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# Hamlet Swing Bridge and Fixed Bridge Replacement

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# 1 INTRODUCTION

Parsons Inc. was retained by Public Works and Government Services Canada (PWGSC) to prepare the detailed design for the replacement of the Hamlet Swing and Fixed Bridges. The Hamlet Swing and Fixed Bridges, owned and operated by Parks Canada Agency (PCA), carries Peninsula Point Road over the historic Trent-Severn Waterway in Hamlet, Ontario. The crossing consists of a 60 m equal arm Swing Span to the west and a 31 m fixed span to the east. The Swing Bridge (Bridge #57) is supported by two through-trusses (Warren trusses), and the Fixed Bridge (Bridge #58) is supported by two through-trusses (Pratt trusses). The Swing Bridge was constructed circa 1915, and the Fixed Bridge was originally built in 1905 for use at another location but was moved to the current location in 1915, and the bridge crossing was finished around 1922 due to World War 1.

This project consists of replacing the Swing Bridge, Fixed Bridge, both abutments, the East River Pier that supports both the Swing Bridge and the Fixed Bridge, Control House, and the rehabilitation of the Swing Bridge Pivot Pier and both Rest Piers. The new roadway profile was raised by 600 mm due to the need to raise the Pivot Pier to avoid flooding of the mechanical equipment.

# 2 STRUCTURAL

## 2.1 Existing Structural Assessment

In recent years the bridges have been subject to multiple load restrictions, and their condition have been deteriorating. Structural inspections of the bridges have been carried out, followed by structural and load-rating.

Based on the visual inspection findings, Non-Destructive Testing (NDT) results, and structural evaluation results, it was found that various components of the existing Swing Bridge had insufficient capacity as per the CAN/CSA-S6-14 Canadian Highway Bridge Design Code (CHBDC), and some components were sub-standard as per the CHBDC requirements. The Fixed Bridge was deemed to be replaced due to the structural condition and functional ratings being inadequate and given the age of the structure which was past its service life. The bridges were previously load posted; however, the load-carrying capacity was further decreased to 3 tons, and an emergency repair of the floor system of the Fixed Bridge was undertaken.

## 2.2 Selection of the Replacement Trusses

Conceptualized bridge design options to replace the existing bridges were undertaken, and a design report was provided with the analysis of the options in terms of time for construction, durability, ease of construction, ease of maintenance, cost, aesthetics and environmental impacts.

### 2.2.1 Swing Bridge Superstructure

The existing superstructure of Hamlet Swing Bridge was replaced with a Warren Truss. To keep the sympathetic look of the existing Swing Bridge, the new Warren Truss includes a double vertical arrangement at the center of the span above the Pivot Pier, similar to the existing bridge, as shown in Figure 2. The existing truss height, width and number of panels were maintained as required by the owner. The new deck clear width is 4.0 m, consisting of a 3.0 m lane and a uniform shoulder width of 0.5 m on both sides throughout the bridge, as shown in section view in Figure 3.

### 2.2.2 Fixed Bridge Superstructure

The superstructure of Hamlet Fixed Bridge was replaced with a Pratt Truss that consists of a total of five (5) panels plus two (2) end panels, similar to the existing bridge, as shown in Figure 2. The new deck clear width matched the new Swing Bridge deck clear width of 4.0 m, consisting of a 3.0 m lane and a uniform shoulder width of 0.5 m on both sides throughout the bridge. The truss height was maintained; however, to increase the vertical clearance from the existing sub-standard clearance, the existing end portal frames and lateral sway bracings were replaced with beams in the replacement Fixed Bridge to maintain the height-to-width ratio of the existing bridges. The existing pinned connections were replaced with conventional connections with bolts and gusset plates to achieve a more durable connection and reflect the design of the current time. The section view of the replacement Fixed Bridge is shown in Figure 3.

