STRUCTURE SELECTION REPORT
for the
WATER STREET BRIDGE REPLACEMENT
ITEM NO. 3-1092

January 2018

Prepared For:

KENTUCKY TRANSPORTATION CABINET

Division of Maintenance
Bridge Preservation Branch
Frankfort, KY 40622

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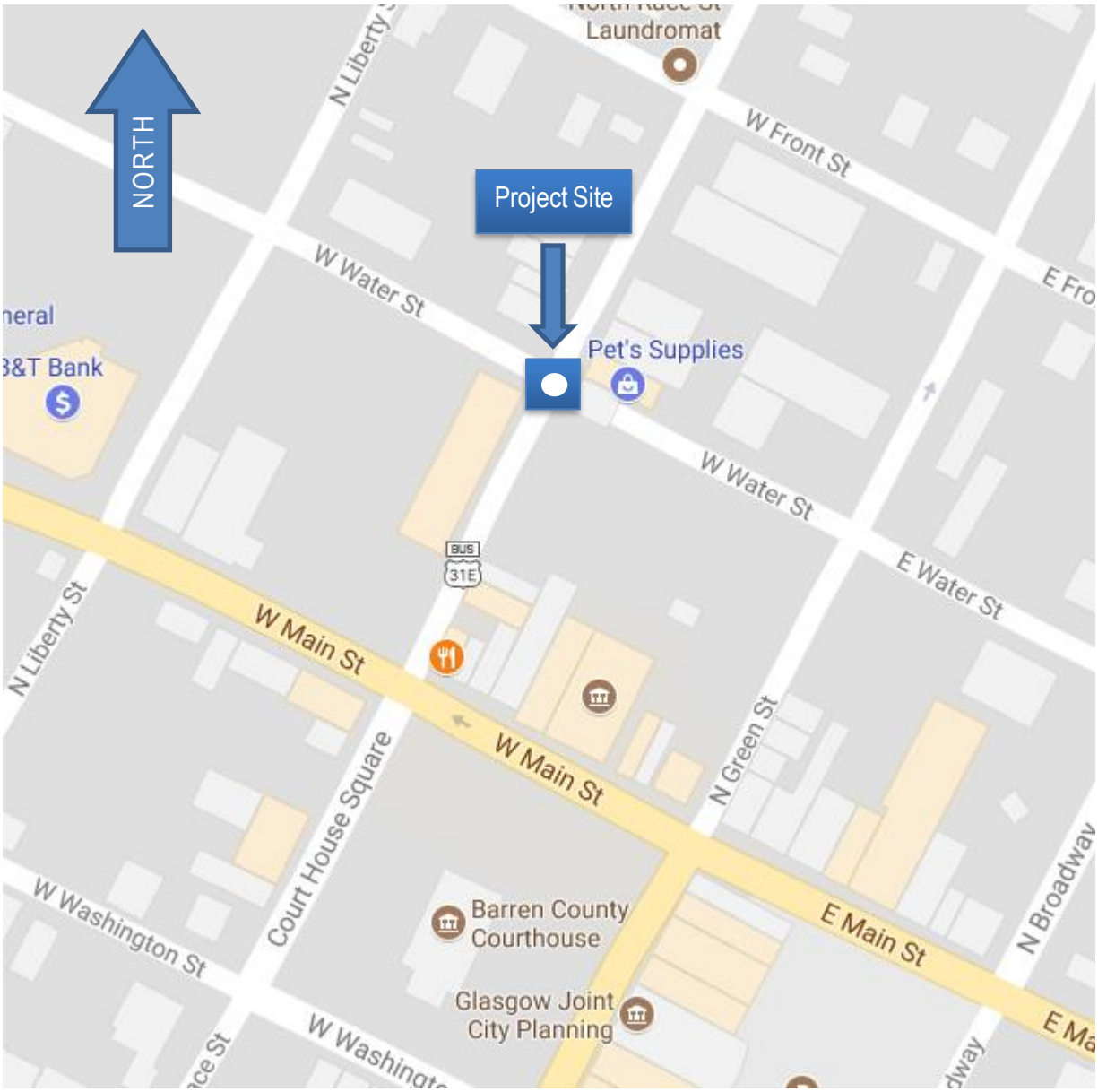
Section 1: Introduction and Purpose

Heavy deterioration of the Water Street Bridge (005B00058N) in Glasgow, Kentucky caused concern for local officials interested in preserving a local landmark. Michael Baker International (Michael Baker) was selected to conduct a special in-depth inspection and data gathering of the masonry stone arch to assess the cause(s) of deterioration, and evaluate the current load carrying capacity. The findings of this inspection, including the non-destructive testing evaluation, can be found in the special inspection report dated May 18, 2016.

