not create undue risk of injury to a person coming in contact with the system
	D	Minimize effect on the existing parapet's Zone of Intrusion
	E	Warrants for crash testing in accordance with MASH criteria
Structural	F	Not have a negative effect on the bridge's load carrying capacity
Operations & Maintenance	G	Not have a negative effect on routine bridge inspection
	H	Not have a negative effect on routine bridge maintenance activities
	I	Not have a negative effect on snow removal
	J	Suicide deterrent system maintenance and inspection
Regulation	K	Not have a negative effect on Coast Guard clearance envelope
	L	Satisfy historic preservation requirements
	M	Satisfy environmental laws

Development of Alternatives

The development of alternatives included an initial process to identify different types of suicide deterrent systems that could be feasible for the bridge. The initial process considered a range of distinct concepts, including both physical and non-physical systems. Following the identification of feasible alternatives, each was screened at a high level against the purpose and need of the study.

Alternatives

Alternatives were identified at a conceptual level to demonstrate the overall characteristics and objectives of each. Sketches were developed to convey the concept; however, the sketches were not intended to convey the aesthetic quality of the alternative at this preliminary stage of development (Appendix A). Some consideration for the aesthetic qualities was given in the use of the infill mesh material (Appendix C) for the barriers to increase the transparency of the barrier, in an attempt to minimize the effect on the user's experience on and off the bridge. Minimizing the effect on the users and the effect on the visual quality of the bridge and adjacent sites may respond to considerations to be evaluated during the NEPA and NHPA Section 106 assessments. The alternatives are summarized in Table 2. The numbering of the alternatives does not indicate an order or preference of the alternatives but provides a means for tracking the alternatives through the evaluation process.

Table 2. Suicide Deterrent System Alternatives

Alternative [1]		Description
1	Physical Barrier behind Existing Concrete Parapet	Construct a physical barrier on the outside face of the existing parapet, while retaining the existing parapet. Since the existing parapet could be used as a stepping point to climb the new barrier, the height of the new barrier will be referenced from the top of the existing parapet. The geometry of the new barrier will be developed to not encroach into the shoulder of the bridge where it could be struck by a vehicle.
2	Physical Barrier on top of Existing Concrete Parapet	Construct a physical barrier on top of the existing concrete parapet. The geometry of the new barrier would be developed to not encroach on the shoulder of the bridge where it could be struck by a vehicle. The barrier will be designed and detailed such that there would be no additional stepping-point above the roadway surface and therefore the new barrier can be measured from the roadway surface. This would likely result in an overall shorter barrier than Alternative 1.
3	Netting Near the Roadway Surface	Construct netting on the outside of the bridge and located at or near the level of the bridge roadway surface.
4	Netting Below the Roadway Surface	Construct netting on the outside of the bridge and located below the bridge roadway surface.
5	Hybrid Physical Barrier / Netting	Construct a physical barrier on the outside face of the existing parapet to lean away from the bridge so as not to encroach on the shoulder of the bridge where it could be struck by a vehicle. Lean the barrier away from the bridge at a slope that would make it difficult to climb. Netting could be used between posts rather than a fence-type material.
6	On-site Security Monitoring	Provide on-site security personnel to monitor the bridge 24/7.
7	Remote Video Monitoring	Install video surveillance cameras and monitor the bridge remotely 24/7.
8	Callboxes and Signage	Install callboxes and additional signage that connect persons in crisis to suicide hotlines and/or emergency personnel.
9	No-Action / No-Build	Do not construct barrier, netting, or other means of restriction. Do not implement any additional non-physical measures beyond the existing signs.

(1) The numbering of the alternatives does not indicate an order of preference.

Initial Screening of Alternatives

The alternatives were qualitatively screened at high-level against the purpose and need of the study. The screening included consideration of the likely effectiveness of the alternative in impeding an individual from jumping off the bridge. As a result of the initial screening, and in coordination with the findings reported by the National Suicide Prevention Lifeline (Draper 2017), Alternatives 1, 2, 3, 4, and 5 were retained for further evaluation. The No-Action / No-Build Alternative was not screened since it would carry forward with the build-alternatives to support the NEPA process. Alternatives 6, 7, and 8, the non-physical alternatives, were not pursued further since MDOT currently uses a combination of the non-physical deterrent systems throughout the entire transportation system. MDOT continuously works with our partners to review operation, training, and safety protocols and procedures.

Evaluation of Alternatives

This section closer examines the features of each suicide deterrent system alternative, as it relates to the factors presented earlier in Table 1 and summarized into the broader categories shown in Figure 4.

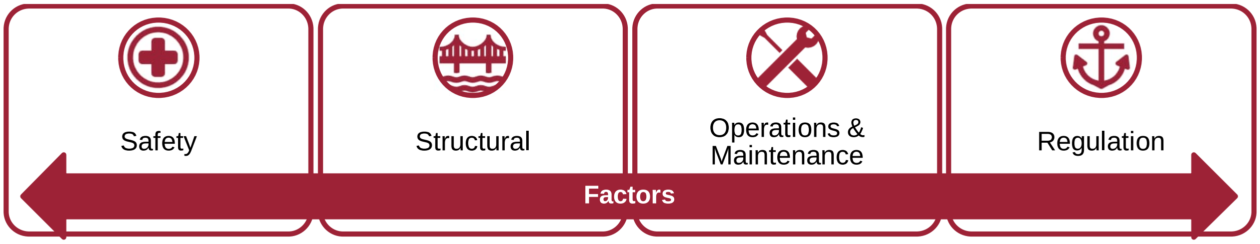


Figure 4. Broader Categories for Evaluation of Suicide Deterrent Systems

Safety

The main objective of each alternative is to deter or impede individuals from climbing the existing bridge parapet and jumping. The height, materials, and shape of the SDS are important in achieving this objective.

Geometry

Investigation into existing and proposed suicide deterrent systems from around the world indicates that a majority of physical deterrent systems are barrier systems. The Golden Gate Bridge is the only major bridge identified as using a horizontal netting deterrent system.

A review of numerous barrier deterrent systems and standard bridge protective fence details indicates that heights vary, but a minimum height of approximately 8 feet is commonly used above the walking or roadway surface, or above any perceived foothold (stepping point). Based on results from a study by Hemmer, Meier, and Reisch, it was determined that barrier suicide deterrent systems be of a height of at least 7.5 feet and secured at their ends to prevent people from climbing around them (Hemmer et al, 2017). Additionally, the barriers are typically developed with anti-climb features and materials, such as an angled return at the top of the barrier and the use of woven wire mesh, that impede the ability of the deterrent system to be scaled. Figure 5 shows the three conceptual suicide deterrent system alternatives that utilize a barrier system. Alternatives 1 and 2 are similar to typical bridge fencing. Alternative 1 is located on the rear face of the existing parapet and set to 8 feet in height from the top of the parapet, since the top of the parapet provides a potential foothold. This alternative provides some additional offset between the SDS and traffic, which provides an opportunity for an anti-climb angled return at the top of the barrier. Alternative 2 is installed on top of the existing parapet and is intended to be detailed such that the top of the parapet cannot be used as a foothold; therefore, the height of the SDS is set at a minimum of 8 feet from the roadway surface. Alternative 5 is intended to be a hybrid between the barrier and netting systems, providing the greatest offset between the SDS and traffic, allowing for an anti-climb return at the top of the SDS, but also limiting the angle and horizontal projection away from the bridge. The height of Alternative 5 is to be further evaluated in final design, if selected.

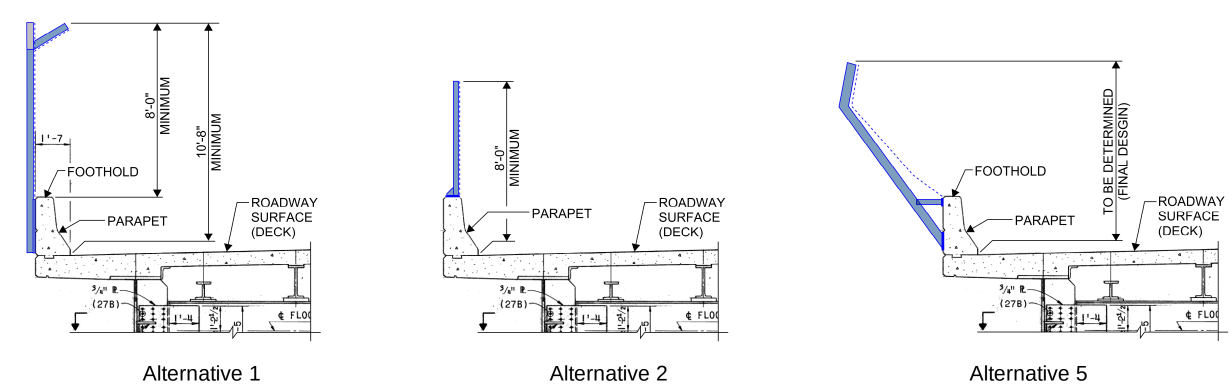


Figure 5. Alternatives 1, 2, & 5 (Barrier) Conceptual Sketches

The geometry of horizontal netting suicide deterrent systems is based on the depth below the roadway surface (pedestrian level) and the horizontal projection (width) away from the edge of the bridge. Limited information is available on geometric recommendations for netting deterrent systems, as a result, two conceptual alternatives were evaluated to explore the range in depth of netting below the roadway surface. The alternatives in Figure 6 show two netting options, where the net is placed near the roadway surface, and where the net is placed towards the bottom of the bridge beam (below the roadway surface) but above the USCG navigation clearance envelope.

