ST. CROIX CROSSING BRIDGE MANAGEMENT PLAN

April 2020

MnDOT Bridge Office

St. Croix Crossing

T.H. 36 over the St. Croix River between Oak Park Heights, MN and Houlton, WI

Bridge Management Plan

Prepared by MnDOT

Final April 2020

Bridge Management Plan Overview

Bridge Management Plans (BMP) are developed to assist MnDOT engineers and planners in managing bridge assets under their jurisdiction. This bridge management plan includes an overview of the current condition for Br. #82045, critical elements, potential risks and concerns, mitigation of risks, and potential options for long term cost efficient work. This BMP is intended to be a "living document" that should be reviewed every 3 to 5 years to ensure bridge conditions, repair costs, and MnDOT overall processes are up-to-date.

The main purpose for the BMP on the St. Croix Crossing Bridge is to provide decision makers with information to program the most cost effective work strategies over the expected life of this new bridge. Since deterioration has not yet occurred, a wide range of potential actions (scenarios) are considered. A recommended scenario is given, as well as additional costs that could be anticipated if the recommended scenario is not followed for any reason (could be funding constraints, changes in policy, etc).

This Bridge Management Plan includes estimated costs for various potential activities. Costs can vary widely for similar activities based on location, availability of contractors, etc., and costs provided in this BMP are based on average unit prices in the current fiscal year, and best engineering and estimating judgement available at the time. Costs are provided in the base year dollars (2019) and then are normalized by using a real discount rate calculation.

The BMP includes estimated deterioration rates that are based upon element level condition history that have been tracked by MnDOT's Bridge Management System (BMS) over time. State DOT's such as CalTrans have a robust BMS but tend to rely on NBI deck, superstructure, and substructure condition ratings and anecdotal expert estimates of deterioration rates as they consider project level bridge management strategies. MnDOT uses the BMS from AASHTOWare as the current element level database to track elements in various environments. MnDOT also uses BRIM to help make network level strategy recommendations, but BRIM is not suited for management of a major bridge such as the St. Croix Crossing. MnDOT anticipates that results from this BMP will be fed into BRIM and the STIP/CHIP for programming consideration.

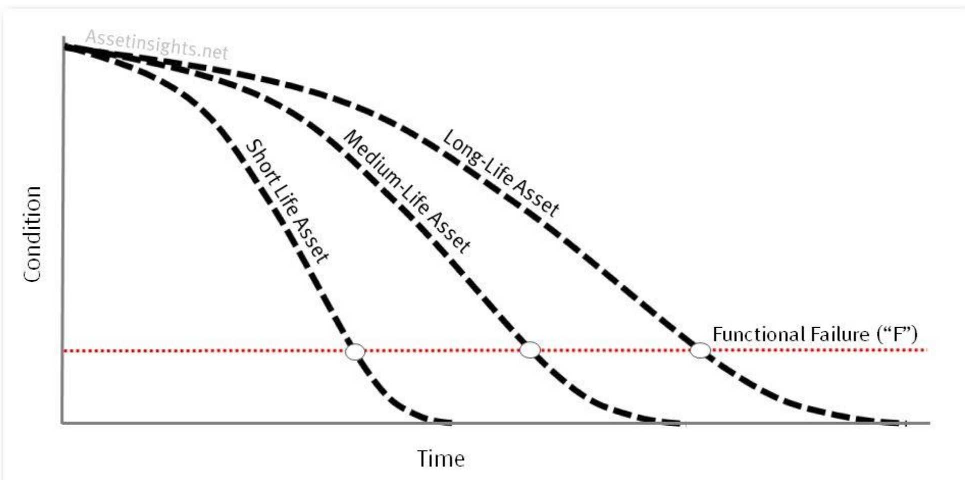
Typical investment strategies for MnDOT bridge assets include maintenance, preservation, rehabilitation, and replacement. This BMP outlines various strategies and how a systematic process can produce the least overall cost while deferring the most expensive replacement options until the full expected life of the bridge is met. Timing of repair strategies obviously depends upon available funding levels. If funding is not available at an optimum time the work can be deferred but may result in higher lifetime costs. This BMP is intended to be a guide in helping MnDOT make optimal bridge funding decisions, but more detailed information available at a later date may well warrant strategies not addressed in this document.

MnDOT has undertaken many different asset management plans over the years, one of the most recent is documented with the Transportation Asset Management Plan (TAMP) in a final report dated June 2019 which meets federal requirements of MAP-21 for a risk-based transportation asset management plan. Parts of TAMP discuss bridge management strategies, but it focuses on network level planning, not project specific planning. TAMP does show that timely preservation work is typically very cost effective. This specific asset management plan for St. Croix takes a closer look at best strategies to minimize life cycle costs. TAMP is intended to support decisions and projects identified in the MnSHIP and HSOP, and the more detailed St. Croix Management Plan will provide even more supporting info. One of the overriding strategies listed in the TAMP related to bridge condition is "*Invest in state highway bridges at optimum points in their life- cycles to ensure safety and structural health*".

MnDOT also uses an analytical management system BRIM to forecast bridge conditions using seven deterioration curves and identifies potential projects based on network level modeling. BRIM does not determine benefit-cost ratios for various alternative work types, and scoping level work is necessary to ensure cost effective solutions are programmed.

This document and the associated speadsheets utilize real discount costs to normalize costs from any time period back to the base year. Variation in the real discount cost obviously affects the bottom line results, and sensitivity analysis can be performed to show the magnitude of difference.

The following schematic shows conceptual deterioration rates if routine preventive maintenance and preservation work is done (long-life asset), if some maintenance and preservation work is done (medium-life asset), and if only reactive maintenance work is done (short-life asset).



Bridge Data

More detailed information on the bridge data is available on the Bridge Inventory and Inspection Reports and in the SCRC Maintenance and Inspection Manual.   The most recent inspection report is stored at S:\Inspection\03 Inspection Reports\01 MnDOT Bridges\Metro District\02 Other Bridges\Br 82045 (Hwy 36 over St. Croix)\BR 82045 ROUTINE REPORT-2019.pdf.

The SCRC MI Manual is stored on the MnDOT shared drive at S:\Inspection\03 Inspection Reports\01 MnDOT Bridges\Metro District\02 Other Bridges\Br 82045 (Hwy 36 over St. Croix)\SCRC MI Manual-HDR_FINAL.pdf The MI Manual is also stored at S:\Construction\BRIDGES\8\82045\Maint and Insp Manual.