It was determined the structure has deteriorated to the point of requiring replacement. The bridge was also posted at 15-tons based on a load rating analysis. Based on the findings with the existing structure, the Kentucky Transportation Cabinet (KYTC) and City of Glasgow (City) intend to provide a new structure that reduces the maintenance needs for this crossing, adequately carries local traffic demands, improves vertical clearance along Water Street and provides elements that complement the original structure aesthetics. To determine the appropriate structure type, a structure selection study was performed. Through this study, a suite of structure type alternatives and configurations were developed. Selected concepts were carried forward and refined through the structure selection process.

The purpose of this report is to document the structure selection process and provide a recommendation for the preferred bridge replacement structure type. This report documents the conceptual structural layout assessment for roadway, utility, and clearance considerations to determine the preferred structure layout alternatives, define potential structure types, and summarize the analytical structure type comparison based on factors such as functionality, cost, and aesthetic preferences.



Map provided by Google Maps

Figure 1-1: Project Vicinity Map

Section 2: Existing Conditions

The existing roadways and bridge over Water Street are described below.

Map provided by Google Maps

Figure 2-1: Aerial View Showing Bridge Site over Water Street

2.1 Existing Roadway

US 31EX (Race Street) runs primarily in a north-south direction past the Barren County Courthouse in the downtown Glasgow district. The existing roadway is 28 feet wide with two 10-foot lanes and an 8-foot shoulder for parking along the east side of roadway. Sidewalks ranging from 6 to 10 feet wide run along each side of roadway.

Water Street is a local roadway running underneath US 31EX. It serves the community and businesses as an east-west urban local thoroughfare. The existing roadway is 23 feet wide consisting of two 10-foot lanes and a 3-foot center wall under US 31EX. A 10-foot by 3.5-foot concrete box runs underneath the westbound lane of Water Street. The top of the concrete box serves as the riding surface. It carries a minimal average daily traffic given the dimensional restrictions of the original bridge

The roadway geometrics used during this study were from KYTC Item 3-1059.

2.2 Existing Bridge

The Water Street Bridge is embraced by the local community and considered a local feature to the City of Glasgow contributing to the historic district designation. The two-span masonry arch is comprised of 10-foot spans with a posted vertical clearance of 7 feet. The masonry arch is suspected to be originally constructed with Bowling Green Limestone and lime-based mortar in 1914. The arch was repaired in the 1980's for stone deterioration. Water Street contains a 10-foot by 3.5-foot concrete box flowing underneath Barrel 2 of the arch. The arches are comprised of four base stone courses below the spring line, and smaller arch ring stone courses above the spring line. The US 31EX roadway slopes across the structure at approximately 1.5% and contains an average aggregate subgrade depth of thirty-six inches.

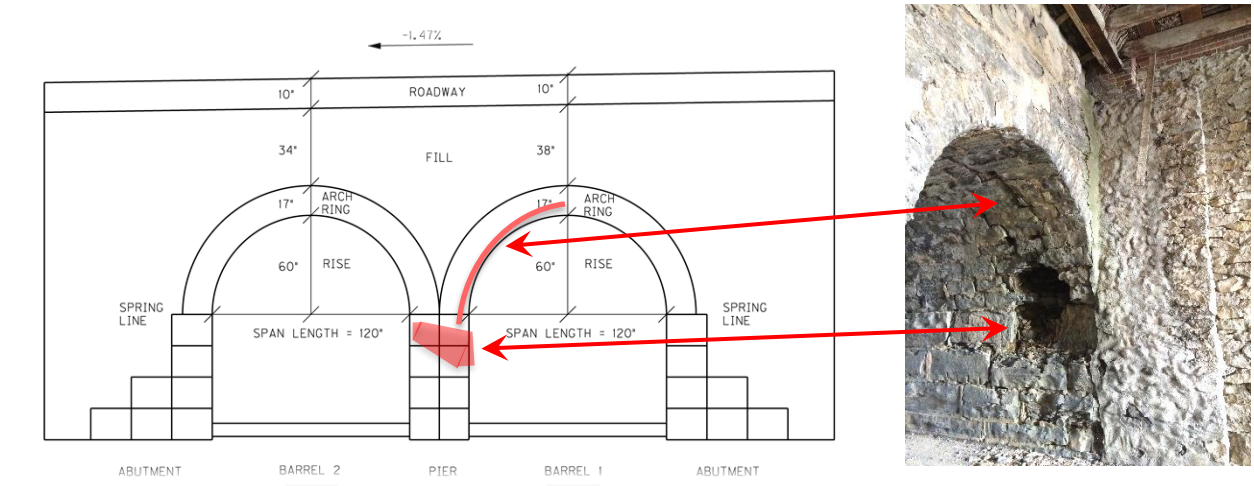


Figure 2-2: Typical West Elevation of the Two-Barrel Bridge with Hole and Arch Ring Cracking

A special arm's length inspection was performed to evaluate localized deterioration at the hole location, evaluate the widespread deterioration across the whole structure to perform a load rating analysis, and assess the current overall condition of the bridge. The hole size is defined as four feet by four feet area with 100% section loss of stones extending through the middle pier. Geometric properties were also determined, as exhibited in Figure 2-2, by utilizing advanced testing techniques as provided by the Kentucky Transportation Center (KTC). The significant deterioration of the hole and arch ring cracking location is located near the east end of the structure by the building wall interface. The bridge was posted for 15 tons following the load rating analysis and received an overall "poor" condition rating based on the inspection findings.

