kpff Consulting Engineers

December 31, 2014

Mr. Jonathan Adams
City of Spokane
Senior Engineer, Design
Spokane, Washington 99201

Subject: City Project Number: Engineering No. 2013186
Evaluation of 11 Pedestrian Bridges - Riverfront Park and Centennial Trail

Dear Mr. Adams:

KPFF has completed all services associated with the above-referenced project and respectfully submits this executive summary and final report providing a summary of our efforts, findings, and recommendations. The draft report was submitted on November 14, 2014. While no comments were received following the City and Parks' review period, we have determined that our analysis of the Centennial Trail, Triangle Truss, and East Wooden Bridges assumed a level of conservatism unnecessary for the subject bridges in our analysis. Consequently, we have revised three load ratings and are resubmitting the individual report for these bridges. The conclusions drawn from the draft report and as shown again here in the final report are unchanged.

PROJECT OBJECTIVES

The goal of this project was to evaluate the structural integrity of eleven pedestrian bridges located in Spokane and to provide recommendations, if any, based on the findings. The evaluation was comprised of either a hands-on inspection of a bridge's structural components, or a combined inspection and load rating of a bridge's superstructure components (structural elements positioned above the bridge bearings). The City of Spokane (City) identified specific bridges for a load rating analysis (not all bridges were structurally analyzed). The inspection and analysis work was performed by professionally licensed bridge engineers, trained in both inspection and analysis techniques, to ensure continuity between the field and office processes, and to ensure that the field data was properly accounted for during the analytical effort.

As part of the field data collection effort, underwater inspections were performed on three bridges: Kardong, East Wooden, and West Wooden Bridges. This work was performed by the Bellevue firm, Echelon. These reports are included in the Appendix of this report.

A second project objective was to develop cost estimates based on concept-level details depicting repair or retrofit ideas to improve those bridges with defects or poor structural capacity. The costs are to be used in the development of capital planning budgets for Riverfront Park. The total costs for all recommendations on all bridges are estimated to be between $10M and $13.5M (2015 dollars). This includes construction costs and all project management and design related costs. The costs, prioritization, and details are provided in Table 3, at the end of this summary.

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Included in the project goals is the development of a summary of permits which would likely be triggered in a future effort to implement any of the retrofit/repair or improvement concepts. This work was performed by the Seattle firm, SWCA. The results are included in a separate, detailed report in the Appendix. As one would expect, bridges tagged for replacement or widening triggered the most significant permits. Most permits fall into the category of a straight-forward, formality level effort.

The final objective was to develop a simple method to report the bridge inspection findings which could be understood by a variety of stakeholders interested in the condition and remaining structural life of the bridges. To this end, we have created a Bridge Inspection Form which neatly summarizes each bridge's historical data, load rating results, and inspection findings. Embedded into this form are detailed inspection rating guidelines which are to be used by future inspectors to assist them in qualifying and rating degrees of deterioration to the bridge elements. This promotes consistency in interpretation of findings between different inspectors over many years of continued inspections. The language in the inspection rating guidelines is derived from the FHWA bridge inspection manual for the Inspection of Highway Bridges, and includes summaries for rating degrees of deterioration for steel, concrete, and timber bridge elements. This form has been created and formatted specifically for these pedestrian bridges but could, in theory, be used for any bridge. It is strongly recommended that the City and Parks Division use these forms for all future inspections of these bridges. Having access to previous reports helps a great deal in knowing when a defect first appeared on a bridge and in the engineer's ability to properly assess the growth and, thus, the impact of the defect.

We recommend that the inspection frequency for these bridges be every two years, following the repairs recommended in this report. This is in keeping with the federal guidelines for the Inspection of Highway Bridges. A bridge's inspection frequency should be increased if its inspection rating attains a general condition of "poor".