Bridge Numbers: 82045 mainline includes Unit 1, Unit 2, and Unit 3
82047 is the westbound off ramp to TH 95
82048 is the eastbound on ramp from TH 95

Bridge Name: St. Croix Crossing Feature Crossed: St. Croix River

Trunk Highway #: Minnesota T.H. 36 , Wisconsin T.H. 64

Average Construction Cost as bid – $650/sf - Note this is higher for main span over the river

Bridge Length: 5,079' for #82045, 961' for #82047, 633' for #82048

Bridge Width: Varies – 82045 Unit 1: 43'-4" EB and 43'-4" WB;
Unit 2: 88'-3" to 55'-10" WB; and 82'-6" to 46'-7" EB
Unit 3: 102'-5" to 98'-6"
82047: 60'-6" to 40'-6"
82048: 35'-4"

Bridge Type: 82045 Unit 1: Precast post tensioned concrete box girder
Unit 2: Cast-in-Place post tensioned concrete box girder
Unit 3: Precast post tensioned concrete box girders (2 girders side by side) and supported by stay cables (extradosed design)
82047: Cast-in place and precast post tensioned concrete box girder
82048: Cast-in-Place post tensioned concrete box girder

Deck Surface: Concrete deck with 3/8" epoxy chip seal overlay

Foundation Type: 82045: Unit 1: Steel H pile driven to rock
Unit 2: Steel H pile driven to rock
Unit 3: River Piers 9' diam drilled shafts, Pier 13 and E Abut 24" CIP piles
82047: Steel H pile driven to rock
82048: Steel H pile driven to rock

Substructure Type: Cast in place concrete on all piers and abutments

Barrier Type: Concrete single slope median and edge barriers, concrete type P-4, concrete P-2 with P-1 traffic barrier, ornamental metal pedestrian rail

Expansion Joint Type: Modular Strip Seal – Manufactured by Watson Bowman

Bearing Type: Disk type – Manufactured by Mageba

Other Features: Lighting system, sidewalk on north side, drainage system, lightning protection system, navigation system, internal box lighting,

Bridge Element Description, Current Condition, and Deterioration Expectations

The St. Croix Crossing bridge was constructed between 2013 and 2017. The river pier foundations for Piers 8 - 12 were constructed in 2013 under SP 8221-82045A. The superstructure including all approach foundations and all piers and concrete box girders was constructed from 2014 to 2017 under SP 8221-01. The bridge was opened to traffic on August 2, 2017.

The main structural superstructure consists of precast or cast-in-place post-tensioned concrete box girders protected with an epoxy chip seal overlay. The critical portions of this type of bridge include the deck since it cannot be replaced and the post-tensioning tendons since they are difficult to replace and also may be difficult to identify any deterioration. Critical areas to consider include the joints between precast segments, cracking and/or delamination in the overlay and deck, and any evidence of post tensioning deterioration. Other critical elements include the stay cables, cross beams on the river piers, pier blades, cast-in-place diaphragms, bearings and joints. The following sections detail current conditions and potential deterioration. Best management practice for the St. Croix Crossing will be to preserve the structure through annual maintenance and occasional preservation projects to ensure a minimum of 100 year life will be achieved prior to any major rehabilitation or replacement.

The initial bridge inspection report in 2017 and the annual inspection report in 2019 outline many cracks in the various concrete elements. Since all concrete typically has some cracks, it is generally recognized that not all cracks are significant nor do they need to be repaired until the crack width or length becomes a concern. The post tensioning on SCC works to compress the concrete at the cracks which should reduce the risk of early deterioration. Table 3-2 of the SCRC Maintenance and Inspection Manual includes a guideline for crack significance by structural element as follows:

Table 3-2. Crack Significance by Structural Element

Structural Element	Width (1 mil = 0.001 in.)
Footing	10 mils (0.010 in)
Piers	12 mils (0.012 in)
Pier Cap	10 mils (0.010 in)
Abutment	10 mils (0.010 in)
Deck	7 mils (0.007 in)
Web Exterior	12 mils (0.012 in)
Web Interior	16 mils (0.016 in)
Bottom Slab Exterior	12 mils (0.012 in)
Bottom Slab Interior	16 mils (0.016 in)
Abutment and Pier Diaphragms	16 mils (0.016 in)

<u>Deck and Overlay and Condition – Precast and Cast-in-Place</u>

Overall quantities:	Br. #82045 –	Structural Deck Area = 509,790 sq. ft.
		Roadway Chip Seal Area = 435,666 sq. ft.
		Sidewalk Chip Seal Area = 46,344 sq. ft.
	Br. #82047 -	Structural Deck Area = 41,320 sq. ft.
		Roadway Chip Seal Area = 27, 578 sq. ft.
		Sidewalk Chip Seal Area = 12,000 sq . ft.
	Br. #82048 -	Structural Deck Area = 22,320 sq. ft.
		Roadway Chip Seal Area = 21,645 sq. ft.

In 2019 the deck condition is good. The 2017 and 2019 inspections document various cracks in the deck and box girder concrete. A quick internal box inspection in 2018 and 2019 shortly after a rain event proved that there was no leakage through any of the precast segment joints, thus no evidence of any deterioration at this time. One potential area of concern is the large number of shims used to erect the precast segments. Shims have the potential to lead to more rapid water intrusion through the segment joints and should be monitored closely. Each inspection cycle should include an internal inspection after a rain event to determine if any joints are beginning to leak.

A top deck inspection from the sidewalk in 2019 showed quite a large number of reflective cracks in the epoxy chip seal overlay at deck access hole penetrations used during construction. There is one large patch in the top deck surface due to ice damage at a PT anchorage blockout during construction in the westbound lanes of span 9 that has some extensive cracking in the structural deck patch material and which has reflected into the chip seal overlay. These areas of reflective cracking should be monitored closely to determine if additional deterioration is occurring.

The 12' wide trail on the north side of the bridge is protected by an epoxy chip seal overlay added as S.A. #26. As of 2019 the condition of the trail is good.

Maintenance, preservation, and rehabilitation options include: remove and replace epoxy chip seal overlay, remove chip seal and replace with other deck protection system such as polyester overlay (PPC), waterproof membrane with asphaltic overlay or with low slump concrete overlay, spot repair of delaminated chip seal overlay areas, inject any leaking cracks with epoxy, and remove overlay above the link and flood seal and replace overlay.

<u>Concrete Box Girder Condition</u>

Overall quantities:	Br. #82045 –	Structural Deck Area = 509,790 sq. ft.
		Precast (segs and link): Unit 1 = 87,989 sf; Unit 3 ~ 340,000 sf
		Cast-in-Place Unit 2 ~ 82,000 sf
		Architectural deck skirt area = 3,121' ea side*6' wide = 37,458 sf
	Br. #82047 -	Structural Deck Area = 41,320 sq. ft.
	Br. #82048 -	Structural Deck Area = 22,320 sq. ft.

In 2019 the concrete box girder condition is good. Some of the items to watch during annual inspections include previous areas of cracking, segment joints that did not fully close, previous repair areas, and stay anchor block regions. During construction there was some cracking in the top deck at the segment joints in the center of Unit 3 segments from about segment #4 to #10; and also cracks were observed extending from the back side of the stay anchor blocks into the deck on most stay block areas. All of these cracks closed during construction with the additional post tensioning forces that were applied. There are cracks in each of the concrete stay anchor blocks that appear to have been increasing slightly during the first two years of service. There also are some shrinkage cracks in the architectural deck skirt areas. The stay block and skirt areas were more closely inspected in 2019 and will be sealed to prevent additional ingress of moisture and chlorides. The MnDOT Bridge Maintenance Crew performed some sealing in October 2019 and will complete sealing on the tops of the stay anchor blocks in 2020.