Safety of pedestrians and vehicular traffic from falling debris onto Water Street was a priority. To prevent possible injury or damage, KYTC closed Water Street at the bridge in 2015. Emergency repairs were completed in February 2017 by KYTC District 3 to prevent a potential local collapse at the hole.

Figure 2-3: West Face of Closed Structure (Top Left); East Face Barrel 2 (Top Right); East Face and Building Walls (Bottom Left); US 31 EX Roadway on Top of Structure (Bottom Right)

2.3 Existing Utilities

There are utilities within the vicinity of the project that will be, or have the potential to be, affected during construction. The following list shows the understanding of area utilities to be considered during final design:

- Overhead electrical lines along US 31EX and Water Street:
  - Contact: David Harrison — Office: 270-659-3506
    Electric Plant Board – Glasgow — Mobile: 270-404-1128
  - Correspondence states that minimal cost is expected to shield the electrical service lines to the Heritage Center.
- 8-inch water pipe line along US 31EX:
  - Contact: Clint Harbison — Office: 270-651-3727
    Glasgow Water Company — Mobile: 270-590-6854
  - Contact: Scott Young — Office: 270-651-3727
    Glasgow Water Company
  - Discussions with Glasgow Water indicate it is preferable to cut and cap and abandon the section of 8-inch water main that is currently running over top of the tunnels. It is not desirable to suspend/hang the line under or adjacent to a structure to avoid a maintenance issue with a suspended/hanging insulated water main. Therefore, it is preferable to tap into the existing 12-inch water main off Water Street. It was stated a flow analysis will need to be performed to determine the best approach at rerouting/taping into existing lines to sufficiently provide service to their existing customers with minimal disruption and no long-term reduction in volume or pressure.
- Gas lines along Water Street and underneath barrel 1:
  - Contact: Ryne White, P.E., Engineer 3 — Office: 270-685-8140
    Atmos Energy Corporation — Mobile: 270-929-1706
    Kentucky/Mid-States Division — ryne.white@atmosenergy.com
    www.atmosenergy.com
  - Contact: Brett Lowe – No information
  - Correspondence with Atmos Energy indicate the section of gas line in question was recently replaced with plastic/poly pipe, and would not have to be removed/replaced/modified, unless it came into physical conflict with the final design.
- Drainage structures from US 31EX roadway and 10-ft x 3.5-ft concrete storm box underneath Water Street in barrel 2:
  - Contact: Kurt Frey — Office: 270-651-5977
    Glasgow Public Works — kurt@glasgow-ky.com
  - There are no issues with changing drainage as long as the system calculates to hold volume.
  - No plans or additional information is available for the concrete box culvert under barrel 2.

The above utility information is subject to change. The designer will be responsible for coordinating with utility companies for relocation or removal during final design. The contractor will be responsible for contacting utility companies for construction activities.

Section 3: Project Goals for Bridge Replacement

An inspection was performed to assess the deterioration of the masonry stone arches and the effect on rehabilitation versus replacement of the structure. Decisions towards rehabilitation versus replacement are affected by the holistic structure condition understood by the load analysis results and if future mitigation of the deterioration can be achieved. After careful consideration of the results, and considering the long-term viability of the structure it was been determined that replacement of the structure was required.

There are four primary project goals identified for replacement of the original structure. The reason for identifying these goals in this report is due to each solution having a direct impact on the structure selection process. The project goals are:

- Provide a structure complementing the original structure aesthetics
- Minimize impacts to adjacent buildings during construction
- Coordinate utility relocation
- Accommodate public access above and below structure for motorists and pedestrians

3.1 Provide a Structure Complementing with the Original Structure Aesthetics

The driving force behind this project is to increase safety for all users of US 31EX and Water Street and reduce ongoing maintenance needs required for the original structure. However, it is understood the original structure holds historical and aesthetic significance to the downtown district. The original structure uses an arch form. The arch is still used in modern day structure design and can be incorporated into this structure replacement. In addition to the arch form, there are several aesthetic options that can be used to simulate the original stone aesthetics and historical significance.