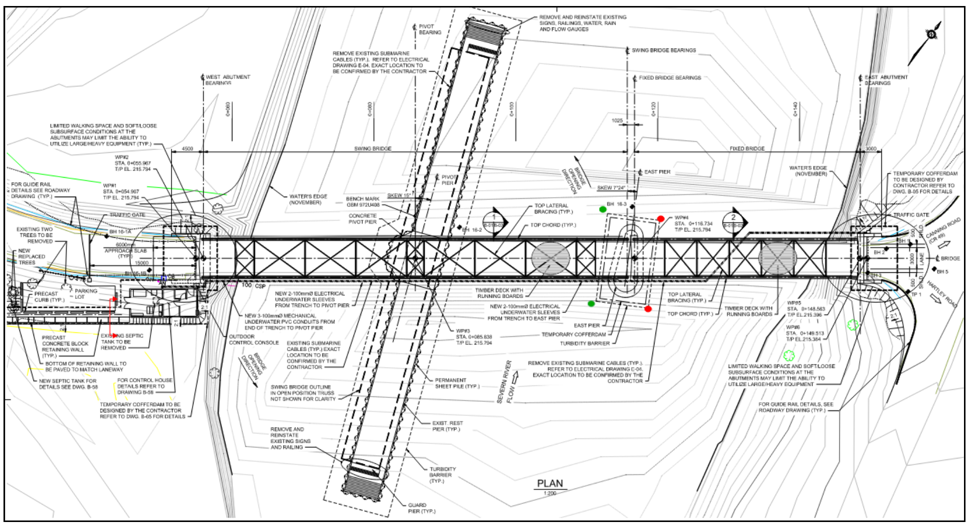


Figure 1: New Hamlet Swing and Fixed Bridges Plan

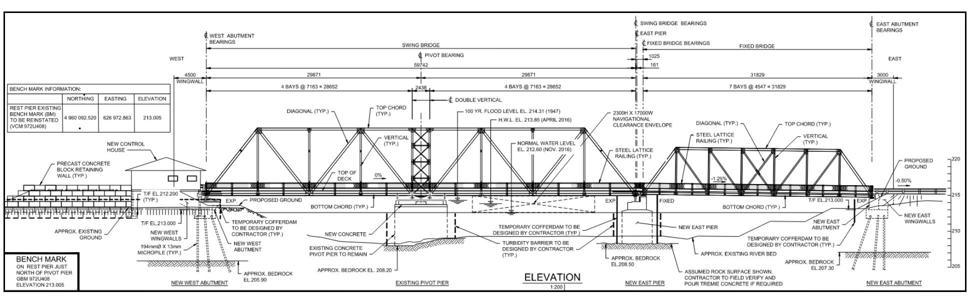


Figure 2: New Hamlet Swing and Fixed Bridges Elevation

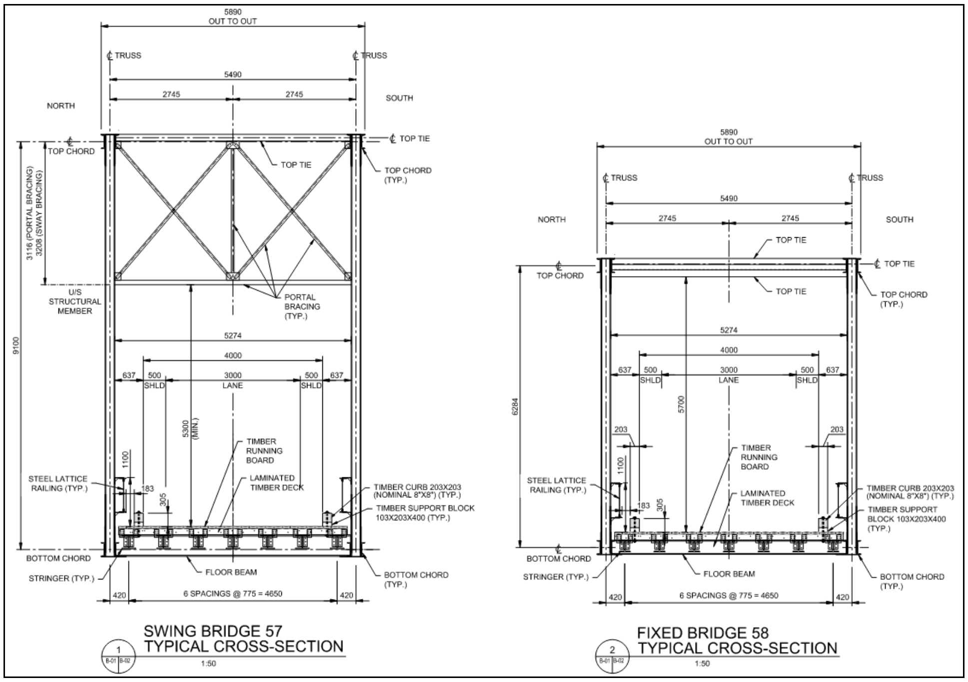


Figure 3: New Hamlet Swing and Fixed Bridges Sections

## 2.3 Functional and Geometric Design

The existing bridge machinery on the Pivot Pier was flooded during each spring, which was detrimental to the service life and operation of these mechanical components. To resolve this issue, a study was performed to determine the height required to mitigate this issue. The proposed profile of the replacement bridge was raised to accommodate raising the Pivot Pier by 600 mm to avoid the 100 years flood level. The raised roadway profile is shown below in Figure 4.