There are some structural shear cracks in various portions of the bridge as outlined in the initial 2017 inspection report and further documented in the 2019 inspection report.

A critical Unit 3 element is the cast-in-place longitudinal link which connects the EB and WB precast segments. The link is located at the westbound inside shoulder. The link has some cracking that should be monitored to ensure there is no deterioration and that cracks that do reflect through the chip seal overlay get sealed.

For Unit 2 there are cracks in the top deck and some repaired areas in the web walls.

Span 1 is over TH 95 and will be subject to more spray from de-icing chemicals than the other spans. Deterioration may occur more rapidly in this span.

Maintenance, preservation, and rehabilitation options include: seal cracks in the stay block regions, inject cracks if sealing does not prevent water infiltration, repair spalled and delaminated concrete, add future post tensioning if needed, …

<u>Post Tension Tendons</u>

Overall quantities: Total 7.9 million pounds of PT strand

Post Tensioning tendons are used to support the precast segments, the cast-in-place box girders, the stay struts, the crossbeams, and the diaphragms. The PT supplier was Freyssinet, and PT details are included on several of the shop drawing submittals including ISD010, ISD028, ISD043, and LA-120B. Longitudinal tendons include cantilever, draped, and external tendons and typically run through round polyethylene ducts and are stressed using standard PT anchorage systems and multistrand jacks. Transverse tendons typically run through flat polyethylene ducts and are stressed using standard PT anchorage systems and monostrand jacks. PT records are available for all of the tendons on the project. Most of the tendons were within specified elongations of +/- 7%, those that were outside of the specifications are recorded and approved as such.

Critical protection portions of PT tendons include the anchorage blockout areas, tendon discontinuities at the precast segment joints, and the tendon grout. During construction there were a few blockout areas that filled with water and ice damaged some surrounding concrete. Locations were on the top deck is westbound span 9, on eastbound Span 1 over TH 95 and other areas noted in NCR-095R2. Unsound concrete was removed and replaced and are areas that should be closely monitored in the future.

All tendon grouting was inspected during construction and project records indicate all tendons are properly grouted. Anchorage regions are protected by very dense epoxy grout and elastomeric membrane which do not enable easy inspection of grout caps in the future. Inspection of the length of grouted tendons also is not readily accessible based on current inspection technology. Inspectors should look for any signs of deterioration during each annual inspection. Note that the tendons are bonded in grout, so if deterioration is noted at one location it may not necessarily mean the entire tendon is compromised.

Provisions for adding future post tensioning are designed into the bridge. If deterioration of PT is evident the future PT may need to be utilized.

Maintenance, preservation, and rehabilitation options include: add future post-tensioning, investigate some anchorages to review condition (long term, maybe 50 years out), drill into ducts to check condition (again a long term need, most likely place of deterioration is at segment joints), or utilize new Non-Destructive Testing (NDT) technology that may not yet be known to review PT tendon condition.

Stay Cable System

Overall quantities: 160 stay cables, total length approximately = 27,600 lin. ft. of stays

76 strands per stay cable so approx. 2,100,000 lin. Ft. of PT strands (or 1.6 million lbs)

The Unit 3 superstructure is supported by stay cables. There are 8 stays in each direction of each span of each tower (32 stay cables at each of piers 8 – 12 or 160 total stay cables). Each stay cable consists of 76 sheathed strands @ 0.6" diameter and are anchored at the face of the concrete stay anchor blocks in the precast segments and inside the pylons/towers in a steel anchor box. Corrosion protection of the bottom anchor region consists of a galvanized steel protection cap, flexible polymer filler, solid filler, and polymer corrosion protection layer (see sheet VSL-214 of shop drawing GSD004R8). The strands are contained inside a UV stabilized HDPE pipe on top and a 30' length of stainless steel pipe on the bottom. There are additional neoprene gaskets to inhibit ingress of debris and moisture.

At each stay location there is a transverse tendon that anchors at the outside web wall of each box girder and extends through a strut at the bottom that ties the side-by-side segments together. Each transverse tendon has 31 PT strands. The anchorage is embedded within the architectural skirt for protection and cannot be inspection without concrete removals.

The stay cables are listed as element #147 on the inspection report and have no deficiencies. The transverse tendons are listed as element #148 on the inspection report and there is indication of cracking in the CIP closure pour and in the concrete box adjacent to the strut CIP closure pour. Cracks were visible prior to application of the surface finish, it is possible the cracking will not be evident now after the surface finish is inplace.

The stay cables are designed to be replaced if needed. This management plan will include a stay cable replacement option if needed.

Maintenance, preservation, and rehabilitation options include: Invasive inspection of an anchorage (about a 20 year cycle), replace stay cables if needed, replace corrosion protection materials, and repair transverse strut.Unit 3 Crossbeams, Pylons, and Blades

Overall Quantities: Each Crossbeam is 98'-8" long between the pier blades, plus 16' on each knuckle

Each pylon extends 67' above the deck, with an approx. surface area of 5,000 s.f.. So for 10 pylons = 50,000 s.f. of surface area.

The pier blades vary in height from 100' to 140'. Approx cross sectional surface area of each blade is 80 sf/ft, so total approx. (120')*(80')*(10 blades)=96,000 sf

The crossbeams distribute the loads from the segments to the north and south pier blades and foundation. The massive elements have some minor cracking based on initial inspection data, and those cracks should be monitored over time. Since the majority of the crossbeams are not subject to the environment it is not anticipated that corrosion on the lower regions will be of great concern. The anchorages for the 52 strand tendons are covered with pourback material and should be reviewed for any deterioration. The top deck portion of the crossbeams are subject to the same deterioration as the rest of the deck. The top slab portion of the crossbeams include 58 pairs of longitudinal tendons (29 pairs in each box) that should be reviewed for any deterioration. Highest likelihood of deterioration is at the joint between crossbeam and pier table.

The pylons (also referred to as towers above the deck level) are subject to road salt spray and should be inspected for signs of any deterioration.

The blades (the narrow 4' wide structural stems extending below the crossbeams down to the foundation) have critical stresses especially in the top. The inspections should pay particular attention to any cracking in the top portion of the blades and track any crack growth.

Maintenance, preservation, and rehabilitation options include: Wash pylons and crossbeams that have been subject to de-icing chemicals, inject cracks with epoxy, ensure deck protection system remains sound, repair areas of delamination and corrosion, and re-apply surface finish to the outer surfaces. Replacement of the crossbeam, pylon, and blades is not possible without complete bridge replacement.

<u>Unit 3 River Pier Foundations</u>

The river piers are founded on 9' diameter drilled shafts, four under each column (8 per pier). The concrete stem extends down to a concrete footing, the bottom of which is just above the river bottom. There is not a large risk for extensive scour of the river bed given the slow flow rate of the St. Croix River in this location, and the weak soils do not provide much lateral stability for the drilled shafts. There is potential for waterline deterioration of the stem concrete. An artesian condition was found during construction of Pier 8 footings and did not appear to have affected structural capacity, but underwater inspections should review for any potential weaknesses.