PROJECT SUMMARY

Bridge improvement plans were developed for the following inspected bridges:

Centennial Trial Bridges:

1. Kardong Bridge
2. Iron Bridge
3. Centennial Trail Bridge at Hamilton Street

Riverfront Park Bridges:

4. Triangle Truss Bridge
5. East Wooden Bridge
6. West Wooden Bridge
7. North Suspension Bridge
8. South Suspension Bridge
9. Howard Street South Channel Bridge
10. Washington Street North Bridge
11. Theme Stream Bridges (five bridges total)

BRIDGE LOCATIONS

The two maps below show the location of each bridge.

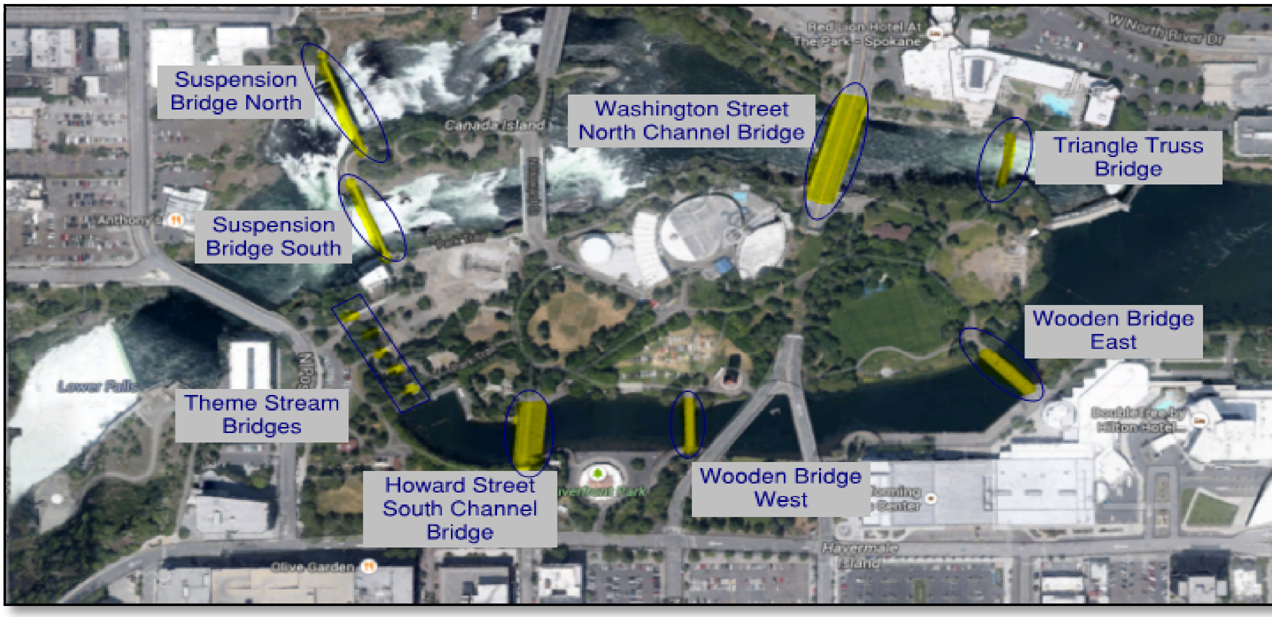

Figure 1: Map of Riverfront Park Bridges (these bridges are part of the River Front Park Complex)

Figure 2: Map of Centennial Trail Bridges (these bridges belong to the City)

BRIDGE REPORTS

The evaluation methods and the bridge improvement plans are detailed in an individual report for each bridge. These reports are contained herein. The contents of each individual report are summarized below in Table 1.