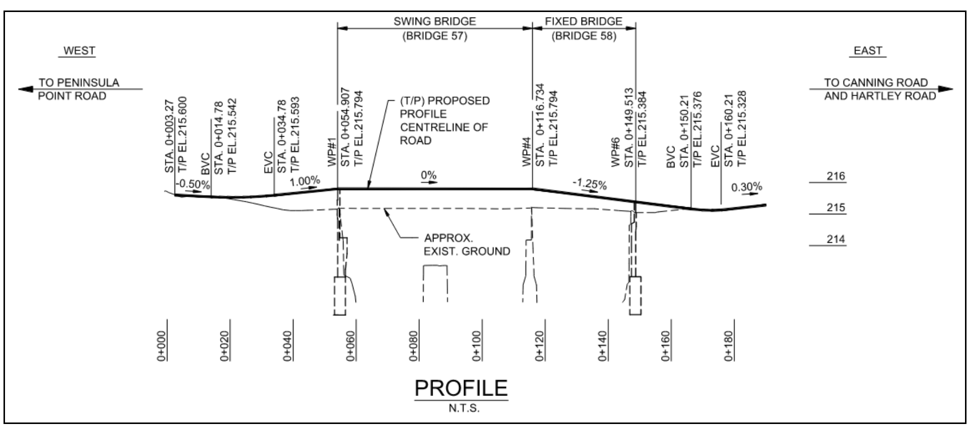


Figure 4: Raised Roadway Profile to Eliminate the Mechanical Machinery Flooding by the 100 Year Flood Level

## 2.4 Substructure Replacement and Rehabilitation

The crossing is at a 15-degree skew angle compared to the river and has a concrete abutment on each shore. On the west side, a 7.3 m wide Pivot Pier supports the bearings on which the Swing Bridge pivots.

The Pivot Pier is flanked by two 4.9m-wide rectangular Rest Piers extending 30.5 m both upstream and downstream from the base. The East River Pier supports both the Swing Bridge when it is in a closed position and one end of the Fixed Bridge. This East River Pier measures approximately 10 m long and has semi-circular ends, with a 5.1 m diameter on the upstream end and a 3.5 m diameter on the downstream end.

For the replacement of the East River Pier and abutments, temporary cofferdams were planned to be used around the substructure to provide dry working conditions. The cofferdams were placed between 1 and 2 m away from the footing's base, thus increasing the pier and abutment width by this amount on each side and therefore decreasing the river's flow area. Because there are several recreational properties along the shore of the Severn River, and historically these properties have seen high water levels, the impact of restricting the channel was assessed by conducting a hydrology and hydraulic study, a bathymetric and land survey. The temporary cofferdams used during construction and the permanent sheet piling system (used to strengthen the Pivot Pier and Rest Piers) only caused an increase in the water level upstream of the bridge of approximately 20mm relative to the existing conditions. This increase was considered negligible and did not have a negative impact on the potential flooding of upstream properties. To significantly minimize the possibility that the river flow will overtop the cofferdams during construction, the designed drawings required that the cofferdams be designed and constructed to 1 m above the 1947 flood level of 214.3 m.

### 2.4.1 Abutments Replacement

The existing East and West Abutments consisted of shallow spread footings founded within the overburden. The geotechnical resistance at the abutment was very low, which is consistent with the movement observed at these locations over the years. Given the limited working space at the East Abutment, the soft/loose subsurface conditions at this location which may limit the ability to utilize large/heavy pile driving equipment, and the general requirement to minimize vibrations and disturbance to the existing bridge and nearby buildings, the use of drilled and grouted micropiles embedded 3 m into sound bedrock was utilized successfully as shown in Figure 5. The micropiles were designed to American Association of State Highway and Transportation Officials (AASHTO), 2017; and, Federal Highway Administration (FHWA), 2005.