The historical significance of the structure is recognized though architectural treatments as shown in section 4. Consideration of the historic limestone, surrounding brick building façades, and a railing consistent with the design aesthetic should be integrated. This can be achieved through cut stone veneer, or a form liner with a selected pattern. Cost will be a strong consideration between stone veneer and form liner. Although more consistent with the existing structure, cut stone can be upwards of three to five times more expensive. Form liner can be modeled to resemble cut stones or brick façades and subsequently stained to desired color schemes. Aesthetics and costs will be balanced when considering each alternative and the final preferred alternative. It is also possible for some of the original stone to be incorporated into non-structural design elements of the new structure. The new structure will be designed and constructed in accordance with current specifications and regulations, with a design-life of 75 years.

The aesthetics shown in this report are for conceptual development and costing purposes. The final aesthetic treatments for the structures façade, railings, lighting, etc. will be determined during the final design process.

3.2 Minimize Impacts to Adjacent Buildings during Construction

Due to the proximity of neighboring buildings to the project site, careful consideration must be taken to minimize impacts during construction. This may include hand tooling when working near the buildings, and installing micropiles or spread footing foundations for the new structure to reduce the impacts of vibrations on nearby structures. The building, shown in the picture to the right, was built during the 1920s and all visual indications show the building walls abutting the current arch walls (built 1914) and are not tied together. Pre- and post-evaluation of the adjacent structure are recommended to determine if any damage occurs during construction activities. Temporary shoring of the building spanning Water Street can also be used to minimize construction impacts.

3.3 Coordinate Utility Relocation

Multiple utilities have been identified in section 2.3 above and some will require relocation. During the design stage, the goal will be to minimize conflicts during construction and provide proactive coordination between the District and local utilities to minimize disruptions during the construction stage.

3.4 Accommodate Public Access Above and Below the Structure

The structure concepts can accommodate pedestrian access below the structure along Water Street and access above the structure along US 31EX. The span lengths investigated can accommodate two 10-foot traffic lanes and a 5-foot sidewalk along Water Street. The sidewalk narrows to avoid columns of the existing building over Water Street. Typical sections for the different span lengths can be seen in section 4 below.

US 31EX is accessed by the public either with vehicles or pedestrians and is an important connection into downtown Glasgow, including access to the Barren County Courthouse and City Hall. The sidewalks above the structure along US 31EX can accommodate a mixed use for pedestrians and cyclists. The railing above the structure will require a design commensurate with a minimum Test Level 2 (TL-2) crash rating and railings with adequate geometry for bicycles and pedestrian standards.

The proposed US 31EX roadway will match the existing roadway section at 28 feet wide gutter line to gutter line consisting of two 10-foot lanes and an 8-foot shoulder for parking along the east side of roadway. Sidewalks ranging from 6-feet along the east side to 10-feet wide along the west side of roadway.

Section 4: Structure Replacement Concepts

Several structure replacement concepts and aesthetic elements were developed. Aesthetic elements are presented for reference and costing purposes only. Project aesthetics will be decided during the final design phase. Four structure replacement concepts were presented and explored by community stakeholders, KYTC, and Michael Baker. This section documents the decisions leading towards the selected structure replacement concept.

4.1 Aesthetic Considerations

Several aesthetic alternatives were presented and provided for consideration closely matching original aesthetics exhibited in Figure 4-1. Aesthetic options presented to the City and considered for preliminary design are exhibited below in Figure 4-2. In the single span options, it is preferred to leave a portion of the existing middle wall as a physical divider of the traffic lanes and pay aesthetic homage to the original structure. Varying arch façades may be applied to the spandrel hide walls (top right, bottom left). Span options such as single and two span configurations should be considered as part of the aesthetic treatment as each has a unique feel and impact on features such as lighting and clearance. KYTC established basic aesthetic criteria to include in the base structure concept and fully funded by KYTC. These include the following architectural and functional treatments:

- Smooth concrete columns and arch façade (see top left and right pictures in Figure 4-3 for concrete arch), or freestanding aesthetic arch
- Stone or brick form liner in the spandrel wall area as shown in the top right picture in Figure 4-3 and basic staining of the form liner to match the surrounding aesthetic. Technique can also be applied to the cast-in-place (CIP) pedestal walls.
- Black or plain steel railing meeting a minimum crash Test Level 2 for vehicles and pedestrians
- Sidewalks on top and below the structure for mixed pedestrian and bicycle access
- Roadside and safety features consistent with current design standards (e.g. sidewalk, basic lighting, curbs, etc.)

Additional treatments may be considered during final design. The City will be given the opportunity to participate in selection of treatments which may result in additional costs compared against the basic treatments. Examples include:

• Architectural railings	• Pilasters and rustications	• Reuse of original stones
• Cut stone veneer	• Ornamental lighting	

Input from the City will be sought on the use of smooth concrete, form liners, or cut stone veneer finishes applied to exposed faces. Form liners are utilized to mold concrete into various shapes emulating genuine material for an economical solution.