Maintenance, preservation, and rehabilitation options include: Spalls would be repaired by patching, cracks could be injected, it is not expected that major structural repairs would be required, but if so it would be extremely costly. Replacement of foundations is not possible without complete bridge replacement.

<u>Cast-in-Place Box Girders and Pier Tables</u>

Approximate quantities: Unit 2W: Structural deck ~ 35,000 sf; chip seal driving surface (not including trail) = 27,344 sf. Depth of box varies from 14'-0" to 18'-0"

Unit 2E: Structural deck ~ 47,500 sf; chip seal driving surface = 46,626 sf. Depth of box varies from 14'-0" to 18'-0"

Br 82047 Span 1 CIP: Structural deck ~ 9,000 sf. Depth of box = 10'-0"

Br. 82048: Structural deck = 22,320 sf. Depth of box varies from 10'-0" to 14'-0"

Potential issues with the CIP box girders are much the same as for the precast segments. Some cracking is evident, especially in the deck surfaces. Some repair areas are present due to construction defects and should be monitored. The CIP box diaphragms and the CIP pier tables have transverse post tensioning inplace that is anchored in the outer webs of the box girder. The PT and anchorages should be monitored, and any distress of anchorage zones noted and tracked. Longitudinal PT in the CIP box girders is in the webs, top deck and bottom soffit.

Maintenance, preservation, and rehabilitation options include: seal cracks in the deck, inject cracks in webs, deck repair prior to extensive deterioration, add future post tensioning if needed, and replace overlay on scheduled cycle to protect deck. Replacement of the deck is not generally feasible, but sections of the deck can be removed and replaced but would be extremely costly.

Traffic Barriers and Pedestrian Railings

Quantities (total all three bridges) : Area in ( ) includes roadway face and top of barriers

Type Mod. P-4 Barrier: 6,942' long, faces ~4' (Area ~ 28,000 sf)
Single Slope 32SS: 1,615', faces ~3.5' (Area ~ 6,000 sf)
Single slope 56SS: 1,642', faces ~5' (Area ~ 8,000 sf)
Type 32S Median Barrier: 3,385', faces ~6.5' (Area ~ 22,000 sf)
Type Mod P-2 parapet with metal tubular rail: 6717', faces ~3' (Area~20,000 sf)
Total Length of Concrete Barriers = 20,300'
Total Area of Concrete Barriers (Roadway face and top only) ~ 84,000 sf
Ornamental Metal Pedestrian railing: 4,940'

There are different types of traffic barriers and pedestrian railings on the bridge. Unit 1 and Unit 2 includes Type Mod. P-4 outside barrier and Single Slope Concrete inside barriers; Unit 3 includes Type Mod. P-2 concrete barrier with structural tube outside barriers and Type 32S concrete median barrier; Br. 82047 and 82048 includes Type Mod P-4 concrete barrier along the inside and outside edges; and the entire north side of the pedestrian trail and overlooks is protected by powder coated ornamental metal railing.

The concrete barriers have stainless steel reinforcement which should minimize corrosion, however there are some epoxy coated couplers in some locations at which corrosion of dissimilar metals could occur. As is consistent with most concrete barriers there are cracks in the barriers that will need to be sealed or repaired.

Maintenance, preservation, and rehabilitation options include: Flush and seal concrete barriers, repaint or powder coat ornamental metal railings and structural tube rails, repair spalled and delaminated concrete, and replace barriers.

Expansion Joints

Quantities: Total 526 linear feet. See table below

The expansion joints are modular strip seal joints with design movements ranging from 9" to 39" as shown in the table below. The joint opening size is calculated to accommodate high and low temperatures and creep and shrinkage of the concrete. The modular joints were fabricated by Watson Bowman Acme. Possible deterioration of modular expansion joints includes leaking strip seal glands due to tears or pullout, corrosion of the transverse steel edge and center beams, deterioration and seizing up of internal springs and bearings, etc., and deterioration of concrete supporting the joints. Maintenance and replacement of modular joints will be required on an ongoing basis. Recording of joint openings should be tracked to show any overall bridge movement issues. Shop Drawings for the joints include GSD018 through GSD026 as shown in the table below.

The 2019 inspection identified some of the nylon keeper pins through the control springs had worked their way out of alignment. Watson Bowman Acme (WBA) and LAJV intend to reposition the keeper pins and add new cotter pins to the system in 2020 to prevent additional movement and distortion.

Maintenance, preservation, and rehabilitation options include: Annual cleaning debris from joints, repair ripped and pulled out glands, estimated at every 10 years, rehab springs and disks every 20 years, and replace joints every 40 years.

Replacement of joints is estimated to occur at years 40 and 80 and is calculated at 1.5 times the cost of original joint installation to account for removals, traffic control, etc., or a total of $3 million.

Bridge #	Location	Design movement per Plans	# of strip seal glands in ISD	Length of Joint	Bid Price in original contract	Shop Drawing #
82045	EB - West Abut	12”	4	41’	$90,200	GSD019
	WB – West Abut	12”	4	41’	$90,200	GSD019
	EB – Pier 4	18”	5	41’	$127,100	GSD025
	WB – Pier 5	18”	5	41’	$127,100	GSD020
	EB – Pier 7	30”	9	45’	$225,000	GSD024
	WB – Pier 7	30”	9	55’	$275,000	GSD024
	EB – East Abut	39”	13	41’	$237,800	GSD026
	WB – East Abut	39”	13	55’	$319,000	GSD026
82047	West Abut	12”	4	59’	$129,800	GSD023
	Pier 5	21”	7	39’	$187,200	GSD023
82048	West Abut	12”	3	34’	$54,400	GSD018R1
	Pier 4	15”	5	34’	$102,000	GSD022
Total				526’	$1,964,800	

Bearings

Quantities: There are a total of 68 disk type bearings on the 3 bridges.

The bearings on the bridge are large disk type bearings and are designed to accommodate large loads and longitudinal and transverse movements as well as rotations. The bearings were fabricated by Mageba and are detailed in Shop Drawing numbers LA-010, LA-178, GSD-028, and the stamped shop drawing which can be found on the Bridge Office shared drive at S:\Construction\St. Croix\St. Croix Information\Superstructure Contract\RFI\Bearings\Stamped bearing shop drawings… See plan sheets 801R and 802RR of Br. #82045; plan sheet 202RR and 203R of Br. #82047; and plan sheet 126R and 127 of Br. #82048.

Deterioration can include corrosion or debris on sliding surfaces which limit available movement, corrosion of metal bearing components, movement of bearing beyond the range it can accommodate due to creep, shrinkage, or other bridge movements, Maintenance, preservation, and rehabilitation options include: Cleaning bearings, especially ensuring that sliding surfaces are clean, replace bearing components such as polytron disks, jack bearings back into proper position, and replace bearings.