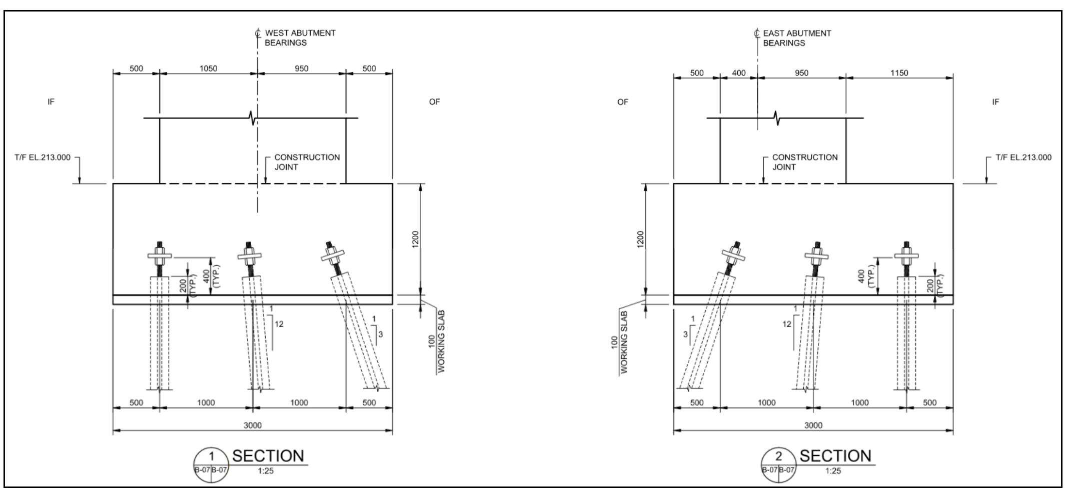


Figure 5: Abutments founded on Micropiles

### 2.4.2 East River Pier Replacement

The existing bridge East River Pier's concrete compressive strength was poor, and this pier was rehabilitated multiple times in the past. The existing East River Pier was replaced with a pier visually sympathetic to the existing (Figure 6); the new pier was founded on bedrock (See Figure 6) and designed to resist a 28 tons vessel collision load.

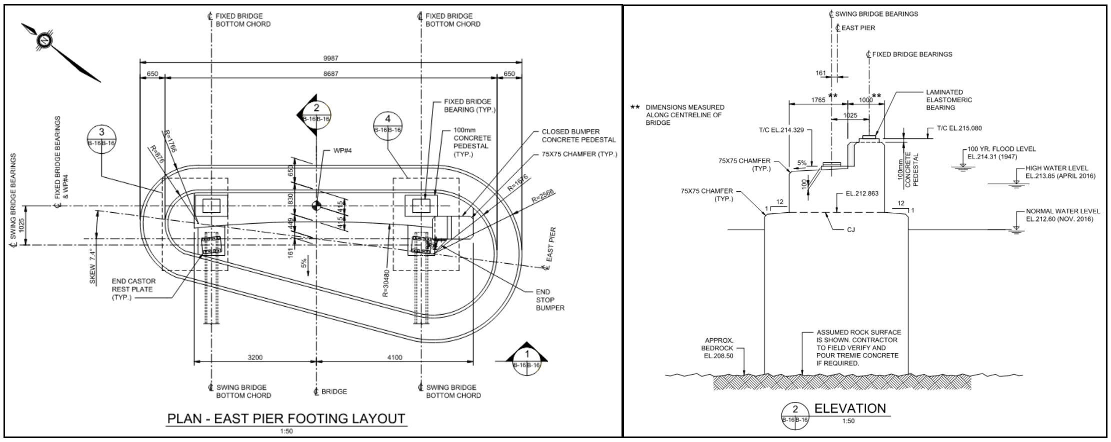


Figure 6: East River Pier Plan and Section

### 2.4.3 Rehabilitation of the Rest Piers and Pivot Pier

The existing Pivot Pier was founded on sound bedrock, and the existing concrete compressive strength was good; however, this pier required refacing. In addition to the concrete refacing (Figure 7), the Pivot Pier was also raised by approximately 600 mm to avoid flooding and deterioration of the mechanical components on top of the pier. The Pivot Pier was retrofitted with a permanent sheet piling system with a rock bolt (Arcelor Mittal Sheet Piling 2018) anchored into sound bedrock for strengthening. Tremie concrete was placed between the sheet piles and the Pivot Pier, and the Rest Piers, as shown in Figure 7.