The bridge superstructure depth (distance from roadway surface to bottom of beam) varies significantly over the length of the bridge. The superstructure depth varies from 4 feet, 6 inches in the approach spans to just over 21 feet, 9 inches in the main span over the navigation channel. Hemmer, Meier, and Reisch recommend that safety nets should lie significantly below the roadway surface (pedestrian level) to deter jumping. As a result of their statistical evaluation, a depth of approximately 13 feet may be required to sufficiently deter jumping. Based on the geometry of the bridge, this distance can only be achieved for Alternative 4 within the main spans. This depth is not readily achieved in the approach spans for Alternative 4 or any of the spans for Alternative 3, considering the net is located above the bottom of the beam. With Alternatives 3 and Alternative 4, particularly where the netting has to be located near deck level due to shallow beam depths, it will likely be possible for a person to climb or jump onto the netting surface, navigate to the edge of the netting, and jump the remainder of the way to the ground or water level. If an individual jumps onto the netting and chooses not to commit suicide, rescue may be required.

The horizontal projection of the netting deterrent system needs to be adjusted to accommodate the distance that the system is located below the roadway surface. The lower the safety net lies below the roadway surface (pedestrian level), the further the net is required to project horizontally from the edge of the bridge (width of net). When measured from the top of the parapet, the longest span of the bridge, not including the vertical haunches of the beams, has a total depth of approximately 16 feet, 8 inches. Analysis shows that if the net system is placed 15 feet below the top of the existing parapet, then the net would conservatively need to project approximately 15 feet from the edge of the bridge deck. The required projection will have implications on the operations and maintenance needs of the bridge.

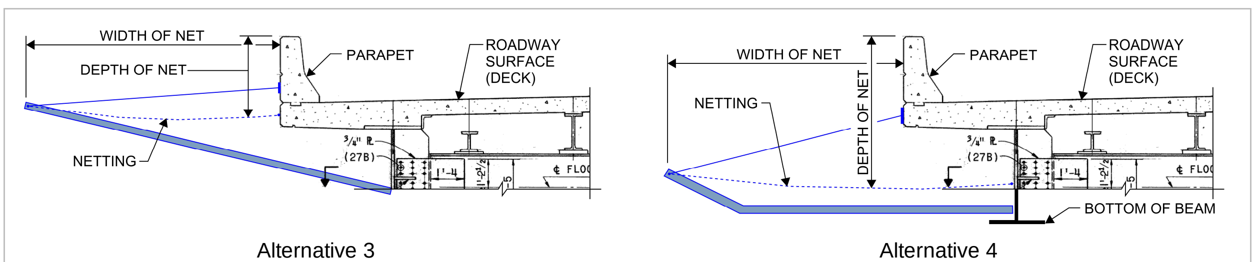


Figure 6. Alternatives 3 & 4 (Netting) Conceptual Sketches

There is limited guidance on how far to extend a barrier or netting along the length of the bridge, in context of the height above land or water (i.e. the distance to fall). However, Hemmer, Meier, and Reisch recommend that safeguarding should be “complete”, or at least not allow jumps of approximately 50 feet or more. In other words, the installation of an SDS should extend the full length of the bridge, or at a minimum, protect areas that are 50 feet or more in height above the ground or water surface. The Governor Thomas Johnson Bridge varies significantly in height, ranging from approximately 15 feet in the approach spans to 160 feet over the navigation channel, with Spans 26 through 53 being 50 feet in height or greater. Since netting deterrent system data is limited, and the height at which an SDS is required could be subjective, for the purposes of preliminary evaluation, the SDS has been considered for the full length of the bridge. This will envelop the constructions costs and schedules for the alternatives.

Zone of Intrusion

The SDS should attempt to minimize effects on the Zone of Intrusion. The ZOI, as defined by the AASHTO Roadside Design Guide, is the region measured above and behind the face of a barrier system (parapet), where an impacting vehicle or any major part of the barrier system may extend during a collision. Effects on the Zone of Intrusion increase the risk of damage to the SDS and potential maintenance costs associated with vehicles coming in contact with the SDS. Effects on the ZOI also influence the warrants for crash testing the parapet and SDS, which is discussed further in subsequent sections.

Alternatives 1, 2 and 5 explore a range of effects on the ZOI. Alternatives 1 and 2 both have an effect on the ZOI, although each to a different degree. Since Alternative 1 is located behind the existing parapet, it has less effect on the ZOI. While still within the ZOI, the risk of damage due to straying vehicles and increased maintenance costs, as a result, are minimized. Alternative 2 has a more substantial effect on the ZOI, however it represents a similar condition to the areas of the bridge where fencing has already been installed on the parapet. Available accident data evaluated between January 2015 and December 2021 indicates there have been no accidents involving the existing fence. Alternative 5, depending on its angle of inclination away from the existing parapet, will likely not have an effect on the ZOI. Alternatives 3 and 4 are outside the ZOI and will have no effect.

Warrants for Crash Testing

According to the AASHTO Roadway Design Guide, FHWA policy requires that all roadside appurtenances, such as traffic barriers, barrier terminals, crash cushions, bridge railings (parapets), sign and light pole supports, and work zone hardware, used on the NHS meet the performance criteria contained in National Cooperative Highway Research Program (NCHRP) Report 350 or MASH. According to the AASHTO/FHWA Joint Implementation Plan, all safety hardware accepted prior to the adoption of MASH, and using criteria contained in NCHRP Report 350, may remain in place and may continue to be manufactured and installed. Agencies are encouraged to upgrade existing highway safety hardware that has not been accepted under NCHRP Report 350 or MASH, either during reconstruction or resurfacing, rehabilitation, or restoration (3R) projects, or when the system is damaged beyond repair. The Governor Thomas Johnson Bridge is located on the NHS. The purpose of this section is to discuss the requirements of MASH, when attaching a suicide deterrent system to an existing parapet.

MASH indicates that new railings or significant revisions to existing designs should be evaluated through full-scale crash testing. Where an engineering analysis clearly shows that the proposed modification will not have a significant effect, crash testing is not needed. Where there is some uncertainty about the performance, analytical methods can help determine if the effect is significant or not. If analytical methods determine the effect is significant, full scale crash testing is required to receive an FHWA Federal-aid reimbursement eligibility letter. The process of crash testing can take approximately 2 to 5 years; however, this depends on initial crash testing results and the need for any additional simulations and re-testing. Upon conclusion, a final report with drawings is developed and submitted for review and acceptance by FHWA.

According to the AASHTO/FHWA Joint Implementation Plan memo, released on January 7, 2016, FHWA updated the FHWA Federal-aid reimbursement eligibility review process for safety hardware devices as of November 12, 2015, requiring that if an agency makes any modifications to any roadside safety hardware that has an existing eligibility letter from FHWA, then they must notify FHWA of such modification in order for the device to continue to be covered by the existing FHWA eligibility letter. As of December 31, 2016, FHWA no longer issues eligibility letters for highway safety hardware that has not been successfully crash tested to the 2016 edition of MASH. Modifications of eligible highway safety hardware must utilize criteria in the 2016 edition of MASH for re-evaluation and/or retesting. Additionally, non-significant modifications of eligible hardware that have a positive or inconsequential effect on safety performance may continue to be evaluated using analytical methods. FHWA encourages individual states to create their own polices for upgrading safety hardware.

Built in 1977, the Governor Thomas Johnson Bridge was not originally designed to meet the contemporary NCHRP or MASH criteria. The MDOT SHA Bridge Railing Manual provides guidance on treatment of existing bridge rails (parapets), including the installation of fencing. The Bridge Railing Manual suggests that based on the installation of the SDS, removal of the existing parapet and replacement with a MASH compliant parapet is not required. Additionally, despite some of the alternatives presented showing an effect on the ZOI, preliminary engineering analysis indicates that due to the existing parapet geometry and presence of existing fencing, the addition of any of the suicide deterrent system alternatives would likely not be considered a significant revision to the existing design, and therefore, would likely not warrant the need for additional crash testing per the MASH criteria. This would need to be examined in further detail during final design in coordination with discussions with FHWA. Since the need for crash testing is unlikely, time for crash testing has not been included in the schedule.

Structural – Suicide Deterrent System

Preliminary structural analyses were performed to size primary structural components of the suicide deterrent systems to inform the structural evaluations of the existing bridge and cost estimates and construction schedules for the alternatives.

Preliminary Analysis

For the purposes of preliminary evaluation, design forces were established to envelop the barrier and netting alternatives. The preliminary forces used for analysis were self-weight, which includes all currently assumed components of the SDS, wind load on the SDS, including the effect of ice accumulation, pedestrian loading to simulate an individual climbing the SDS, and impact from falling objects to simulate an individual falling onto the netting-based deterrent system. The forces developed were used to support preliminary analysis of the suicide deterrent systems and their effects on the bridge.

Connection to Bridge

The connections of the suicide deterrent systems to the bridge are separated into two cases, connection to the parapet and connection to the bridge beams.

The barrier SDS alternatives, Alternatives 1, 2, and 5, will likely be connected to the bridge by utilizing post-installed anchors to positively anchor the SDS to the existing parapet. This method will require drilling into the existing concrete and installing the post-installed anchors (undercut, expansion, adhesive, etc.) per the manufacturers' recommendations. Care will need to be taken to avoid the parapet reinforcement to the full extent possible and the embedded utility conduit. This method of connection will require the removal of any existing fencing prior to installation of the SDS. Alternative 2 will also need to avoid conflict with the existing fence anchor bolts, which may control post locations and spacing. Additionally, repairs may need to be made to the existing parapet prior to installation of the barrier SDS to ensure adequate structural capacity. Refer to subsequent sections.

The netting SDS alternatives, Alternatives 3 and 4, will likely need to be connected directly to the steel and prestressed concrete beams, avoiding conflicts with existing floorbeams and diaphragms in the steel girder spans. This is a disadvantage for these alternatives, as drilling into prestressed beams is typically not recommended and may not be possible. Some of the prestressed beams have been previously repaired with fiberglass wrapping which will also need to be accounted for when considering the connections. Drilling holes into the steel girders is feasible but may not be recommended due to fatigue sensitive details present on the bridge and the fracture critical nature of some of the spans. Additionally, if the bridge's existing paint contains lead or other hazardous materials, drilling into the existing steel members will require containment and/or special equipment, increased worker health and safety protocols, and stringent requirements related to the disposal of any wastes generated by these operations. Furthermore, the netting system's cable connection to the existing concrete parapet or deck would likely necessitate the use of post-installed anchors in sustained tension, which is an undesirable loading condition. Repairs may need to be made to the existing parapet / superstructure prior to installation of the netting SDS to ensure adequate structural capacity. Refer to subsequent sections.