It was also recommended by community stakeholders to create a repository of the original stone for future applications.

Figure 4-1: Original Bridge and Stone Aesthetic

Shown in Figure 4-2 are various span configurations with a form liner headwall. Original renderings were developed with a brick form liner finish for the spandrel wall adjacent to smooth grey concrete finishes for the columns and arches to match the surrounding architectural components. However, this can be modified to match aesthetic treatments desired by the stakeholders. See Figure 4-3 and 4-4 for additional examples.

Precast Concrete Box Beams

Single Precast Concrete Arch

Twin Precast Concrete Arch

Rolled Steel Beams

Figure 4-2: Aesthetic and Structural Span Concepts

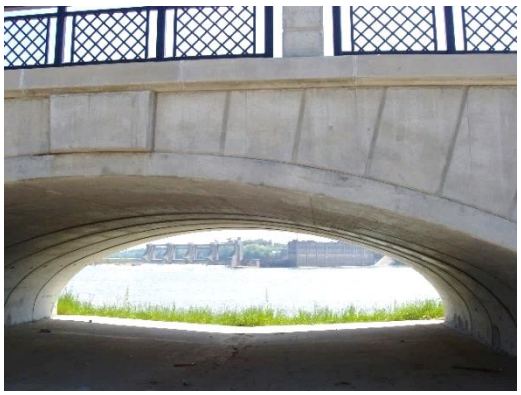
Stained Brick Form Liner Spandrel with Combo Railing, Smooth Concrete Arch and Trim

Stained Brick Form Liner Spandrel with Masonry Railing, Smooth Concrete Arch and Trim

Stone Form Liner with Steel Pedestrian and Concrete Vehicular Railing

Stone Veneer with Steel Pedestrian Railing and Concrete Pedestals

Stone Form Liner with Steel Pedestrian Railing and Concrete Pedestals



Stone Form Liner on Precast Headwall with Steel Pedestrian Railing and Concrete Pedestals

Figure 4-3: Façade Aesthetic Options

Multi-Stained Cobble Form Liner, Concrete and Steel Railing Combo

Pilasters and Concrete Rustications, Flagstone Form Liner

Ornamental Steel Railing

Cut Stone Veneer with Steel Pedestrian and Vehicular Railing, Masonry Railing Posts

Figure 4-4: Additional Aesthetic Options

4.2 Superstructure Options Considered

4.2.1 Structure Types Carried Forward for Selection

Structure type criteria was established in coordination with KYTC, and preliminary designs were developed in response to the geometric and aesthetic alternatives. The following were chosen as a balance of aesthetics and economy. As stated before, aesthetics, vertical clearance, geometrics, sidewalk placement and surrounding buildings were all considered. The following discussion summarizes the structure options carried forward into final selection.

Summary of engineering parameters considered are:

- Existing buildings adjacent to structure to remain
- Provide 10-foot lanes underneath structure
- Provide 5-foot sidewalk underneath structure
- Mitigate or prevent impacts to adjacent building support walls from construction activities
- Provide two 10-foot lanes and an 8-foot parking lane on US 31EX
- Provide a 6-foot sidewalk and a 10-foot sidewalk on US 31EX
- Provide minimum TL-2 rated barriers for pedestrians and vehicles on top of structure

Four initial structural options considered:

- Single Span Bridge with the following structure types:
    - Side-by-Side Precast Concrete Box Beams
    - Precast Concrete Arch
    - Rolled Steel Beams
- Two Span Bridge with the following structure types:
    - Two Span Precast Concrete Arch

The steel beam and side-by-side concrete box beam options were removed from consideration during a meeting with KYTC and community stakeholders. It was determined that a true arch shape was desired thus eliminating the concrete beam option, and the steel beams would allow for pigeon habitation and the community eliminated this option.

Two structural options are therefore recommended to be carried forward:

- Single Span Bridge with the following structure type:
    - Precast Concrete Arch
- Two Span Bridge with the following structure type:
    - Twin Precast Concrete Arches

For the two precast arch options, various span lengths were considered. It was important to find a balance between span length and the new vertical clearance. Factors affecting vertical clearance included the existing profiles of US31EX and Water Street, placement of sidewalk and driving lanes, and the arch shape of the

new structure. The goal was to optimize vertical clearance while minimizing overall cost and span length to reduce encroaching on the neighboring buildings.

Additional structure type criteria include:

- Micropile and spread footing foundations were considered for all options to reduce vibrations at the site affecting nearby buildings.
- Full closure is anticipated due to concerns of partial removal of the existing stone arch.
- Existing retaining walls are to remain unless engineering factors warrant replacement or retrofitting during final design.