The existing Rest Piers were constructed on timber cribbing filled with rock, with precast concrete blocks located above and topped with mass concrete extended the full length of the pier. An underwater inspection revealed that the timber cribbing exhibits signs of deterioration. For this reason, it was recommended that the Rest Piers be strengthened by installing sheet piles around the circumference of the Rest Piers (Figure 8), using ties that hold together the east and west walls and tying with tiebacks and using deadman anchors at the north and south faces. In addition, new sheet piles wall with rock bolts embedded into sound bedrock were designed to Arcelor Mittal Sheet Piling 2018 and rock berm were provided at the toe of the sheet piles on the riverbed (Figure 8). The Rest Piers' top elevation was raised by approximately 300 mm with a reinforced structural slab, and its width was increased by roughly 500 mm on each side. The sediment trapped between the sheet piles and the Rest Piers was removed by hydro-vac before the tremie concrete placement.

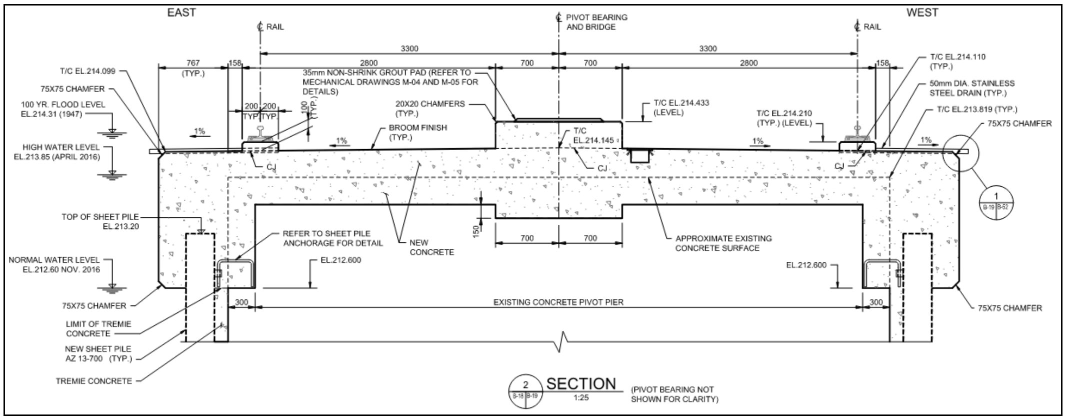


Figure 7: Pivot Pier Rehabilitation and Retrofitting with Sheet Piles Similar to the Rest Piers

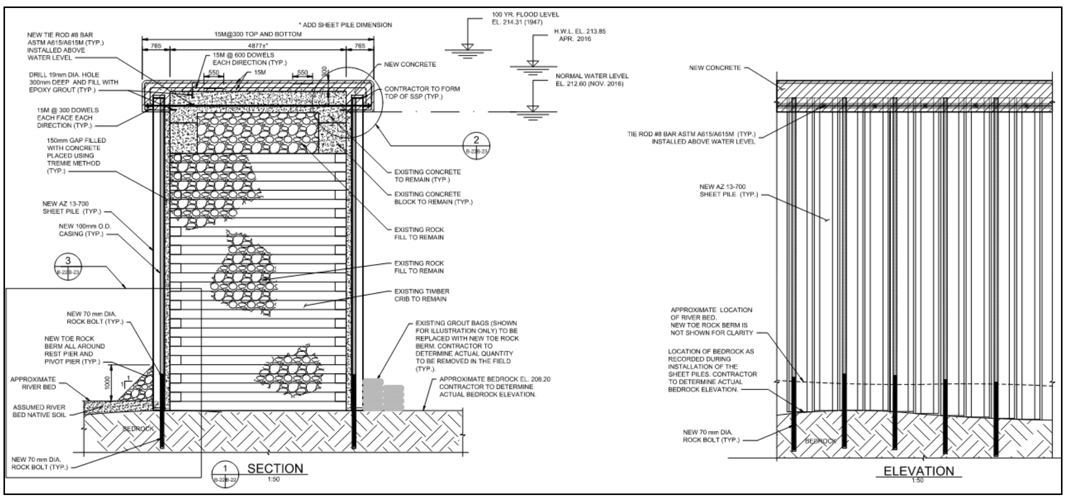


Figure 8: Rest Piers Rehabilitation and Retrofitting with Sheet Piles

# 3 MECHANICAL

## 3.1 Existing and New Machinery Configurations

The existing Hamlet Swing Span had active and passive machinery systems. The active systems included two Hydraulic Cylinders to rotate the Swing Span, two End Lift Cylinders at the West Abutment only and one Locking Pin at the West Abutment. The passive systems included the Center Pivot Bearing, Balance Wheels and Track, End Castors at the East River Pier and End of Travel Bumpers.