Structural – Existing Bridge

The addition of a physical suicide deterrent system will increase the weight and wind loads on the bridge. The increase in load requires analysis of the existing bridge to evaluate the effects and feasibility of adding a suicide deterrent system to the bridge.

The following sections discuss the design and configuration of the existing parapet; the preliminary structural evaluations performed to assess the adequacy of the existing parapet to bridge deck connection and the existing bridge deck overhang; and the preliminary structural evaluations performed to assess the adequacy of the existing bridge superstructure and substructure to ensure sufficient capacity, when subjected to the additional loads from the proposed SDS.

The bridge superstructure consists of the bridge parapet, deck (roadway surface), supporting beams (girders), and bearings. The bridge deck overhang is that portion of the deck between the outside beam and the outside edge of the deck that supports the parapet. The bridge substructure consists of the intermediate supports (piers) and end supports (abutments) and their foundations. Reference to bridge element and member numbering and designation is in coordination with the bridge as-built drawings and NBIS bridge inspection reports. The bridge is comprised of several units, where two or more spans is considered a unit. A span is a section of the bridge from pier-to-pier or pier-to-abutment. The units are established to address the bridge thermal expansion and contraction due to temperature variations and inform the location of the fixed and expansion piers and associated joints in the bridge deck.

Existing Conditions of Bridge

The 2021 [NBIS] Routine Bridge Inspection Report was reviewed to determine the existing condition of any bridge elements that are anticipated to interface with the connections of the SDS barrier or netting alternatives, and to assess whether certain repairs should be performed prior to installation of the SDS. The current NBIS ratings (0-9) for the bridge indicate the deck is in satisfactory (6) condition; the superstructure is in fair (5) condition; and the substructure is in satisfactory (6) condition. Overall, the bridge is rated in fair (5) condition.

Based on the review of the existing bridge element conditions, there is likely only a minimal quantity of repairs that may be required in conjunction with the installation of the SDS. These are generally associated with repairs to the existing parapets. The locations of the existing fiberglass wrapping on the prestressed beams and confirmed, or possible, fatigue cracks in the steel beams will need to be considered in the final design of the netting SDS connections.

Parapet and Deck Overhang

The existing concrete parapet is 2 foot, 8 inches in height, measured from the roadway surface (Figure 7). The existing parapet was designed in accordance with the AASHTO Standard Specifications for Highway Bridges and is intended to perform as a vehicular protection system only. There is a 5-foot-tall chain link fence installed on the top of the existing parapet in some spans between Abutment A to Pier 5 (both sides), Pier 11 to 13 (north side only), Pier 19 to 34 (both sides), Pier 48 to 49 (south side only), and Pier 49 to 54 (both sides). The existing bridge deck overhang is typically 3 foot, 7 inches measured from the edge of deck to the centerline of the exterior beam. The deck overhang increases to 4 foot, 7 inches in Spans 39 to 41.

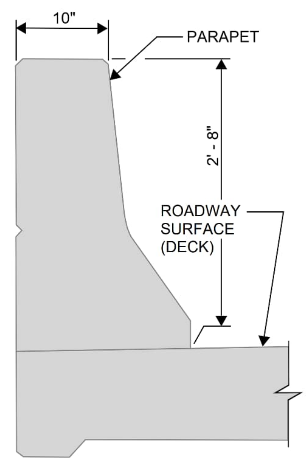


Figure 7. Existing Parapet Dimensions

Structural evaluations utilizing AASHTO Standard Specifications for Highway Bridges, 2002 (AASHTO Standard Specifications) were performed to assess the adequacy of the existing parapet to deck connection and the bridge deck overhang under existing conditions and when subjected to the additional enveloped loads associated with the installation of the proposed barrier suicide deterrent systems (Alternatives 1, 2, and 5).

The evaluation of the existing parapet to deck connection included a combination of self-weight, the AASHTO Standard Specifications 10-kip (10,000 lb) railing load for which the existing parapet was likely designed, and wind load applied to both the parapet and the SDS. The wind load applied to the SDS included the effect of ice accumulation. Preliminary analysis based on the as-built condition of the existing parapet found adequate capacity to resist the additional SDS loads.

The evaluation of the existing deck overhang included a combination of self-weight, the AASHTO Standard Specifications 10-kip (10,000 lb) railing load or HS-20 truck wheel loading, and wind load applied to both the parapet and the SDS. The wind load applied to the SDS included the effects of ice accumulation. Preliminary analysis based on the as-built condition of the existing bridge deck overhang found adequate capacity to resist the additional SDS loads.

Effects to the existing parapet to deck connection and deck overhang for Alternatives 3 and 4 were not analyzed at this stage of preliminary development. With their horizontal orientations and associated smaller projected wind areas, combined with load sharing between their lower (beam level) and upper (roadway surface) connections, these alternatives are not anticipated to control the evaluation.

Superstructure

For the purposes of evaluating the effect of the SDS on the bridge superstructure, the existing as-built bridge load ratings were used as a basis to determine how much of an effect the SDS has on the bridge. The load ratings result in the determination of load rating factors for each of the legal and permit vehicles. Load rating factors indicate how the load of the vehicle (live load) relates to the computed structural capacity (resistance) of the bridge member. The Operating Rating Factor was used as a primary basis for evaluation, where it represents the maximum permissible live load to which the member may be subjected.

The controlling spans for all vehicles are Spans 1 and 2 based on the existing load ratings. Spans 1 and 2 are a two-span, continuous, prestressed concrete girder unit. As a basis for screening the effects of adding the SDS to the bridge, the analysis investigated the amount of additional load that could be added to the controlling span until the controlling Operating Rating Factor fell below 1.0. When the Operating Rating Factor of any Maryland legal load vehicle is less than 1.0, a weight restriction must be implemented as discussed in the MDOT SHA Office of Structures Guidelines and Procedures Memorandum SI-12-21(4). The results of the analysis indicate that the additional loads from the SDS do not adversely affect the as-built load ratings. The load ratings will decrease; however, the as-built Operating Rating Factors will not fall below 1.0. Therefore, the bridge will not require a weight restriction for the added SDS.

Local effects associated with connecting the Alternative 3 and 4 SDS to the existing steel girders were not analyzed at this preliminary stage. While the connections of the SDS to the existing girders are anticipated to occur at web-stiffened locations, such as at existing floorbeams or diaphragms, with loads shared between the SDS connections to the parapet / deck and to the girder, the existing bridge girders will experience additional loads and their adequacy to resist these loads will require more detailed analyses. Also, the netting SDS alternatives will need to be located at, but not conflict with, existing floorbeam or diaphragm elements or connections. Detailing of the SDS to girder connections will therefore require careful examination of the existing bridge drawings to avoid, or at least minimize, the potential for conflicts between new and existing bridge elements.

Substructure

For the purposes of evaluating the effect of the SDS on the existing bridge substructure, the tallest fixed pier (Pier 39) was evaluated. The evaluation was performed to preliminarily screen the effect and the feasibility of adding the SDS; however, more detailed analyses will need to be performed in final design. An 8-foot-high fence was used in the evaluation to envelop the effects of adding an SDS.

The calculations used for the analysis of the piers in 1988 were used as a basis of the evaluation. The applied loads are in accordance with the AASHTO Standard Specifications. The transverse wind load applied to the fence is 15 pounds per square foot (psf), applied transversely to a solid area that is 8-foot high. The analysis included both the post-tensioned pier cap and the reinforced concrete column. The results of the analysis are as follows:

- The post-tensioned pier cap can adequately support the loads associated with the addition of an 8-foot fence attached to the top of the existing bridge parapet.
- The column may require strengthening based on the initial results. The analysis methodology and results will need to be further examined in final design. It is recommended that a fixed pier be analyzed for each of the different continuous units.

Operations and Maintenance

The Governor Thomas Johnson Bridge is 59 spans long. The superstructure is comprised of prestressed concrete beams (Spans 1-23), steel multi-beams (Spans 24-35 and 45-59), and two-girder fracture critical beams (Spans 36-44, also referred to as the fracture critical spans). The fracture critical beams are located adjacent to and in the main span over the navigation channel. The fracture critical spans comprise 9 of the 59 spans, or approximately 15 percent of the bridge. The substructure consists of 58 reinforced concrete piers and two reinforced concrete abutments.

Bridge inspection is an important part of providing a safe infrastructure. The Code of Federal Regulations (CFR), Part 65, Title 23, Subpart C, Article 650.303, regarding applicability of the NBIS, states that all structures defined as highway bridges located on all public roads undergo routine inspections at intervals not to exceed 24 months (Federal Register National Archives and Records Administration, 2020). The NBIS further indicates that all fracture critical members on a bridge be identified, and an inspection frequency described. MDOT SHA performs routine bridge inspections on a 24-month cycle and a special monitor inspection on a 12-month cycle, which includes a hands-on inspection of the fracture critical members.

The Bridge is 45 years in age, has fracture critical members, and a history of fatigue cracks. It is imperative that its routine inspections and maintenance be completed in an efficient and effective manner. The effects the SDS has on routine inspections, maintenance and operations are evaluated in the subsequent sections.