4.2.2 Ancillary Considerations

- Railings and sidewalk types:

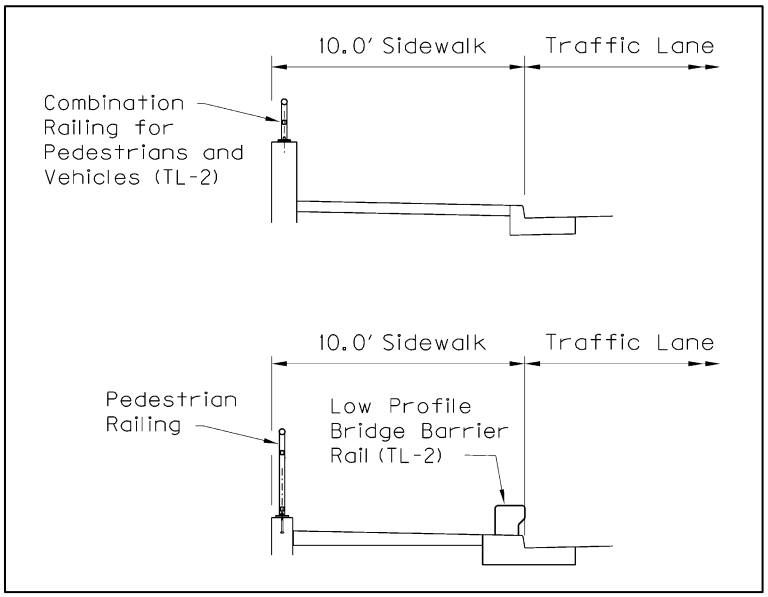


Figure 4-5: Sidewalk Railing Variations

Figure 4-5 shows options for a combination railing of concrete barrier and steel railing (top) or a separated concrete barrier and steel railing option (bottom). The vehicular portion of the system will be rated to a minimum TL-2 for impacts and the pedestrian railing will be at least 42 inches high and may contain a bicycle railing.

- Lights

Aesthetic lighting can be incorporated into the structure and will be evaluated during final design at the City's request. Both the single and two span options can accommodate lights, but requires additional cost. Although lighting for this bridge is not warranted per KYTC policy, basic lighting for safety can be provided for the new sidewalk under the new structure along Water Street.

4.2.3 Two Span Precast Arch Option

This structure option consists of (2) 18-foot precast concrete arch spans, supported on cast-in-place concrete pedestal walls, as shown in Figure 4-6. The precast concrete arches provide a clean arch profile for an aesthetically appealing, economical superstructure (see Figure 4-2). This superstructure type is precast to minimize construction impacts. Vertical clearance is impacted due to the sloping arches encroaching on the travel lanes. The two-span option will have a middle pier wall delineating the two barrels similar to the original structure. Given the height of the abutment walls, aesthetic treatments can be applied along the interior faces.

Roadside safety will need to be considered during final design to protect the ends of the middle wall from motorist impacts. Assuming a 25mph design speed, this may be accomplished using a non-mountable curb and/or with an end treatment, such as an impact attenuator. Traffic calming devices placed along Water Street before each end of the structure could also assist to ensure proper motorist speed.