The machinery for the replacement Swing Span includes new replacements for all of the machinery components and systems used for the existing bridge and adds Live Load Rollers at the Pivot Pier. All new machinery was designed based on the CAN/CSA-S6-14 Canadian Highway Bridge Design Code for greater loads than the existing machinery. At the beginning of the project, rehabilitation of the Swing Span was being considered, and ultimately, the replacement of the superstructure was selected.

## 3.2 Swing Span Operation Sequence

When the Swing Span is to be opened for waterway traffic, the highway traffic is signaled to stop with traffic signals and then warning gates are lowered. Using power from the HPU, the End Lifts are lowered when commanded by the operator. When the operator commands the span to open, the Locking Pin is retracted hydraulically, and the Swing Span is opened using the Span Drive Hydraulic Cylinders. As the Swing Span approaches the fully open position, the nearly open limit switch is tripped, and the Swing Span is decelerated to creep speed, and the span contacts the fully open end of travel bumper at the south end of the Rest Pier (fender) and trips the fully open limit switch. After the waterway traffic has passed the bridge, the Swing Span may be commanded to close by the operator and is rotated towards the closed position by retracting the Span Drive Hydraulic Cylinders. As the Swing Span approaches the fully closed position, the nearly closed limit switch is tripped, the Swing Span is decelerated to creep speed and contacts the fully closed End of Travel Bumpers at the West Abutment, and the East River Pier as the fully closed limit switch is tripped. The Locking Pin is extended with spring force and relief of the hydraulic pressure keeping it retracted. The End Lifts are commanded by the operator to raise, and the End Lift Cylinders are retracted raising the End Lifts and the west end of the swing span. The warning gates are raised, and the traffic signals allow traffic to proceed.

## 3.3 Swing Span Support Conditions

### 3.3.1 Reactions

The Center Pivot Bearing supports the entire dead load of the Swing Span minus the small imbalance when the End Lifts are retracted. When the End Lifts are extended, a reaction equal to the End Lift reactions is created on the castors at the east end. The end reactions are sufficient to maintain a positive reaction of at least 1.5 times the reaction necessary to prevent uplift.

The magnitudes of the live load reactions are related to the location of live load on the swing span, similar other two-span continuous truss spans. Live load is transmitted to the West Abutment through the End Lifts and to the East Pier through the End Castors. The live load is transmitted to the Pivot Pier using the two Live Load Rollers and the Center Pivot Bearing. The Balance Wheels are not in contract with the Track when the End Lifts are extended, and the span is lifted and no dead or live load is transmitted through them.

### 3.3.2 Balance

The symmetrical Swing Span is not balanced symmetrically. Steel plates have been fastened to the floor beams at the west end of the Swing Span to compensate for the weight of the End Castors at the east end and to cause the west end to be heavier than the east end. This causes the span to tilt west end low as the End Lifts are lowered. The desired effect of this is to cause the east end to rise, eliminating the reaction there and creating clearance between the castors and their rest plates at the east end to allow the span to swing.

## 3.4 Hydraulic System

The hydraulic system for the Hamlet Swing Span is an open-loop system using a pair of 30 HP electric motors that operate alternately, each driving a horsepower-limiting pump. The speed of the Swing Span is controlled with proportional valves. The Locking Pin and the End Lifts are commanded with directional valves, and the speed is adjusted with flow controls. The End Lifts are synchronized during raising and lowering with a gear type flow divider. The motors, pumps, reservoir, accumulator and control valves make up the HPU. The HPU is located on the main level of the Control House and is connected to the Hydraulic Cylinders using stainless steel tubing and rubber hoses. The connection to the Span Drive Cylinders required that hydraulic conductors run from the Control House to the Pivot Pier. Three hydraulic lines (pressure, return and tank) run underwater to the Span Drive Cylinder on the Pivot Pier. All Hydraulic Cylinders on the bridge are arranged to be fully retracted and under no load when the Swing Span is in the closed position and open to highway traffic.

Locating the HPU in the Control House is enabled by locating the End Lifts at the West Abutment only. Mounting the HPU outside on the Swing Span was undesirable but would have lent itself to having End Lifts at both ends of the swing span. Locating the HPU on the Rest Pier (fender) would have required five (5) festoon hydraulic hoses between the Swing Span and the Pivot Pier to operate the Locking Pin and End Lifts.