Routine Bridge Inspection

The Governor Thomas Johnson Bridge has several constraints that complicate the routine condition inspection of the bridge, including Maintenance of Traffic (MOT), nighttime work, seasonal restrictions, and hard-to-reach areas which require hands-on inspection. The monitor inspection, conducted on a 12-month cycle, includes a hands-on inspection of all possible or known steel cracks in the fracture critical spans, a hands-on inspection of certain defects in the prestressed concrete girder spans, and field measurements of some bearings that have shifted. It is important that any suicide deterrent systems not prevent, or significantly hinder, the ability for under-bridge inspection vehicles to sufficiently clear the deterrent system and access the bridge for inspection. The effects on inspection are different between the barrier (Alternatives 1, 2, and 5) and horizontal net (Alternatives 3 and 4) suicide deterrent systems and will be discussed separately.

Suicide Deterrent System Alternatives - Barrier

Figure 8. Under-Bridge Inspection Vehicle

The under-bridge inspection vehicles utilized to inspect the bridge provide the ability to clear obstacles in excess of 10-foot, 0-inch up to 15-foot, 0-inch, when measured from the roadway surface. See Figure 8 for an example of an under-bridge inspection vehicle currently used on the Governor Thomas Johnson Bridge. The tallest barrier alternative is preliminarily proposed at 10-foot, 8-inches above the roadway surface, therefore each of the SDS barrier alternatives evaluated are within the limits of the inspection vehicles. The Aspen Aerial A62 under-bridge inspection vehicle, which has an 11-foot maximum fence clearance, is used to inspect the fracture critical spans. Clearance over the tallest conceptual SDS barrier may be very close with this equipment but possible. The bridge superstructure depth varies along its length, which adds additional complexity to the inspection. Inspections following the installation of the barrier suicide deterrent system can be performed without major changes to current practice in most spans; however, the inspection of the fracture critical spans will prove to be difficult or impossible without modifications to current practice. The total duration that the inspection takes may need to increase to allow for additional time to maneuver under some of the deeper spans and to prevent accidentally damaging the SDS. Full inspection of the fracture critical spans becomes increasingly difficult in the vicinity of the deeper girders in these spans. Even without the installation of the SDS, there are difficulties accessing some of the fatigue sensitive details and fracture critical elements for hands-on inspection in these spans. Currently, the boom for the under-bridge inspection vehicle must be lowered to just above the existing parapet to reach some of the inner-most fatigue sensitive details. The addition of any SDS barrier in these fracture critical spans will make this maneuver, and as a result, the hands-on inspection of these elements not possible under current practices. However, some of these limitations could be mitigated through the use of special SDS design details and / or alternative methods of inspection, as follows:

- Design the SDS to incorporate removable panels at set intervals within these spans
- Inspect from existing maintenance access platforms in these spans
- Inspect using rigging and / or Society of Professional Rope Access Technicians (SPRAT) rope-access techniques

Incorporating removable panels into the SDS will allow the boom for the under-bridge inspection vehicles to be lowered to the appropriate level to allow access to the difficult to reach areas. These panels would need to be located during final design to ensure all areas can provide adequate coverage for inspection. It is probable that requiring routine bridge inspectors to remove panels during the inspection timeframe will increase the duration of inspection, and as a result, the cost and schedule to inspect. This work may require the engagement of an MDOT SHA on-call contractor in coordination with the routine inspection teams.

Avoiding the use of under-bridge inspection vehicles and inspecting from the maintenance access platforms in these spans may require modifications to the existing platforms and platform access. Currently the manholes that provide access to the maintenance access platform at Piers 36 and 46 are in the middle of the roadway, making access while traffic is present on the bridge not possible. A temporary full-bridge closure or modification allowing access from a single lane may be required. Access via an under-bridge inspection vehicle to the maintenance access platform or nearby pier from which access could be attained may be a possible solution.

Inspection from the maintenance access platforms may be used in combination with other rigging and SPRAT rope-access techniques to ensure access to all locations, without the need to build additional platforms. Rope access refers to a set of techniques, where ropes and specialized hardware are used to provide access for inspection. There are approximately 250 to 500 NBIS/SPRAT certified inspectors nationwide. This field is highly specialized and not always readily available; however, rope access work is currently being performed in the State of Maryland. Depending on the techniques utilized, the typical cost and duration of the bridge inspection will be affected.

Suicide Deterrent System Alternatives - Netting

The installation of the SDS netting alternatives will have a significant effect on the inspection of all spans of the bridge, not just the fracture critical spans. Based on preliminary analysis at the deepest beam depth, the netting system would need to be approximately 15 feet wide to be effective. This would make the use of under-bridge inspection vehicles impossible. Spans with shallower beams depths may allow for narrower netting systems; however, studies indicate that these types of systems become less effective in preventing suicides, when the distance from the roadway surface to netting is reduced. A narrower net may alleviate some of the issues but may still have a significant effect, since the presence of the netting restricts the movement of the under-bridge inspection vehicle. If horizontal netting is selected, rigging and SPRAT rope-access techniques, or a combination thereof, would be the most viable options to inspect the bridge.

Routine Bridge Maintenance and Operation

For a bridge that is 45 years old, easy access for routine bridge related maintenance activities is imperative. Topside maintenance activities will likely remain unchanged for any of the SDS alternatives. Under-bridge maintenance activities are subject to the same bridge access considerations discussed for bridge inspections, where the barrier alternatives will have a significant effect in some spans, and netting will have a significant effect in all spans.

The addition of barrier alternatives will have a minor effect on snow removal operations, with Alternative 2 potentially affecting it the most. However, snow removal should not be any more difficult than the areas of the existing bridge that currently have fencing on the parapet. The preliminary wire mesh diameter and opening size for the horizontal netting is likely to be of a size that build-up of snow and ice is not anticipated to require additional operational or maintenance activities.

Routine Inspection and Maintenance of Suicide Deterrent System

The inspection of safety features, lighting, and signs is typically performed during routine bridge inspections. It is up to each governing agency to set their own policies. These features are typically inspected for fatigue cracking, corrosion, collision damage, and functionality. The SDS would fall within these types of structures and will need to be inspected as required by MDOT SHA. An SDS that allows for ease of routine safety inspections, also allows for ease of access for maintenance purposes. It is anticipated that the inspection and maintenance of the barrier alternatives will be easier than the netting since access to the netting will be more difficult. The barrier or netting connections to the bridge will need special consideration during inspection and any repairs will need to be made to ensure proper functionality of the SDS.

Other than normal wear and tear, some key maintenance considerations are as follows:

<u>Barrier Alternatives</u>

- Collision damage due to vehicular impact of SDS
- Functionality of SDS special details at bridge expansion joints
- Functionality of SDS special details at removable panels, if warranted
- Maintain proper tension of SDS wire mesh, as warranted, to ensure proper functionality of system

<u>Netting Alternatives</u>

- Maintain clean surface from bird debris (nesting, feces, etc.)
- Removal of roadway debris from horizontal netting surface, as required
- Functionality of SDS special details at bridge expansion joints
- Maintain proper tension of SDS netting wire mesh, as warranted, to ensure proper functionality of system

Regulation

In the preliminary evaluation of the suicide deterrent system alternatives, several aspects of regulation were assessed for construction permitting including the Rivers and Harbors Act (RHA) of 1899 Sections 9 and Section 10; Clean Water Act (CWA) Section 404 and 401; Maryland Tidal Wetlands Act; Maryland Critical Area Act; Federal Aviation Act of 1958 and 14 CFR Part 77; Migratory Bird Protection Act (MBTA); National Environmental Policy Act; and National Historic Preservation Act, Section 106.

Bridge Modifications and Construction Permitting

With a wide range of alternative solutions and funding options under consideration, there are a number of regulatory and statutory requirements to consider (Refer to Table 3). While the level of regulatory consideration is not factored into this evaluation, the subsequent sections are intended to inform future planning activities and project scheduling.

Table 3. Potential Permits for Bridge Modifications and Construction Activities

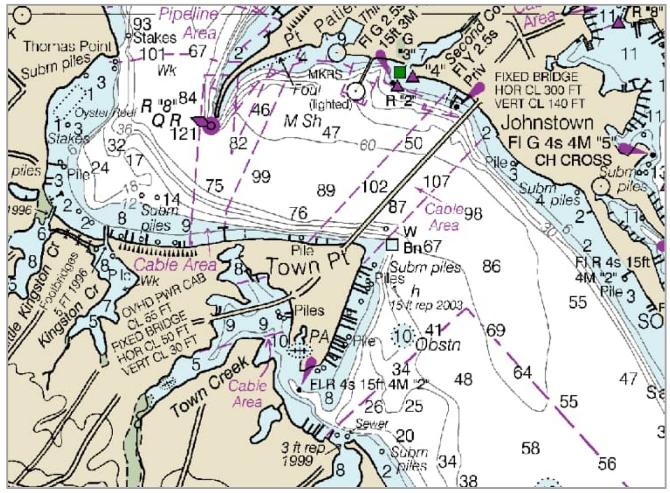
Permit Name	Agency	Estimated Time to Procure Permit	Activity
RHA of 1899 Section 9 Bridge Permit	USCG	8 weeks	Modifications to existing bridge
Private Aids to Navigation	USCG	12 weeks	Installation of navigation aids by the contractor to alert boaters to construction activities
CWA Section 404 / RHA Section 10 authorization	US Army Corp of Engineers (USACE)	12 weeks	USACE authorizations are not anticipated; bridge modifications are authorized by USCG under RHA Section 9
MD Tidal Wetland Permit/ License/CWA Section 401	Maryland Department of the Environment (MDE) Wetlands and Waterways	12 weeks	Any work in, on, over or under state tidal waters
Erosion and Sediment Control (ESC) Approval	MDE	12 weeks	Landside staging areas may require ESC control plan
MD Critical Area Consistency	Maryland Department of Natural Resources (DNR) Critical Area Commission	8 weeks	Landside staging areas
Airspace Obstruction Approvals	Federal Aviation Administration (FAA)	3-4 months	Construction equipment obstruction in airspace for arrival, departure or en route flight operations for nearby civilian or military airports
Listed Species Coordination	US Fish and Wildlife Service (USFWS) and DNR Wildlife Heritage	6 weeks	Record of breeding peregrine falcons on/near the bridge

Rivers and Harbors Act of 1899 Sections 9 Bridge Permit. The Governor Thomas Johnson Bridge is regulated by USCG under the Rivers and Harbors Act of 1899 Section 9. The USCG regulated clearance envelope for the bridge is 140-foot vertical and 300-foot horizontal within its main span. The navigation channel is not maintained or surveyed by the federal government, but natural water depths in this portion of the Patuxent River range from 3 feet near the shore to over 100 feet along the main span of the bridge (Figure 9).