Other Items

The Drainage System including the top drainage grates and the piping system will need annual cleaning and maintenance. The system may need rehab or replacement at some later point.

The roadway lights, trail lighting system, navigational lighting system, accent lighting system, and internal box lighting system will need regular changing of light bulbs/LED fixtures and occasional replacement of hardware.

Mitigation of Risk

The most important risk mitigation item is to ensure the deck protection system is maintained to keep chlorides from getting to the structural concrete, rebar, and post tensioning. If chlorides get through the chip seal overlay it can began to deteriorate the concrete, can get through the epoxy joints at the precast segments to the post tensioning tendons, and can deteriorate construction joints, PT tendons, and anchorage pourbacks.

Mitigation possibilities for deck protection include re-application of epoxy chip seal overlay, replacement with a more durable overlay such as 1" polyester or low slump concrete overlay, or replacement with a waterproof membrane and bituminous overlay. In later years the deck life may be extended by milling off the top surface and adding a 4" thick reinforced concrete wearing course on top (which would affect load capacity).

Other important items are maintaining sound modular joints and preventing bearings from seizing up.

Concrete surfaces can be protected by re-applying special surface finish or sealant, especially in splash zones of the pylons and adjacent to and over traffic, injecting cracks in the box girders, and repairing spalled areas.

Flow Chart for Mitigation of Risk Activities

Consider adding a flow chart showing decisions and risks. Still need more work on this. Try to make a separate one for other BMP's. Provide information on why a certain option is selected.

Methodology for Determining Costs of Various Bridge Scenarios

This purpose of this Bridge Management Plan is to identify the most cost effective way to manage and preserve a costly transportation asset. This BMP uses estimated element deterioration rates, estimated repair costs, estimated replacement costs, and expert knowledge and opinion to calculate cost effective strategies for best managing the St. Croix Crossing Bridge. A separate spreadsheet has been developed with separate tabs for:

- Summary-costs (with scenarios)
- Condition and Predictions
- Element Deterioration
- Costs

The Element Deterioration spreadsheet utilizes expert knowledge to estimate deterioration rates for different elements if there are 1) no repairs prior to major work and 2) regular repairs prior to major work. The deterioration rates form the basis for when certain activities are performed for each scenario.

The Summary-costs tab of the spreadsheet includes types of work for the main elements of the bridge. Often there are two or three variations of the same work to enable assignment of different durations or extent of work to the different scenarios. For instance deck preservation includes deck repair on a 5 year, 15 year, and 30 year cycle and one of these items is assigned to each scenario.

The Summary-costs tab utilizes a check mark "x" in a cell to flag when a certain activity is assigned to a scenario. Then a cell is filled in under a given year with the estimated cost (in $1,000's) of that activity. These costs are based on cost history where known and the cost and deterioration expert analysis performed as part of this BMP development. See the Estimated Cost section that follows for more details of the costs assumed for this BMP (this info is also copied in the Costs tab of the spreadsheet).

Scenarios for Bridge Maintenance, Preservation, Rehabilitation, and Replacement

The following scenarios include consideration of various Maintenance activities. Definitions from the bridge maintenance manual include:

> **Preventive Maintenance** includes routine maintenance activities performed according to an assigned frequency, as well as periodic minor repairs with the intent of preserving the bridge.
>
> **Reactive Maintenance** is scheduled in response to an identified condition that may compromise public safety or bridge structural function, and is further broken down into high, medium, and low priority.
>
> > **High Priority Reactive Maintenance** is in response to bridge conditions that may impair the safe function of the bridge or deteriorate to critical if not repaired within one year.
> > **Medium Priority Reactive Maintenance** is in response to bridge conditions that are expected to deteriorate within three years to a high priority condition.
> > **Low Priority Reactive Maintenance** is in response to bridge conditions that are not likely to impact public safety or structural function if deferred three years or more.

Scenario 1: Active annual preventive maintenance such as washing deck, pylons, railings, and joints along with regularly scheduled preservation activities such as replacing overlay with PPC polyester, sealing cracks, patching concrete, replacing joints, cleaning and resetting bearings and rehab work when needed.

Expected life cycle costs:

Scenario 2: Minimal annual preventive maintenance but regularly scheduled preservation activities such as replacing overlay with epoxy chip seal, sealing cracks, patching concrete, replacing joints, cleaning and resetting bearings.

Expected life cycle costs:

Scenario 3: Active annual preventive maintenance such as washing deck, pylons, railings, and joints but minimal preservation activities such as replace overlay and patch deck until conditions force it.

Expected life cycle costs:

Scenario 4: Very little preventive maintenance, reactive maintenance only until major rehabilitation is required. Add maintenance definitions…..

Expected life cycle costs:

Scenario 5: No work at all (other than a few deck repair items to maintain ride) until bridge is replaced (the Do-Nothing scenario).

Expected life cycle costs:

Replacement Costs and Remaining Service Value (considered as a salvage value) -

The St. Croix Crossing Bridge is designed and constructed to have an expected life of 100 years. If ongoing routine maintenance, preservation, and rehabilitation is not performed on the bridge the bridge will not last 100 years. To provide a systematic way of showing the additional cost of not achieving 100 years of life a replacement cost of $500 million is assigned at the expected life for each scenario, and then a remaining service value for each scenario is provided at year 100 to estimate a value of the additional life left in the bridge (either the original bridge or the replaced bridge). The formula used is:

Remaining Service Value = (replacement cost)*((100 – age at year 100)/100)

i.e. for bridge replaced at year 80 = ($500M)*(80/100) = $400Mil

Bridge replacement cost impact considers the assumed life of the original bridge given the work activities defined in the various scenarios. The assumed life is based on expert opinion and the knowledge of element deterioration when preservation actions are not taken. The following table summarizes the assumed life for each scenario.

Scenario	Assumed Life Expectancy	Comments
Scenario #1 - Annual maintenance, regular preservation & PPC OL, avoid rehab	110 years	Regular maintenance and preservation extends life
Scenario #2 - minimal maintenance, regular preservation, avoid rehab	100 years	
Scenario #3 - Annual maintenance, minimal preservation, reactive rehabilitation	80 years	
Scenario #4 - Very little maintenance and preservation, reactive rehabilitation	75 years	
Scenario #5 - No work at all until bridge is replaced. Do nothing strategy.	60 years	Deck deterioration will lead to PT failure

A sensitivity analysis was performed and if the life of scenarios #3, #4, and # 5 were increased to 95 years, 85 years, and 75 years the present value lifecycle cost is still significantly more than Scenarios 1 and 2 which do not have replacement costs in a 100 year life cycle (since age at replacement is 110 years and 100 years respectively). Thus the replacement cost is a large cost driver in this analysis.