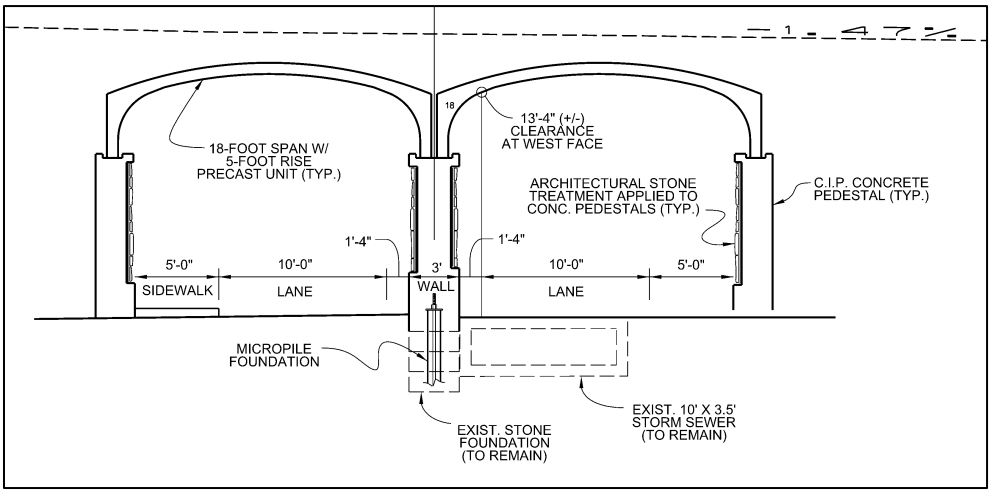


Figure 4-6: Two Span Precast Arch Option

4.2.4 Single Span Precast Arch Option

This structure option consists of a 42-foot, single-span precast concrete arch bridge as shown in Figure 4-7. The precast concrete arch provides a clean arching profile for a more aesthetically appealing superstructure (see Figure 4-2). This superstructure type is precast to minimize construction. Vertical clearance is impacted due to the sloping arches encroaching on the travel lanes. The single span option will utilize the existing middle wall as a barrier. Not only will it serve as a safety buffer between lanes and protect the adjacent buildings center wall, but also pay homage to the original structure. This will be accomplished through reuse of the existing masonry stone blocks, if the stones are determined to be sound for reuse during final design.

As stated in section 4.2.3, roadside safety will need to be considered during final design to protect the ends of the middle wall from motorist impacts. Assuming a 25mph design speed, this may be accomplished using a non-mountable curb and/or with an end treatment, such as an impact attenuator. Traffic calming devices placed along Water Street before each end of the could also assist to ensure proper motorist speed.

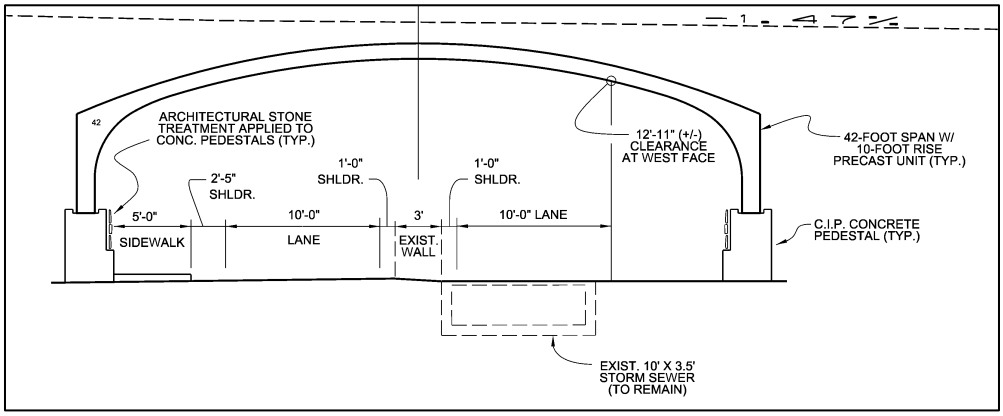


Figure 4-7: Single Span Precast Arch Option

4.3 Substructure and Foundation Considerations

Geotechnical

A preliminary geotechnical report (P-003-2017) was provided by KYTC for guidance on foundation types. Micropile or spread footing type foundations are recommended. Vibration monitoring is also recommended during construction. There are also potential karst considerations at this site. The boring logs indicate refusal at a depth of approximately 10 to 11 feet at the site. Additional geotechnical studies are recommended during final design.

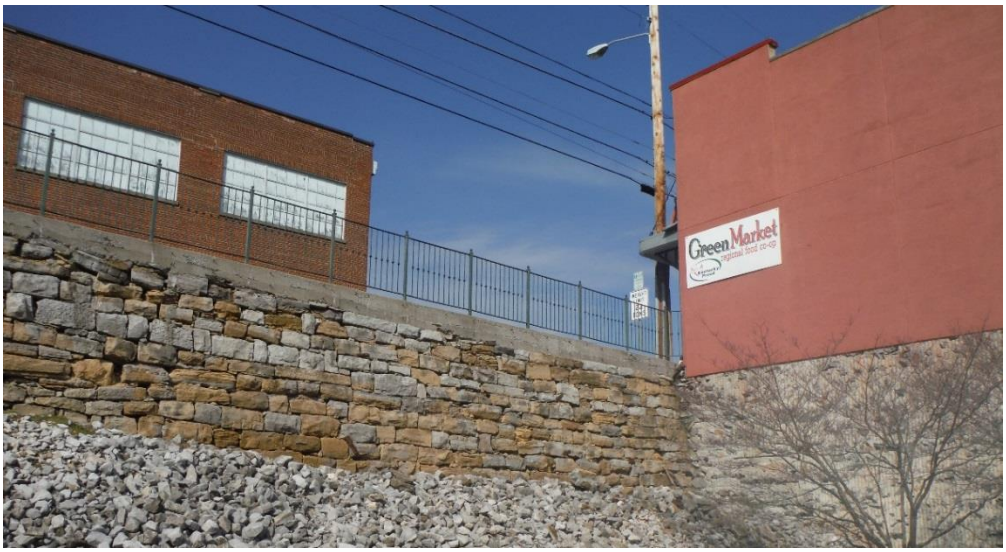
Bridge Substructure

Pedestal wall abutments are being considered for the bridge options: shorter abutments for the single-span option and taller abutments for the two-span option. The two-span abutments allow for an aesthetic architectural treatment such as a form liner or stone veneer applied on their interior faces. The precast arch units in both span configurations will sit in a keyway atop the abutment walls. The two-span option will also utilize a middle pier wall where the current middle wall exists.