The clearance envelope is measured from the water surface to the bottom of the bridge beam. The barrier and netting alternatives are proposed to be located above the bottom of the bridge beam to avoid permanent effects on the envelope and the navigation channel. Temporary effects to the clearance envelope to accommodate the construction of the netting may or may not occur and will need to be examined in more detail during final design if netting is selected.

The evaluation of the effects on the USCG clearance envelope considers the following range of actions. A greater effect on the envelope will require more of an allowance of time in the schedule to conduct the necessary coordination and permitting. At this level of development of the alternatives, the more likely range of actions are between no effect and minor to moderate effect, the latter based on possible temporary impacts during construction for the netting.

- No effect; *no USCG coordination necessary*
- Minor effect; *USCG coordination required; no permit required*
- Moderate effect; *minor modification to Section 9 Bridge Permit; may include authorization for temporary impacts*
- Substantial effect; *major modification to Section 9 Bridge Permit with Public Notice*
- Substantial effect; *not mitigatable*



NOAA BookletChart™ Chesapeake Bay – Patuxent River and Vicinity (NOAA Chart 12264)

Figure 9. Patuxent River Water Depth Chart

Private Aids to Navigation. Temporary effects to the navigation channel to accommodate the construction of a suicide deterrent system may or may not occur and will need to be examined in more detail during final design. If Private Aids to Navigation (PATON)s are needed, a USCG permit will be required to place any day beacons, buoys, structure lights or signage within the limits of the Patuxent River.

Maryland Tidal Wetlands Act. The MDE regulates projects conducted in, on, over, under, or through State or private tidal wetlands. Tidal wetlands, by definition, include all lands beneath tidal waters and tidal waters up to the mean-high-water line and vegetated wetlands. The evaluation of effects on MDE regulated tidal wetlands must consider any suicide deterrent system that extends over the Patuxent River beyond the authorized footprint of the bridge. Coordination with MDE will be necessary to confirm if the suicide deterrent system is considered a "maintenance activity," which requires no authorization, or a new impact, which requires state authorization. A review of the state regulations enforcing the federal CWA Section 401 will be conducted concurrently and a Water Quality Certification (WQC) issued by the state.

Sediment and Erosion Control. The bridge modifications under consideration are not likely to require ESC measures. However, should landside construction staging areas be needed to install a suicide deterrent system, then ESC approvals will need to be evaluated.

Critical Area Act. Critical Area Consistency review is required for all State actions resulting in development in State-Owned lands in the Critical Area. Should the installation of a suicide deterrent system require land based staging areas, then the applicability of the 2019 SHA Memorandum of Understanding (MOU) will need to be evaluated.

FAA Air Space Obstructions. 14 CFR Part 77 defines the standards and notifications for objects affecting navigable airspace. The bridge is located within the navigable airspace of the Naval Air Station Patuxent River, so each suicide deterrent system alternative, and the recommended construction means-and-methods, should be evaluated using the FAA Notice Criteria Tool to determine if an FAA permit is required. FAA permits are typically obtained by the contractor selected to build the project.

State and Federal Protected Species. The *MD 4-Thomas Johnson Bridge Planning Study*, *September 2015,* and the Maryland DNR Living Resources data identify a state record for

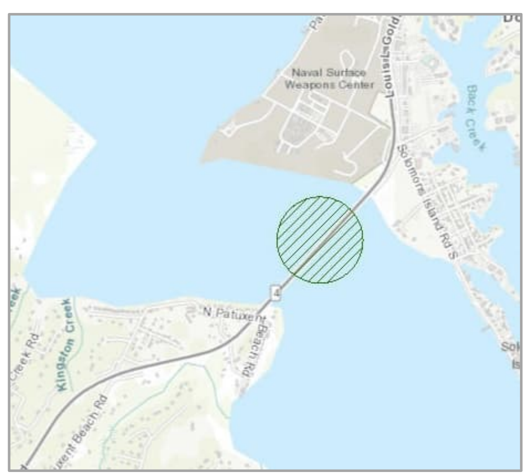


Figure 10. Protected Species Map

a breeding record for the *Falco peregrinus anatum* (American peregrine falcon) on or near the bridge (Figure 10). The American peregrine falcon is a Species of Concern in Maryland, protected under the Maryland Nongame and Endangered Species Conservation Act. It is also protected at the federal level by the Migratory Bird Protection Act (MBTA). Coordination with DNR and USFWS will need to be initiated during the NEPA process to assess if a time of year work restriction is necessary to construct the suicide deterrent system.

National Environmental Policy Act / National Historic Preservation Act

It is important to consider possible environmental, regulatory and stakeholder considerations as early as possible in the project planning process. Federal funding for the design and implementation of any of the proposed solutions would require some level of documentation under the National Environmental Policy Act and in many ways determine the level of regulatory agency and public stakeholder involvement. Overall schedule for the timing of any solutions could also be influenced by the level of NEPA documentation. Absent federal funding, documentation under the Maryland Environmental Policy Act (MEPA) would still be required, although such documentation is generally considered less rigorous and comprehensive.

The Governor Thomas Johnson Bridge has not been evaluated for eligibility for the National Register of Historic Places to date. This evaluation could factor into the level of environmental documentation required. Another consideration is the surrounding area within the viewshed of the bridge and possible improvements.

The other environmental, cultural and other resources that will need to be evaluated more will be dictated by the solutions under consideration. For example, construction techniques and duration could be a consideration for the Patuxent River itself and associated resources.

Assuming the use of federal funding or other federal "triggers", the range of possible NEPA documentation is presented below. At this time in the evaluation, the working assumption is the proposed solutions could be processed and approved using a Programmatic Categorical Exclusion Evaluation. This will be confirmed once an interagency scoping process is conducted under a future phase of project development for planning and preliminary engineering.

- Does not result in a detectable change to resources, no impact; Programmatic Categorical Exclusion Evaluation
- Results in minor detectable change to resources that may or may not be mitigated; no significant impact; Documented Categorical Exclusion Evaluation
- Results in moderate detectable change to resources that can be mitigated; significance of impact not known; Draft Environmental Assessment/Finding of No Significant Impact (FONSI)
- Results in substantial detectable change to resources that can be mitigated; significance of impact not known; Draft Environmental Assessment/Finding of No Significant Impact (FONSI)
- Results in a substantial detectable change to resources that cannot be mitigated; significant impacts expected; Draft and Final Environmental Impact Statement (EIS)/Public Hearing/Record of Decision (ROD)

Similarly, the range of possible outcomes under the National Historic Preservation Act are shown below. It is important to consider the project setting and the possible visual effects of proposed actions on any surrounding historic places, districts or landscapes. At this time in the evaluation, it is premature to predict a likely path forward until the bridge and surrounding resources are evaluated by a qualified historian meeting the Secretary of the Interior's standards.

- Completely avoids effects to historic properties; No Effect, Section 106 complete
- Mostly avoids and/or minimizes effects to historic properties; No Adverse Effect Determination
- Minimizes and mitigates effects to historic properties; Adverse Effect, MOU or Programmatic Agreement
- Mitigates effects to historic properties, but would not be minimized; Adverse Effect, MOU or Programmatic Agreement
- Does not avoid, minimize, or mitigate effects to historic properties; Adverse Effect, MOU or Programmatic Agreement

Construction Considerations

Several other factors were considered in the evaluation of the SDS alternatives, including temporary maintenance of traffic during construction, sequence of construction for the SDS, and temporary work zone protection during construction. These factors assist to inform the estimated cost and schedule for construction.

Maintenance of Traffic

Maintenance of Traffic involves the location and configuration of traffic on the bridge and approach roadways during construction. Maintenance of Traffic during any construction, maintenance, inspection, or incident-management activity on the Governor Thomas Johnson Bridge presents a challenge. The elements which contribute to this challenge include the following:

- The 28-foot-wide pavement surface, from face-of-parapet to face-of-parapet, essentially requires the closure of one of the two lanes during any non-traffic activity.
  - Even if reduced lane widths were to be considered, the remaining cross-section available for non-traffic activity would be impractical for use by equipment and personnel.
- Of the 7,200-foot length of the bridge, over 4,900 feet is on a 5 percent grade or on the crest vertical curve connecting the 5 percent upgrade and 5 percent downgrade.
  - The grade affects normal traffic operations, particularly for large trucks, but also for automobiles whose drivers may feel some discomfort at being on a such a grade, for such a distance, without being able to see the horizon.
- If traffic is required to stop on the bridge:
  - Drivers may become uncomfortable, due to vibration of the structure and wind conditions.
  - Restarting is sluggish on the upgrade, particularly for large trucks.
- The closest alternate route involves the Benedict Bridge on MD 231, well to the north of the Governor Thomas Johnson Bridge.
  - Traveling from one side of the Governor Thomas Johnson Bridge to the other using this alternate route would require a detour of approximately 55 miles, using MD 4, MD 231, MD 5 and MD 235.
  - The Benedict Bridge is a movable bridge, which opens, at least occasionally, for marine traffic.