Considerations and Drivers for Bridge Replacement

This section is intended to capture potential issues in the bridge population as a whole that need to be considered in a Bridge Management Plan, and these are not necessarily an issue on St. Croix. As a bridge ages and decisions need to be made about replacement versus continued preservation or rehabilitation, several vulnerabilities must be considered including the following list and potential issues on the St. Croix Crossing:

Vulnerability	**Potential on St. Croix**	**Potential reasons to drive bridge replacement**
Overall condition	Yes – Deck, box girder, crossbeam, pylon condition	Deterioration of deck concrete, post tensioning, structural concrete
Structural Deficiency, load rating issues	Minimal if conditions are maintained	Loads could increase, deterioration of concrete or PT
Function adequacy or accident history	Minimal	Standards change, traffic growth requires additional lanes

Scour issues	Minimal – footings above mudline, large drilled shafts	Issues noted with drilled shaft condition
Traffic growth and capacity	Minimal	If traffic demands increase dramatically may need more lanes
Steel fatigue or fracture critical	Minimal – cable stays	Fatigue of cable stays
Corridor Improvements	Minimal	Unlikely at this time to improve this intrastate route

From NCHRP report "*Characteristics of Decommissioned Bridges*" (June 2018) only 12% of bridges are replaced due to poor condition alone, 22% are replaced due to functional inadequacy alone, and 35% are replaced due to a combination of functional inadequacy and poor condition. So while this management plan heavily considers preservation and rehabilitation action necessary to prolong the life of the bridge, the other factors must also be recognized.

<u>Life Cycle Costs</u>

Strategies to compare bridge maintenance, preservation, rehabilitation, and replacement costs at various times in the life of the bridge must be considered at a common point in time. From research on the subject it appears that both FHWA and MnDOT recommend using the real discount rate to calculate the present value of a future investment. To document considerations of Life Cycle Cost Analysis (LCCA) the following excerpts from the FHWA LCCA Primer are included:

> *For LCCA, costs occasioned at different times must be converted to their value at a common point in time. A number of techniques based on the concept of discounting are available. The FHWA recommends the present value (PV) approach (also known as "present worth")…. The PV approach brings initial and future dollar costs to a single point in time, usually the present or the time of the first cost outlay*.
>
> *Regarding Inflation and Discounting: Dollars that include the effects of inflation or deflation over time are known as nominal, current, or data year dollars. Dollars that do not include an inflation or deflation component (i.e., their purchasing power remains unchanged) are called constant or base year dollars. Costs or benefits (in constant dollars) occurring at different points in time—past, present, and future—cannot be compared without allowing for the opportunity value of time. The opportunity value of time as it applies to current versus future funds can be understood in terms of the economic return that could be earned on funds in their next best alternative use (e.g., the funds could be earning interest) or the compensation that must be paid to induce people to defer an additional amount of current year consumption until a later year. Adjusting for the opportunity value of time is known as discounting.*

In this management plan we have used the following formula (obtained from FHWA Life-Cycle Cost Analysis Primer dated August 2002):

$$\text{Present Value} = \text{Future Value} * \frac{1}{(1+r)^n}$$

Where Present Value = Cost of work in 2019 dollars with discount applied
Future Value = Agency Cost of work, in base year dollars

r = Real discount rate
n = number of years beyond 2019 that work is done

The Real Discount Rate used does have a significant impact on the result. Some possible discount rates are:

Source document	Discount Rate	Comments
MnDOT Benefit-Cost Analysis for Transportation Projects, Appendix A, Table A.1, 2018	1.2%	1.2% is used for this BMP
MnDOT Transportation Asset Management Plan 2014	2.2%	
FHWA Life Cycle Cost Analysis Primer	3% to 5%	

The 1.2% real discount rate has been used in the analysis. We tested the 2.2% discount rate and the scenario rankings stay the same but the magnitude of the higher cost scenarios decreased so there is less difference from the optimal scenarios.

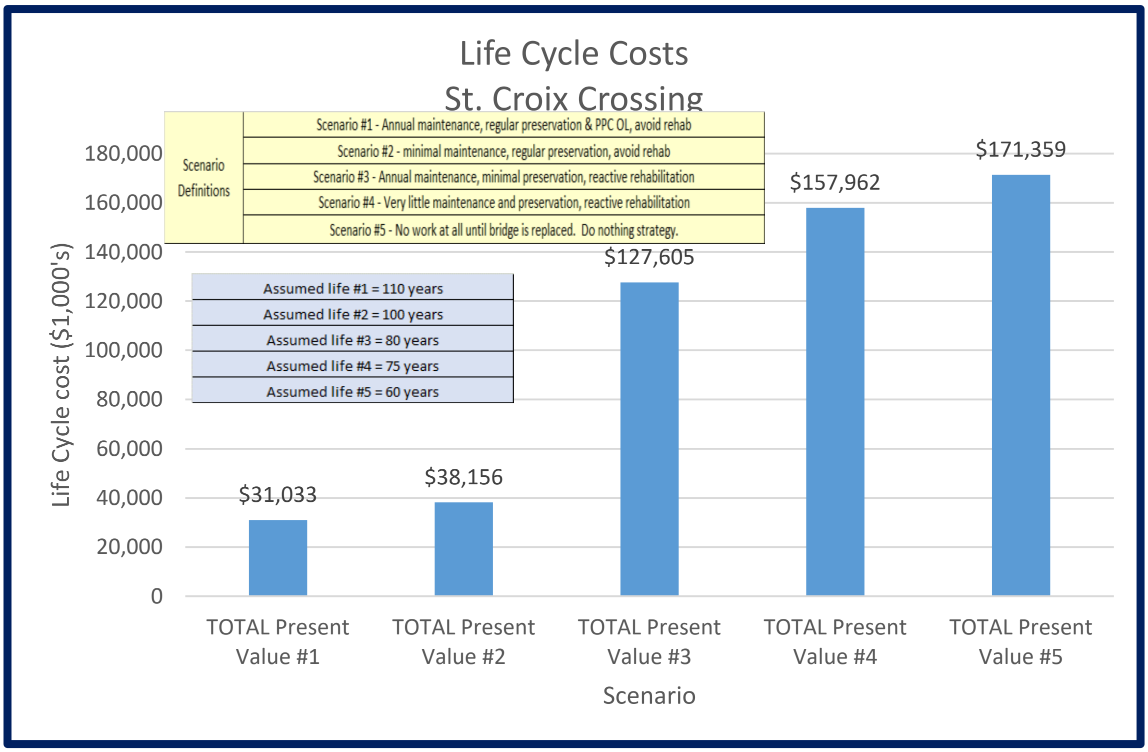
User costs

Although consideration of user costs such as traffic delays, etc. could be analyzed, they are difficult to accurately portray and they can have a huge impact on the results. This BMP does not attempt to include user costs.

Draft Results for 5 Scenarios, and Recommended Work

This BMP uses the LCCA Deterministic Approach as outlined in the FHWA LCCA Primer to calculate the difference between the various scenarios. The agency costs for each activity are in constant, base year dollars. As shown below, results from the spreadsheet show that the optimal life cycle cost is Scenario #1 which provides ongoing and regular maintenance, preservation, and rehabilitation work. These findings are in line with findings from MnDOT's 2019 Transportation Asset Management Plan (TAMP) which found that typical MnDOT preventive maintenance strategies extend the average service life of each structure from about 50 years to about 80 years. The TAMP provides a network level approach to asset management and suggests additional work to understand the deterioration of bridges and specific life cycle costing is needed.