The two types of foundations being considered are: spread footings and micropiles. The specific foundation type will depend on the final geotechnical report, but in general, micropiles are preferred to reduce vibrations on the surrounding buildings.

Retaining walls

Currently, retaining walls exist at the ends of the structure as seen below. A reinforced concrete retaining wall exists along the west face and a dry stacked masonry stone retaining wall exists along the east face. KYTC assessed the masonry stone retaining wall and commented that a number of the stones comprising the face of this wall are degraded and the wall is bulging along the north end. The wall appears stable but not up to current design standards. KYTC recommends that the design team consider addressing this wall as part of this project.



4.4 Summary of Construction Costs

The varying costs are affected by many factors considered throughout the selection process. Table 4-1 summarizes the parameters considered to develop initial construction costs. Table 4-2 summarizes the approximate costs of each parameter for the various span configuration types. These costs are preliminary approximations to aid in the decision-making process and are subject to change during final design.

Table 4-1: Breakdown of Cost Considerations

Structure	Structure, Excavation, Demolition, Shoring, Backfill, Pavement	
Aesthetics	Base Config	• Arch like appearance • Use of concrete form liner • Standard Railing and Pedestals • Paint or stain
	Enhanced Config	Example Architectural Treatments • Arch Like Appearance • Decorative Railing and Pedestals • Stone Veneer • Decorative Lighting
Utilities	Gas, Water, and Electric Impacts	
Misc.	MOT, Mobilization/Demobilization	
Contingency	Contingency for project budget (assumed at 20%)	

Table 4-2: Initial Estimated Costs per Option

Baseline Project Costs				
	Two Span Precast Arch	Single Span Precast Arch	Single Span Precast Box Beams	Single Span Steel Beams
Structure	$535,000	$542,000	$526,000	$520,000
Base Aesthetics	$69,000	$34,000	$51,000	$46,000
Utilities	$61,000	$61,000	$61,000	$61,000
Retaining Wall	$173,000	$173,000	$173,000	$173,000
Misc.	$67,000	$66,000	$66,000	$65,000
Contingency	$272,000	$263,000	$264,000	$260,000
Total	$1,177,000	$1,139,000	$1,141,000	$1,125,000

Table 4-3: Estimated Costs for Recommended Options

	Baseline Cost	Enhanced Aesthetics
Single Span Precast Arch	**$1,139,000**	**$95,000 (+/-)**
Two Span Precast Arch	**$1,177,000**	**$207,000 (+/-)**

Section 5: Structure Option Recommendation

KYTC is committed to providing a cost efficient and aesthetically pleasing replacement of the Water Street Bridge. The historic value of the structure is understood and will be carried through into all options. As described in Section 4.1, KYTC will provide for basic architectural treatments which were considered together with the basic structural elements in the costing options presented in Section 4.4.

Stakeholders expressed preference for a new structure that uses the arch form for its main load carrying members. At the time of this report writing, the stakeholders were continuing to evaluate the merits of the single span arch and two span arch options, including seeking feedback from the general public. Given the preference for an arch form, the close comparison between project factors (i.e. vertical clearance, aesthetics, and constructability), and the estimated costs at less than 4% difference, the project team recommended to carry forward the single-span arch bridge and the two-span arch bridge into final design consideration.

Both options provide the aesthetics closely matching the original structure arch form and are cost-efficient as a bridge replacement solution. The arch options will be moved forwarded to final design with understanding that if the two-span option is determined infeasible due to site constraints (e.g. foundation issues discovered at the center pier wall) then the single span option may be utilized as well. The stakeholders will be engaged to select a preferred span option during the preliminary stage of final design. Notable features of the selected options include (subject to revision during final design):

- New bridge structure approximately 40-foot long by 44-foot wide
- Bridge superstructure consists of precast concrete arches with an asphalt riding surface
- Aesthetic treatments to complement surrounding environment and the original structure
- Form liners used for aesthetic treatments
- Bridge substructure on spread footings or micropiles
- New sidewalks above and below the structure for pedestrian traffic
- Water line relocation along US31EX
- Vibration monitoring utilized during construction and precondition survey of nearby structures

Additional options the City may consider and funded by the City are:

- Architectural, ornamental, or weathering steel railings
- Specialty stains (multi-color)
- Cut stone veneer
- Pilasters and rustications
- Ornamental lighting
- Retaining or reusing original stones
- Sidewalks leading up to the new structure along Water Street