As a result, lane closures on the Governor Thomas Johnson Bridge are typically restricted by MDOT SHA District 5 to nighttime hours. For the purposes of the preliminary evaluation of the alternatives, it has been assumed that lane closures will generally be permitted in a similar manner to those permitted for the NBIS routine inspection of the bridge, with the exception of the seasonal restriction of November 1 – March 31. The details of these lane closures include:

- Permitted only from 9:00 pm – 5:00 am
- One lane closed across the entire bridge—no shorter work zones permitted
- Flagger required at each end of bridge, under temporary lighting
- Pilot vehicle required

The amount of time required to set up the traffic control plan at the start of a construction shift and to dismantle the plan at the end of the shift has been found to be approximately two to three hours. As a result, five to six hours of physical construction work can be performed during each shift. Therefore, a five-hour construction work period per shift has been assumed in the development of the preliminary costs and schedules for the construction of the alternatives. The total duration required to construct the suicide deterrent system will be highly dependent on the number of crews working simultaneously, the number of hours per shift, the number of days per week, and the number of calendar days per year that construction activity is permitted on the bridge. These factors will also affect the construction cost. This and other MOT options will be evaluated during final design as part of the MDOT SHA Maintenance of Traffic Alternatives Analysis (MOTAA) process.

Sequence of Construction

While varying in construction complexity, all of the alternatives are generally similar in construction sequence with only minor variations. Overall, the construction sequence for the SDS installation is repetitive. Each of the alternatives follows the same basic sequence:

- Install SDS posts / support members
- Install SDS mesh / netting

The posts of the barrier alternatives (Alternatives 1, 2, & 5) will be connected to the existing concrete parapet using post-installed anchors. The support members of the netting alternatives (Alternatives 3 & 4) will be connected to existing steel girders or concrete beams. The netting alternatives will also likely have a cable attached with a connection plate to the existing concrete parapet.

It is assumed that construction of each of the alternatives would be under many of the same requirements implemented for the NBIS routine inspection of the bridge as discussed previously in the Maintenance of Traffic section of this report. Therefore, construction would be performed at night, along one side of the bridge at a time, and under temporary single-lane closures.

Initial evaluation of the alternatives considers construction occurring from the top of the roadway; however, consideration should be given to whether or not the SDS will be permitted to be constructed from the ground beneath the bridge when over land, or if it should be required to be constructed from the roadway surface with limited to no impact to the ground beneath the bridge.

It is recommended that a staging area off the bridge is provided to accommodate material and equipment storage, with space for any pre-assembly that may be required to expedite the construction process.

Temporary Work Zone Protection

The installation of additional work zone protection measures on or adjacent to the bridge should be considered to prevent vehicles from entering the work zone during construction. Additional work zone protection measures below the bridge should also be considered, as appropriate. For spans over water, this may include the implementation of a PATON to alert vessels of the work being performed on the bridge above. Consideration should also be given to having a safety boat on site during all construction activities over the water. For spans over land, appropriate measures will need to be put in place to protect the land, properties, pedestrians, and motorists beneath the work zone from falling objects or other debris during construction, particularly over local roads. Debris shielding can potentially include those that provide localized protection of certain areas or features beneath the bridge, or the entire area, including green space. Additional temporary protection measures may include the stationing of watchpersons on the ground beneath the work zones, temporary lane closures along local roads, or some combination of these measures.

Preliminary Cost and Time to Implement

The alternatives were evaluated at a conceptual level to determine an estimated cost to construct and time to implement. Thus, it is not fully indicative of the possible overall cost, feasibility, and timeline for implementation.

Estimated Construction Cost

Preliminary estimated construction costs were developed for the SDS alternatives. Due to the similarities between certain alternatives, some of the alternatives were grouped together for construction cost estimation purposes, as generally similar construction costs are anticipated. Construction costs were developed for the following groups of alternatives:

- Alternatives 1 & 5 (Physical Barriers behind Existing Concrete Parapet)
- Alternative 2 (Physical Barrier on top of Existing Concrete Parapet)
- Alternatives 3 & 4 (Netting Systems)

For the purposes of the construction cost estimates, the total construction cost was broken down for each group of alternatives into labor, equipment, and material costs. Additional items considered were existing bridge parapet repairs, MOT, debris shielding, safety boat services, lightning protection, PATON, mobilization, construction survey and staking, construction schedule, and field office.

Equipment needs vary for the three groups of alternatives. While Alternative 2 can be constructed entirely from the bridge deck, Alternatives 1, 3, 4, and 5 require special access equipment, including hydra platforms (truck- or trailer-mounted mobile work platforms) or under-bridge inspection vehicles. This equipment is needed in order to access the rear face of the existing parapet or steel and concrete beams for the suicide deterrent system post or horizontal support member installation, resulting in higher equipment costs for these alternatives. The increased connection and access-related complexities for Alternatives 3 and 4 were also considered in the estimated construction costs, as more time is required to access and connect deterrent system members to the existing steel girders or concrete beams than to the parapet at the roadway surface.

The installation of the horizontal support members for the netting alternatives (Alternatives 3 & 4) requires drilling into the existing steel girders. If the existing paint contains lead or other hazardous materials, drilling into the existing steel members will require containment and/or special equipment, increased worker health and safety protocols, and stringent requirements related to the disposal of any wastes generated by these operations, all of which have the potential to significantly increase both the duration and cost of construction.

Material costs for each group of alternatives differ for various reasons. The most impactful is the proposed height, or width (for netting alternatives), of the SDS. The height or width directly affects the length and size of each deterrent system's posts or support members and the quantity of proposed stainless-steel wire mesh that is used in each panel of the system. For the purposes of the estimate, it was assumed that the proposed post spacing for the barrier alternatives (Alternatives 1, 2 and 5) is 10 feet, a common post spacing for protective fencing and a spacing utilized on the recently constructed suicide deterrent system for the Sunshine Skyway Bridge. A spacing of 40 feet was assumed for the horizontal support members of the netting alternatives (Alternatives 3 and 4) to roughly coincide with the approximately 20-foot spacing of the existing intermediate diaphragms in the steel girder spans.

In order to satisfy the "Buy American Steel" Act, costs for the stainless-steel wire mesh were enveloped to capture the higher cost associated with this product when domestically produced (see Appendix C). See Table 4 for estimated construction costs for each group of alternatives.

Table 4. Estimated Construction Cost for the Alternatives

Alternatives		Total Cost (1)
1 & 5	(barrier behind parapet)	$9.9 million ($690 / LF of SDS)
2	(barrier on top of parapet)	$8.5 million ($590 / LF of SDS)
3 & 4	(netting)	$13.3 million ($925 / LF of SDS)

(1) Total Cost is in 2022 dollars

The total estimated construction costs shown in Table 4 are significantly affected by the domestic wire mesh costs, the MOT costs, and the reduced number of actual working hours per shift associated with MOT set-up and removal operations at the beginning and end of each shift.

Estimated Construction Schedule

Preliminary construction schedules were developed for the three groups of alternatives (Alternatives 1 & 5, Alternative 2, and Alternatives 3 & 4). The intent of the preliminary construction schedule is to determine the total construction duration for each group of alternatives from construction Notice to Proceed (NTP) to Final Completion.

For each activity, durations were established based on assumed crew size and production rates. Production rates used are based on the normal historic rates of efficient contractors, as well as feedback from post-installed anchor representatives. Construction durations were estimated based on the complexity of the construction operations and other alternative-specific requirements, including access-related needs, and may vary based on actual number and size of crews.

Table 5 provides a summary of the total construction duration for each group of alternatives. General assumptions that were made in developing the construction schedule durations include:

- Total durations are based on 5-hour working shifts. Shifts are assumed to be from 9:00 pm to 5:00 am with actual working shifts defined as 10:30 pm to 3:30 am (5-hour actual working shifts) to account for the time required for nightly MOT set-up and removal.
- Total durations assume work is performed on weeknights only. Weekends are assumed to be non-working days.
- Total durations assume 3 crews working simultaneously.
- No seasonal restrictions.

Table 5. Total Construction Duration for the Alternatives

Alternatives		Total Construction Duration (1) (Calendar Months)
1 & 5	(barrier behind parapet)	11 to 13
2	(barrier on top of parapet)	10 to 12
3 & 4	(netting)	12 to 14

(1) Total Construction Duration (Calendar Months) includes contractor mobilization, shop drawing reviews, survey and staking, existing parapet repairs, material fabrication and delivery, construction of the SDS, final inspection, and project closeout.

The construction durations assume that work is performed on weeknights only. The total construction duration could be significantly reduced if work was also permitted to be performed on weekends, especially if the single lane closures could be kept in place for the entire weekend. The construction durations shown above do not include the seasonal calendar restriction that is required for the bridge's routine inspections, which limits the timeframe during which work can be performed to November 1 through March 31. This seasonal restriction limits construction activities to a time of year that is generally considered a winter shutdown period for construction, due to the anticipated cold temperatures and the increased likelihood for inclement weather and lost workdays. The cold temperatures during this time of year are also not conducive to certain anticipated construction activities, including existing bridge parapet repairs, anchor bolt installation operations, or any potential painting operations. The implementation of the seasonal calendar restriction on this project would significantly increase the total construction duration, likely extending construction activities by an additional 10 to 12 months. A final determination of permitted working times will need to be further assessed during final design in coordination with the MOTAA process.

Estimated Time to Implement

The time to implement the alternatives includes two phases, design and construction. The design phase includes project planning and preliminary development (NEPA/Section 106) and final design. One of the larger unknowns at this stage of the evaluation is what the duration will be for the NEPA/Section 106 process. Until the evaluation is progressed, and scoping occurs, this will not be known. Depending on whether a Categorical Exclusion, Environmental Assessment or Environmental Impact Statement is required, the duration could vary from approximately 3 to 24 months. For the purposes of evaluating the time to implement, three months has been used for NEPA compliance considering the likelihood of a Programmatic Categorical Exclusion. The estimated duration in months for the time to implement the alternatives is summarized in Table 6.