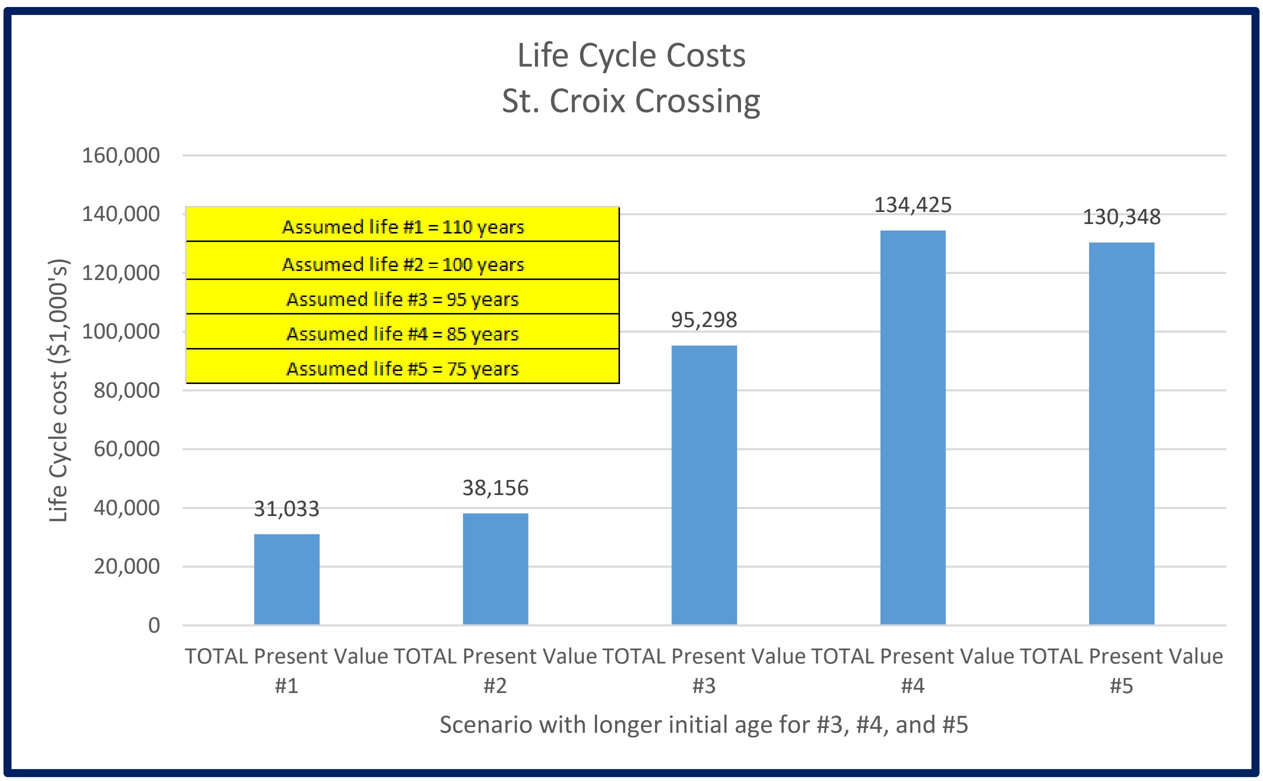
The life cycle costs shown below are given in present value and utilize a 1.2% real discount rate.



The cost scenarios can further be broken down into annual costs (funding allocated each year to manage the St. Croix bridge).

Scenario	Total Life Cycle Cost (Present value)	Average Annual Cost over 100 Years (Present Value)
Scenario #1 - Annual maintenance, regular preservation & PPC OL, avoid rehab	$31,000,000	$310,000/year
Scenario #2 - minimal maintenance, regular preservation, avoid rehab	$38,200,000	$380,000/year
Scenario #3 - Annual maintenance, minimal preservation, reactive rehabilitation	$127,600,000	$1,276,000/year
Scenario #4 - Very little maintenance and preservation, reactive rehabilitation	$158,000,000	$1,580,000/year
Scenario #5 - No work at all until bridge is replaced. Do nothing strategy.	$171,400,000	$1,714,000/year

Per the discussion above, the assumed age of the original bridge at time of replacement is a large influence on the life cycle cost analysis. To show the impact of age at replacement the following graphic shows how the numbers change if the only revised parameter is the expected age at time of replacement for scenarios 3, 4, and 5. The results show that the maintenance and preservation scenarios are still far more cost effective on a life cycle basis.



Recommended work during the 100 year life cycle include:

- Regular preventive maintenance such as washing deck, joints, barriers, and spray zones
- Preserve chip seal overlay for first 15 years
- Repair deck as needed, estimated every 5 years for this BMP
- Program new PPC polyester concrete overlay in year 15, then every 35 years thereafter
- Repair modular joints when needed and replace modular joints every 40 years
- Seal concrete cracks and repair any spalls and delams in concrete on regular basis
- Replace other items including stay cables, barriers, railings, drainage system when needed
- With these and other programmed work the bridge is estimated to last at least 110 years.

Additional detail showing the activities, costs, and schedule for the Scenario #1 actions are included in the spreadsheet and summarized below:

Summary of Scenario #1 Work Types	2019 Cost per time	Year(s) programmed
Flush deck, joints, railing, pylon	$20K	Annually
Seal Deck Cracks	$100K	5 year cycle
Patch Deck	$100K	5 year cycle
New PPC Overlay	$6.8 Mil	15, 50, 80
Major deck repair	$7 Mil	50
Seal Conc Barriers	$230K	10 year cycle
Repair Concrete Barriers	$200K	20 year cycle
Replace Concrete Barriers	$3 Mil	80
Seal Cracks in Stay Anchor Blocks	$100K	5 year cycle
Seal cracks in pylons	$100K	10 year cycle
Repair spalls on box girders	$300K	15 year cycle
Repair Modular Joints	$500K	15, 25
Replace Modular Joints	$3 Mil	40, 80
Repair Piers at Waterline and spalls	$400K	Avg 30 year
Replace Ornamental Metal Rail	$1.1 Mil	60
Replace Bearings	$2 Mil	60
Rehab Substructures and Pylons	$500K	50, 90
Replace Selected Stay Cables	$10 Mil	80

Estimated Costs for various activities

Original Bid Prices for construction, and estimated replacement costs for some elements. Replacement cost includes a cost for removal of inplace element.