## 3.5 Machinery at the Pivot Pier

The center pivot bearing has a spherical concave stainless-steel lower disc and a spherical convex bronze upper disc with self-lubricating disc inserts. A spherical roller thrust bearing was considered but not selected because the span tilts while not rotating when the End Lifts raise and lower. The bearing may also be lubricated with compatible grease and is provided with a grease fitting. The spherical surfaces are self-aligning and allow the span to tilt and equalize the loads across the bearing.

Two Span Drive Cylinders (Figure 9) located under the bridge are used to rotate the Swing Span 75 degrees to the open position due to the skew angle of 15 degrees between the roadway and the river. Both cylinders extend to rotate the Swing Span in the counterclockwise direction to open the navigation channel. Retracting the cylinders causes clockwise rotation and returns the span to the closed position to carry highway traffic over the river. The cylinders are parallel to each other, and therefore the reactions cancel, and the net force on the Swing Span is zero. Each of the Span Drive Cylinders is mounted in a cardanic ring located at the approximate average center of gravity of the cylinder. The cardanic ring has a pair of vertical axis bearings and a pair of horizontal axis bearings. These bearings are bronze sleeve bushings with self-lubricating inserts and ride on stainless steel pins. The cardanic ring is equivalent to a universal joint and allows the cylinder to tilt on a horizontal axis and turn about a vertical axis. It does not allow twisting about the cylinder axis, which a spherical bearing would. The cardanic ring has one less degree of freedom than the spherical bearing, which is desirable, but the key advantage is supporting the cylinder at the approximate average center of gravity when extended, reducing the bending moment due to gravity when the cylinder rod is extended. The cylinder rod end connects to the Swing Span with a spherical bearing and a clevis type bracket mounted to the underside of the Pivot Girder.

The Pivot Pier mounted Live Load Rollers are passive and contact load plates attached to the bottom of the Pivot Girder only when the Swing Span is closed. As the span rotates to the fully closed position, the beveled edges of the load plates contact the roller and ride up the roller if required, leveling the Swing Span transversely. The live load on the Swing Span is transmitted to the Pivot Pier mainly through these rollers.

There are eight Balance Wheels mounted in clevis style brackets connected to the underside of the Swing Span superstructure. The wheels have bronze sleeve bushings with self-lubricating discs in their bores and ride on stationary clevis pins. The Balance Wheels contact the Track on the heavier (west) arm of the Swing Span to limit the tilt. The Balance Wheels should generally not be in contact with the Track when the End Lifts are supporting the Swing Span.

The Steel Balance Wheel Track is made from ASCE rail, 39.7 kg/m (80 pounds per yard). It is circular and able to resist vertical loads from the Balance Wheels at any angular position. There are three gaps in the rail to allow for thermal expansion of the rail. The single rail is supported at 24 locations with steel support plates on short concrete plinths.

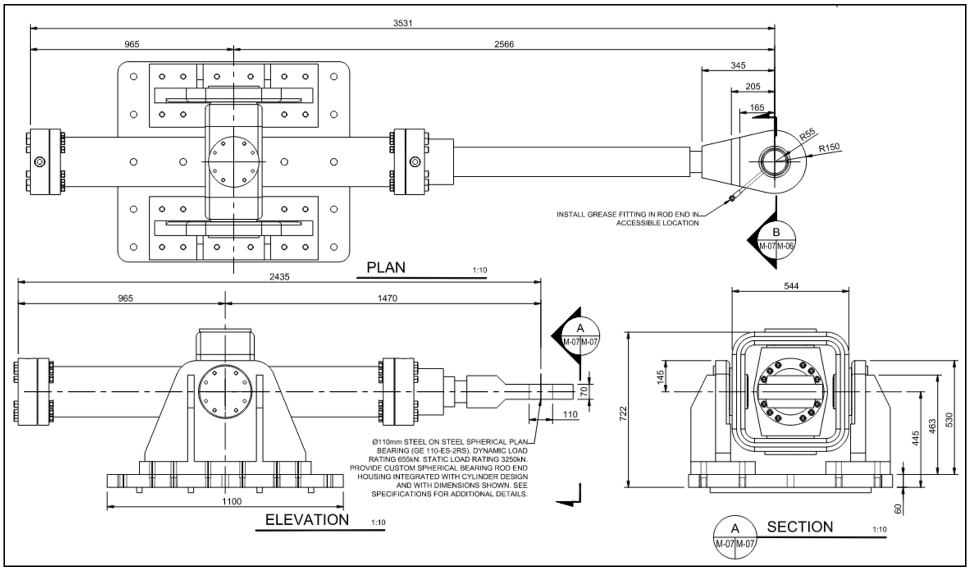


Figure 9: Span Drive Cylinders Plan, Elevation and Section

## 3.6 Machinery at the West Abutment

One Locking Pin is located at the southwest corner of the swing span. The Locking Pin is mounted to a steel support connected to the West Abutment with anchor bolts. The Locking Pin is pushed by a spring to extend and retracted with Hydraulic Cylinder pressure. The Locking Pin contacts a strike plate mounted to the underside of the bottom chord of the Swing Span south truss. The Locking Pin holds the Swing Span in the closed position while the End Lifts are raised or lowered.