Table 6. Time to Implement the Alternatives

Alternatives		Time to Implement (Calendar Months)		
		Design	Construction	Total
1 & 5	(barrier behind parapet)	16 to 18	11 to 13	27 to 31
2	(barrier on top of parapet)	16 to 18	10 to 12	26 to 30
3 & 4	(netting)	18 to 20	12 to 14	30 to 34

Conclusion

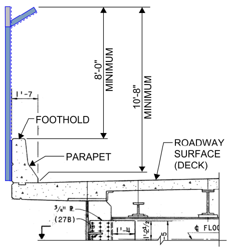
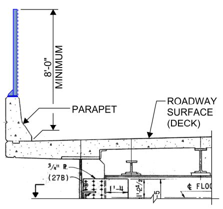
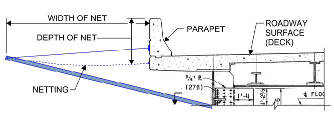
Five physical alternatives, tall barrier and netting, were preliminary evaluated against several factors, considering safety, structural, operations and maintenance, and regulation. The alternatives were assessed based on recent bridge condition inspections, existing bridge details, AASHTO code requirements, and MASH criteria. The alternatives were evaluated over a range of topics including effects on the bridge; costs to construct; time to implement; maintenance of traffic during construction; permit and/or agency coordination; bridge maintenance and inspection; and other considerations.

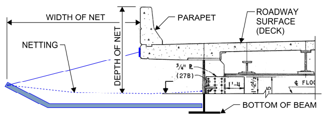
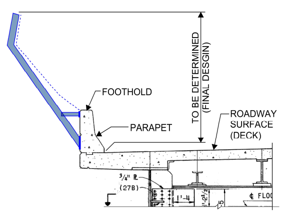
The main objective of each alternative is to deter or impede individuals from climbing the existing bridge parapet and jumping. Each alternative has advantages and disadvantages, which are summarized in Table 7. A comparison of the alternatives against the factors considered is included in the Comparison of Suicide Deterrent System Concept Alternatives Table in Appendix B.

Both barriers and netting adversely affect the routine condition inspection of the bridge; however, the netting alternatives significantly affect, if not prohibit, the bridge beams from being inspected from the top of the roadway for the entire length of the bridge. A preliminary analysis of the bridge indicates that although the addition of a suicide deterrent system is feasible, it may require strengthening of some of the pier columns. Further analysis will be necessary for the final design.

In terms of construction cost and schedule to implement a suicide deterrent system, one of the major contributing factors is the restrictions for maintaining traffic during construction. Since the bridge only has two lanes of traffic, and the next closest crossing over the Patuxent River requires a 55-mile detour, single-lane closures have been evaluated for construction. Historically, for the routine condition inspection of the bridge, lane closures have only been permitted at night during the period of November 1 to March 31; however, this period is typically when many construction operations shut down for the winter. Therefore, preliminary construction costs and schedules have been based on nighttime, single-lane closures during the week without seasonal restrictions. Additional economies and a shorter period of construction can be realized if sustained daytime lane closures and/or weekend work is permitted. If the normal seasonal restriction is imposed, it will likely take an additional 10 to 12 months for construction to be completed.

Table 7. Advantages and Disadvantages of the Alternatives

Alternative [(1)]	Advantages	Disadvantages
1 Physical Barrier behind Existing Concrete Parapet 	• Increased clear distance from front face of parapet to SDS, providing larger setback, reducing risk of accidental collision with vehicles • Less effect on ZOI, reducing warrants for crash testing • Can provide a return at top of the SDS post for additional deterrent without impeding on narrow shoulder • Generally easier to inspect and maintain than netting or hybrid system	• Access to outside of parapet required for construction, increasing construction cost and duration • Significant adverse effect to routine bridge inspections and maintenance activities in fracture critical spans
2 Physical Barrier on top of Existing Concrete Parapet 	• Ease of installation, not requiring access to outside face of parapet • Generally easier to inspect and maintain than netting or hybrid system	• SDS is within ZOI and may result in increased maintenance due to accidental collision with barrier, especially considering narrow shoulders • SDS within ZOI, which may increase warrants for crash testing • Cannot provide a return at top of the SDS post for additional deterrent without impeding on narrow shoulder • Anchor bolt locations and associated post spacings will likely have to be adjusted to not conflict with the existing fencing anchor bolts that will remain upon existing fence removal • Significant adverse effect to routine bridge inspections and maintenance activities in fracture critical spans
3 Netting Near the Roadway Surface 	• No effect on ZOI	• Access to outside of parapet required for construction, increasing construction cost and duration • Significant adverse effect to routine bridge inspection and maintenance activities in all spans • Generally, more difficult to inspect and maintain than barrier alternatives • Requires connection to fracture critical steel girders, which may not be recommended • Depending on existing steel girder paint system, may require lead-based paint procedures and protocols, which increases cost and time to construct • Requires connection to prestressed concrete beams. Drilling into prestressed beams should be avoided; alternate connection type is required • Cable connection to existing concrete parapet/deck may require the use of post-installed anchors in sustained tension, which is an undesirable loading condition

Alternative [1]	Advantages	Disadvantages
4 Netting Below the Roadway Surface  	• No effect on ZOI	• Access to outside of parapet required for construction, increasing construction cost and duration • Significant adverse effect to routine bridge inspection and maintenance activities in all spans • More difficult to inspect and maintain than near-roadway alternative • May have a temporary effect on the USCG navigation clearance • Requires connection to fracture critical steel girders, which may not be recommended • Depending on existing steel girder paint system, may require lead-based paint procedures and protocols, which increases cost and time to construct • Requires connection to prestressed concrete beams. Drilling into prestressed beams should be avoided; alternate connection type is required • Cable connection to existing concrete parapet/deck may require the use of post-installed anchors in sustained tension, which is an undesirable loading condition
5 Hybrid Physical Barrier / Netting  	• No effect on ZOI • Can provide a return at top of the SDS post for additional deterrent without impeding on narrow shoulder	• Access to outside face of parapet required for construction, increasing construction cost and duration • Sloped SDS more scalable than vertical alternatives • Significant adverse effect to routine bridge Inspections and maintenance activities in fracture critical spans; depending on size, may be problematic in other spans • Generally, more difficult to inspect and maintain than the other barrier alternatives

(1) The numbering of the alternatives does not indicate an order or preference.

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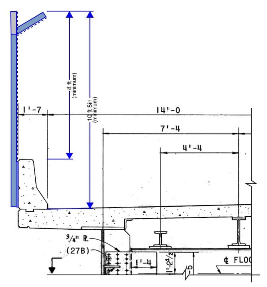
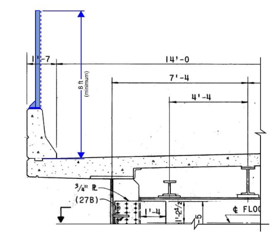
Appendix A
Alternative Conceptual Sketches

ALTERNATIVE NO. 1 - PHYSICAL BARRIER BEHIND EXISTING CONCRETE PARAPET



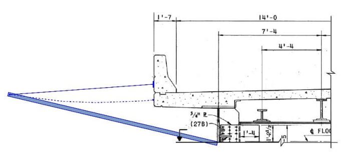
Construct a physical barrier on the outside face of the existing parapet, while retaining the existing parapet. Since the existing parapet could be used as a stepping point to climb the new barrier, the height of the new barrier will be referenced from the top of the existing parapet. The geometry of the new barrier will be developed to not encroach into the shoulder of the bridge where it could be struck by a vehicle.

ALTERNATIVE NO. 2 - PHYISCAL BARRIER ON TOP OF EXISTING CONCRETE PARAPET



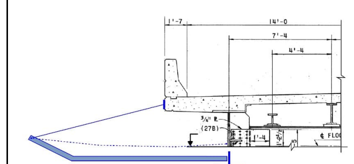
Construct a physical barrier on top of the existing concrete parapet. The geometry of the new barrier would be developed to not encroach on the shoulder of the bridge where it could be struck by a vehicle. The barrier will be designed and detailed such that there would be no additional stepping-point above the roadway surface and therefore the new barrier can be measured from the roadway surface. This would likely result in an overall shorter barrier than Alternative 1.

ALTERNATIVE NO. 3 - NETTING NEAR ROADWAY SURFACE



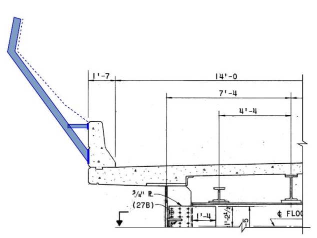
Construct netting on the outside of the bridge and located at or near the level of the bridge roadway surface.

ALTERNATIVE NO. 4 - NETTING BELOW ROADWAY SURFACE



Construct netting on the outside of the bridge and located below the bridge roadway surface.

ALTERNATIVE NO. 5 - HYBRID PHYSICAL BARRIER / NETTING



Construct a physical barrier on the outside face of the existing bridge parapet to lean away from the bridge so as not to encroach on the shoulder of the bridge where it could be struck by a vehicle. Lean the barrier away from the bridge at a slope that would make it difficult to climb. Netting could be used between posts rather than a fence-type material.

ALTERNATIVE NO. 6 - ON-SITE SECURITY MONITORING

Provide on-site security personnel to monitor the bridge 24/7.

ALTERNATIVE NO. 7 - REMOTE VIDEO MONITORING

Install video surveillance cameras and monitor the bridge remotely 24/7.

ALTERNATIVE NO. 8 - CALLBOXES AND SIGNAGE

NATIONAL SUICIDE PREVENTION LIFELINE
1-800-273-TALK (8255)
suicidepreventionlifeline.org

Install callboxes and additional signage that connect persons in crisis to suicide hotlines and/or emergency personnel.

Note: The sketches demonstrate the overall concept of the alternatives and is not necessarily indicative of the final detailing and appearance of the alternatives. Sketches are not to scale.