Item	Original Quantity	Unit Bid Price per 8221-01 contract	MnDOT cost history from Avg Bid Prices	Estimated Replacement Unit Cost in 2019 $	Estimated Replacement Cost in 2019 dollars
Ornamental Metal Rail	4,940 lf	$150/lf	$160 - $200/lf	$225/lf	$1,100,000
Concrete Barriers	20,300 lf	$60/lf avg	Remove $65/lf New $70-$140	$160/lf	$3,000,000
Modular Expansion Joints	526 lf	$3,733 avg	Varies based on joint width	$5,600/lf	$3,000,000
Disk Type Bearings	68 each	$16,500 each	Varies $9,000+	$30,000 each	$2,000,000
Stay Cable System	Lump Sum	$10,397,500	N.A.	$10,000,000	$10,000,000
Drainage system	Lump Sum	$1,002,884	N.A.	$1,500,000	$1,500,000
Chip Seal Wearing Course	485,000 sf	$3.00/sf	$5-$6/sf (without mill)	$8.00/sf	$3,880,000
2” low slump concrete OL	485,000 sf	N.A.	$4-$6/sf (without mill)	$8.00/sf	$3,880,000
1” polyester OL (PPC)	485,000	N.A.	$12.00/sf	$14.00/sf	$6,800,000
Milling 3/8” Chip Seal Wearing Course	485,000	N.A.	$2.00/sf	Included in costs above	

Deck Repair Costs – The following table is taken from Preliminary work done by Bridge Office and stored in “*Copy of wc-lifeycle-r3-static.xlsx*” on the S:/Construction/…drive

Description of Work	Estimated Cost	Expected Life	
Mill and Overlay with LS Overlay	$8.50/sf	35 Years	
Seal Cracks in Deck	$750/gal	5 years	
New Epoxy Chip Seal	$6.00/sf	20 years	
Chip seal replenishment	$4.50/sf	10 years	
Mill Novachip, epoxy chip seal or PPC	$1.75/sf to $2.25/sf		
PPC Overlay (polyester)	$12.00/sf	40 years	
Remove and Patch Type D	$35.00/sf	10 to 20 years	
Remove and Patch Type E	$60.00/sf	10 to 20 years	
Remove and Patch Type F	$85.00/sf	10 to 20 years	

Table of Potential Maintenance, Repair and Rehabilitation Items

Item	Type of Work	Frequency	Unit cost (in 2019 $)	Quantity (estimated)	Estimated Cost
Annual Maintenance	Flush expansion joints, wash pylons, barriers and concrete near deck level, clean drainage system	Annually			2 to 5 bridge maintenance crew days
Epoxy Chip Seal Overlay	Seal Cracks and spot repair surface	Every 3 to 5 years	$10/sf	10,000 sf	$100,000
	Replace Overlay with chip seal	Every 10 – 15 years	$8/sf	485,000 sf	$3,880,000
	Replace sidewalk chip seal	Every 25 years	$10/sf	58,000 sf	$580,000
	Replace overlay with 1" polyester OL	At 30 to 40 years	$12/sf	485,000 sf	$5,820,000
Precast Box Girders	Seal cracks in stay anchor blocks and deck	Every 5 years (decrease $)	$4/sf	17,600 sf	$84,480
	Repair deck deterioration, inject segment joints (with OL)	Every 10 – 15 years			$500,000
	Repair deterioration inside and outside of box girder	Every 25 to 30 years			$500,000
	Major deck repair, replace PT, add post tensioning	At 75 to 100 years			$30,000,000
Cast-in-Place Box Girders, CIP diaphragms	Repair deck deterioration, inject cracks in top deck	Every 10 – 15 years			$200,000
	Repair deterioration inside and outside of box girder	Every 20 to 30 years			$200,000
	Major concrete repair, replace PT, add external post tensioning	At 75 to 100 years			$20,000,000
Pylons, Crossbeams, Pier blades	Seal cracks/apply special surface finish especially in roadway splash zones	Every 10 years			$100K for pylons $100K blade
	Repair waterline deterioration on piers	Every 30 to 40 years			$300,000
	Paint interior of steel anchor box	At 60 to 75 years			$1,000,000
	Repair spalls and delamination	Every 20 to 30 years			$100,000 to $400,000

Substructures – Piers and abutments	Clean surfaces adjacent to traffic and reapply surface finish	Every 10 years			$50,000
	Repair delamination and spalls	Every 20 to 30 years			$200,000
Stay Cables	Inspect anchorage zones and check strands on sample stays	Every 15 to 20 years			$200,000
	Replace stay cables	At 50 to 75 years			$10,000,000
Modular Strip Seal Expansion Joints	Replace glands, repair internal components of joints	Every 15 to 20 years	$1,000/lf	526 lf	$500,000
	Replace modular joints	Every 30 to 40 years	$5,600/lf	526 lf	$3,000,000
Disk Bearings	Clean bearings,	Every 5 to 10 years			$50,000
	Replace sliding plates or other components	Every 20 to 25 years	$5,000 ea	68 ea	$340,000
	Replace bearings	Every 50 years	$30,000 ea	68 each	$2,000,000
Drainage system	Repair leaky components	Every 20 years			$300,000
	Replace drainage system	At 50 to 75 years			$1,500,000
Accent, trail, & roadway lighting	Replace bulbs/LED	Every 10 years			$100,000
	Replace fixtures	Every 40 to 50 years			$500,000
Concrete roadway barriers and ornamental metal railings	Clean and seal concrete barriers, seal cracks	Every 10 years	$2.50/sf	84,000 sf	$210,000
	Repaint or re-powder coat metal barriers	Every 20 to 30 years	$30/lf	4,940 lf	$150,000
	Replace concrete barriers	At 60 to 75 years	$150/lf	20,300 lf	$3,000,000
	Replace metal railings	At 60 to 75 years	$225/lf	4,940 lf	$1,100,000

Summary and Draft Recommendations

Br. #'s 82045, 82047, and 82048 are post tensioned concrete box girders that carry 4 lanes of traffic and a pedestrian trail over the St. Croix River. With an initial construction cost of over $430 million it is imperative that MnDOT manage this asset to get the longest possible life by using the most cost effective actions. This Bridge Management Plan considered five scenarios, each with varying levels of maintenance, preservation, and rehabilitation actions. The results show that regular bridge maintenance and preservation work is the most cost effective way to manage this bridge asset.

The spreadsheet "*St Croix Br Management Plan 2019.xlsx*" used to develop this BMP includes estimates of when various maintenance and preservation actions should be taken. Annual maintenance and ongoing preservation projects should be scheduled on a regular frequency. On a bridge like the St. Croix Crossing, it is important to protect the deck surface as the deck cannot be replaced and any significant rehabilitation of the post tensioning will be extremely expensive. One of the actions for Scenario #1 is to replace the existing epoxy chip seal overlay with a more durable Polyester Polymer Concrete (PPC) overlay at year 15 and then on a 30 year cycle thereafter. It is recommended that MnDOT program funds so that maintenance and preservation actions will be able to be taken before extensive deterioration starts to set in.

More detail for assumed actions and timing of the actions for each Scenario can be reviewed in the spreadsheet. Sensitivity analysis performed during development of this BMP show that variability in discount rates and assumed life do impact the overall costs of each scenario, but the relative ranking remains the same.

This BMP is the first attempt to predict life cycle costs of this significant MnDOT asset. It is recommended that this document and spreadsheet be reviewed occasionally and improvements to deterioration and cost models made as appropriate.