There are two hydraulically actuated End Lifts mounted to the West Abutment under the trusses. The western end of each truss is lifted by a roller on the eccentric lobe of an eccentric shaft. The eccentric shafts are within rollers that roll against load plates under the gusset plates that connect the floor beam with the trusses. The eccentric shafts are rotated by hydraulic cylinders to raise and lower the trusses. The cylinder rod ends are connected to crank arms on the ends of the eccentric shafts. The linear motion of the cylinder as it extends or retracts is converted to a rotational motion of the eccentric shaft by the crank arm. The Hydraulic Cylinder retracts, rotating the eccentric shafts to the raised position. In the raised position, the End Lift Roller is over-center and in contact with a rest plate that prevents further rotation and supports the span. No force or hydraulic pressure in the cylinder is required to keep the End Lift in the raised position. As the End Lifts raise the west end of the span, the east end lowers until the End Castors are in contact with the rest plates. Further raising of the End Lifts creates a dead load reaction at the western ends of the trusses and superimposes the same reaction at the eastern ends of the trusses.

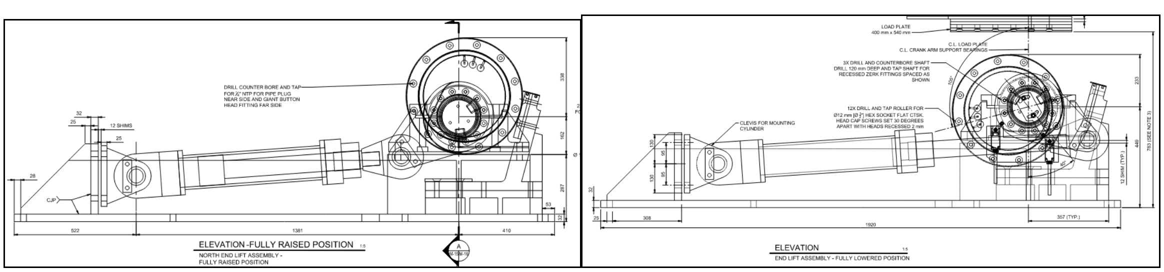


Figure 10: End Lifts Fully Raised and Fully Lowered Position

### 3.7 Machinery at the East River Pier

Two End Castors are mounted to the east end of the Swing Span under the gusset plates that connect the trusses to the end floor beam. As the span swings open or closed, the Castors can roll down or up the ramps at the rest plates on the East River Pier. The span balance is intended to be west end span heavy, decreasing the likelihood of the East End Castors contacting their rest plates while the End Lifts and the west end of the span are lowered.

### 3.8 End of Travel Bumpers

There are two End of Travel Bumpers in the span closed position and one in the span open position. The bumpers are mounted to the East River Pier and West Abutment and the south end of the Rest Pier (fender). The end stops consist of D shape rubber shock absorbing bumpers bolted to steel supports, which are connected to the substructure with anchor bolts. There are strike plates mounted to the corners of the Swing Span aligned with the End Stop Bumpers.

# 4 ELECTRICAL

During the design phase, various options for the electrical systems associated with the bridge were considered, and discussions were held with Parks Canada regarding their preferences, standardization of the electrical systems of all their bridges and the historical characteristics of the existing Hamlet Swing Bridge. The conclusion was that the overall design philosophy for replacing the electrical systems should be similar to the existing systems on other Parks Canada bridges with enhancements and up-to-date technology. A new 575 V three phase electrical service was installed, and the semi-automatic sequence control is provided by a Programable Logic Controller (PLC). The operators control console layout incorporates a similar flow and nomenclature as the other swing bridges in the system. The control system uses semi-automatic sequence control except that the Locking Pin and Swing Span are automatically sequenced to operate together. The traffic control design incorporated replacement warning gates, traffic signals, radar vehicle sensors and the lessons learned from operating and maintaining the existing Hamlet Bridge and other bridges on the Historical Trent Severn Waterway.

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