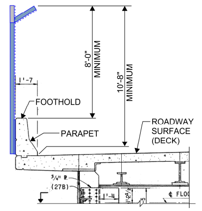
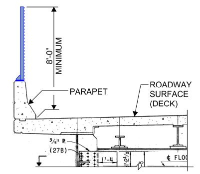
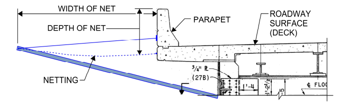
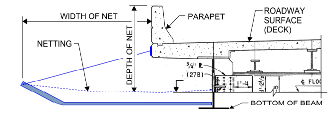
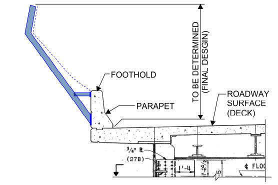
Appendix B

Comparison of Suicide Deterrent System Concept Alternatives

Comparison of Suicide Deterrent System (SDS) Concept Alternatives

Rating Scale

Best ★★★★★
★★★★
★★★
★★
Worst ★

		Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
									NATIONAL SUICIDE PREVENTION LIFELINE 1-800-273-TALK (8255) suicidepreventionlifeline.org
Factor		**Physical Barrier behind Existing Concrete Barrier**	**Physical Barrier on top of Existing Concrete Barrier**	**Netting near Deck Level**	**Netting below Deck Level**	**Hybrid Physical Barrier / Netting**	**On-site Security Monitoring (1)**	**Remote Video Monitoring (1)**	**Callboxes and Signage (1)**
Safety	Not cause safety or nuisance hazard to roadway users	Strongly Agree ★★★★★	Somewhat Agree ★★★★	Strongly Agree ★★★★★	Strongly Agree ★★★★★	Strongly Agree ★★★★★	-	-	-
	Not create undue risk of injury to a person in contact with system	Strongly Agree ★★★★★	Strongly Agree ★★★★★	Somewhat Disagree ★★	Strongly Disagree ★	Somewhat Agree ★★★★	-	-	-
	Minimize the effect on the existing parapet's Zone of Intrusion (2)	Minor Effect ★★★★	Some Effect ★★	No Effect ★★★★★	No Effect ★★★★★	No Effect ★★★★★	-	-	-
	Warrants for crash testing in accordance with MASH criteria (3)	Likely not Warranted ★★★★	May or May Not be Warranted ★★★	Not Warranted ★★★★★	Not Warranted ★★★★★	Not Warranted ★★★★★	-	-	-
Structural	Not have a negative effect on the bridge's load carrying capacity	Some Effect (Additional Analysis Warranted) ★★★	Some Effect (Additional Analysis Warranted) ★★★	Some Effect (Additional Analysis Warranted) ★★★	Some Effect (Additional Analysis Warranted) ★★★	Some Effect (Additional Analysis Warranted) ★★★	-	-	-
Operations & Maintenance	Not have a negative effect on routine bridge inspection	Some Effect (significant in Fracture Critical spans) ★★★★	Some Effect (significant in Fracture Critical spans) ★★★★	Significant Effect (significant in all spans) ★★	Significant Effect (significant in all spans) ★★	Moderate Effect (significant in Fracture Critical spans) ★★★	-	-	-
	Not have a negative effect on routine bridge maintenance activities	Some Effect (significant in Fracture Critical spans) ★★★★	Some Effect (significant in Fracture Critical spans) ★★★★	Significant Effect (significant in all spans) ★★	Significant Effect (significant in all spans) ★★	Moderate Effect (significant in Fracture Critical spans) ★★★	-	-	-
	Not have a negative effect on snow removal	Minor Effect ★★★★	Some Effect ★★★	No Effect ★★★★★	No Effect ★★★★★	No Effect ★★★★★	-	-	-
	Difficulty of deterrent system maintenance / inspection	No Difficulty ★★★★★	No Difficulty ★★★★★	Significant Difficulty ★★	Significant Difficulty ★★	Moderate Difficulty ★★★	-	-	-
Regulation	Not have a negative effect on coast guard clearance envelope	No Effect ★★★★★	No Effect ★★★★★	Likely No Effect ★★★★	May have Temporary Effect ★★★	No effect ★★★★★	-	-	-
	Satisfy historic preservation requirements (4)	Requires Eligibility Determination ★★★	Requires Eligibility Determination ★★★	Requires Eligibility Determination ★★★	Requires Eligibility Determination ★★★	Requires Eligibility Determination ★★★	-	-	-
	Satisfy environmental laws (5)	Likely Minor to No Detectable Change; Anticipated PCE ★★★	Likely Minor to No Detectable Change; Anticipated PCE ★★★	Likely Minor to No Detectable Change; Anticipated PCE ★★★	Likely Minor to No Detectable Change; Anticipated PCE ★★★	Likely Minor to No Detectable Change; Anticipated PCE ★★★	-	-	-
Estimated Implementation Time (calendar months)	Design: Construction: Total:	16 to 18 11 to 13 27 to 31	16 to 18 10 to 12 26 to 30	18 to 20 12 to 14 30 to 34	18 to 20 12 to 14 30 to 34	16 to 18 11 to 13 27 to 31	-	-	-
Estimated Construction Cost (2022 dollars)		$9.9 million ($690 / LF of SDS)	$8.5 million ($590 / LF of SDS)	$13.3 million ($925 / LF of SDS)	$13.3 million ($925 / LF of SDS)	$9.9 million ($690 / LF of SDS)	-	-	-

Note: Assessment based on preliminary data and subject to change as design progresses

(1) Inconsistent efficacy in preventing suicides. Retired from additional evaluation. May be considered in combination with barrier or netting.
(2) AASHTO Roadway Design Guide defines Zone of Intrusion as an area above and behind the face of a barrier system, where an impacting vehicle or any major part of the system may extend during an impact.
(3) AASHTO Manual for Assessing Safety Hardware (MASH). Warrants for crash testing are based on preliminary analysis and requires further consideration / coordination with the Federal Highway Administration (FHWA).
(4) Requires scoping for further evaluation. Bridge requires determination of eligibility for listing on the National Register of Historic Places (NRHP). If eligible, will require consideration of effect of suicide deterrent system on bridge.
(5) Assumes federal funding or other federal warrants. Requires scoping for further evaluation. Programmatic Categorical Exclusion (PCE)

Appendix C
Woven Stainless-Steel Wire Mesh

Woven Stainless-Steel Wire Mesh

Background, Characteristics, and Use

Suicide deterrent systems often implement the use of durable, lightweight, woven stainless-steel wire mesh with mesh openings sized to be resistant to climbing. The wires comprising the mesh are generally only 1.5mm to 2mm in diameter, making the mesh highly transparent, and thus reducing the impact to views from the bridge.

Woven stainless-steel wire mesh has recently been implemented on the suicide deterrent systems or access restriction barriers of several high-profile, long-span bridges, including the Sunshine Skyway, Verrazano Narrows, Golden Gate, and Tappan Zee Bridges (refer to Figure C1, Figure C2, Figure C3, and Figure C4 respectively).

Woven stainless-steel wire mesh is often referred to by the generic term, zoo-mesh, due to its frequent use at zoos for bird, big cat and other animal enclosures, though several companies supply this type of mesh under branded names.

Research to date suggests that most woven stainless-steel wire mesh is produced overseas and would be considered a non-domestic product. Boegger Industech, Ltd. (China) supplies woven stainless-steel wire mesh under the generic name “ferrule rope” mesh. Carl Stahl Architecture (Germany) supplies woven stainless-steel wire mesh under the name “X-Tend” mesh. While most of Carl Stahl Architecture’s X-Tend mesh is produced in Germany, some, in limited mesh sizes, is produced in the United States.

The following table presents the cost per square foot for generally similar mesh from China, Germany and the United States, as well as an estimated overall total mesh cost for the 115,300 square feet of mesh that is anticipated to be required for the suicide deterrent system on the Governor Thomas Johnson Bridge.

Mesh Type & Origin	Unit Price	Total Cost (for 115,300 SF)
Ferrule Rope Mesh (Boegger Industech, Ltd. - China)	$1.88/SF	$217,000
X-Tend Mesh (Carl Stahl Architecture – Germany)	$7.50/SF	$865,000
X-Tend Mesh (Carl Stahl Architecture – United States)	$21.12/SF	$2,435,000

The price of woven stainless-steel wire mesh is highly variable, with non-domestically produced mesh being significantly less expensive than domestically produced mesh. However, the use of domestic versus non-domestically produced mesh needs to comply with the “Buy American Steel” Act, reference Code of Maryland Regulations (COMAR), Section 21.11.02 and MDOT Standard Specifications for Construction, Section GP-7.28. Therefore, the price of the domestically produced mesh has been used in the development of the preliminary cost estimates.

Example Stainless-Steel Wire Mesh Implementaion

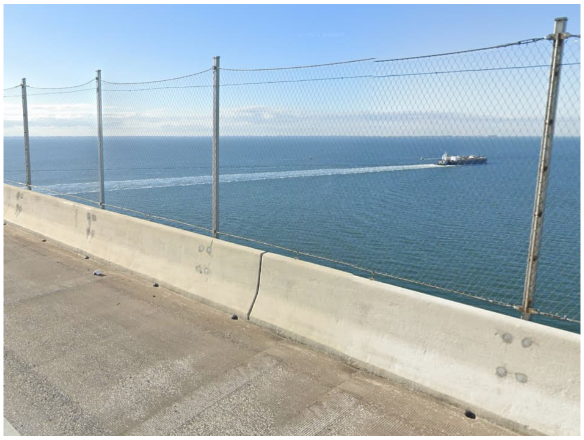


Figure C1. Sunshine Skyway Bridge

Figure C2. Verrazano Narrows Bridge

Figure C3. Golden Gate Bridge

Figure C4. Tappan Zee Bridge

MARYLAND DEPARTMENT OF TRANSPORTATION

STATE HIGHWAY ADMINISTRATION