Table 1: Summary of Report Contents

Report Deliverable ↓ / Bridge Name →	Kardong	Iron	Centennial Trail	Triangle Truss	East Wooden	West Wooden	North Suspension	South Suspension	Howard St South	Washington St North	Theme Stream
▪ Inspection Form ▪ Select Photographs ▪ Labeling System	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
▪ Improvement Details ▪ Cost Estimates	✓			✓	✓	✓	✓	✓	✓	✓	✓
▪ Load Rating Results & Calculations			✓	✓	✓	✓	✓	✓			
▪ Underwater Inspection Report	✓				✓	✓					
▪ Photograph Log ▪ Photograph Contact Sheet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
▪ Permit Reviews	✓			✓	✓	✓	✓	✓	✓	✓	✓

ANALYSIS

A load rating (structural analysis) was performed to determine the safe load carrying capacity of six bridges, identified above in Table 2. The goal of the load rating analysis is to generate an overall “rating factor” (RF) for each bridge. The bridge’s RF will be determined, and indeed derived from, the analysis of all the bridge’s superstructure elements such as the girders, deck, floor-beams, cap-beams and stringers. The bridge RF will then be based on the element with the lowest RF. This is premised on the “weak link” approach by which a bridge is deemed only as good as its weakest component. Should that (weakest) component fail, the bridge will then be closed until it is repaired. Furthermore, and most importantly, the general public using the bridge is at risk of injury due to the weakest element (rather than the strongest). An RF of 1.0 or greater means that the bridge can safely carry the specific load under investigation.

The Load and Resistance Factor Rating (LRFR) method was used to perform the load rating calculations. In this procedure, the RFs are determined for inventory and operating live loads. The inventory rating represents the maximum load the bridge can safely carry for an indefinite period of time, often thought of as the service capacity. The operating rating represents the maximum load the bridge can safely carry for a brief period, often thought of as a temporary over-load capacity.

Each of the bridges in Table 2 was analyzed for a uniform pedestrian loading of 90 psf. This is equivalent or greater than the entire bridge deck area covered with tightly-spaced pedestrians. Each bridge in Table 2 was also analyzed for specific vehicle loads (live loads) provided by the City’s Engineering Department, as follows:

- The Centennial Trail Bridge was load rated for a Maintenance Vehicle, which has a total weight of 35,700 pounds (35.7 kips).
- The Suspension Bridges were rated for two types of inspection vehicles, which have total weights of 16,200 pounds (16.2 kips), and 21,100 pounds (21.1 kips).
- The Triangle Truss, East, and West Wooden Bridges were rated for the AASHTO-H10 design vehicle, which has a total weight of 20 kips.

The load rating analysis was performed with either the pedestrian load on the bridge or the vehicle load on the bridge, but not both. The vehicle rating was performed with only one truck on the bridge and did not include an allowance for impact. If the bridge inspection found structural members to be in fair or poor condition, their strength capacity was decreased by a reduction factor correlating to the level of deterioration. A summary of the load rating results is shown below in Table 2.

In Table 2 below, only the inventory RFs (concerned with normal/daily loads) are shown. Operating RFs (concerned with rare loads) are included in the individual reports in the Appendix. Please note that the pedestrian operating RFs for all the bridges are greater than one (RF>1). Also note that the Centennial Bridge’s RF of 0.93* is equivalent to 84 psf uniform load and for the East Wooden Bridge a RF of 0.82** is equivalent to 74 psf uniform load.

Table 2: Load Rating Summary

Bridge Name →	**Centennial Trail**	**Triangle Truss**	**East Wooden**	**West Wooden**	**North Suspension**	**South Suspension**
Pedestrian Live Load	90 psf	90 psf	90 psf	90 psf	90 psf	90 psf
Pedestrian RF	0.93 *	1.25	0.82 **	1.25	0.51	0.51
Controlling Component	Concrete Stress	Diagonals	Floorbeam	Floorbeam	Deck	Deck
Vehicle Live Load	35.7 kip	H 10	H 10	H 10	16.2 / 21.1 kip	16.2 / 21.1 kip
Vehicle RF	2.04	0.16	0.16	0.16	1.45	1.59
Controlling Component	Concrete Stress	Timber Deck	Timber Deck	Timber Deck	Girders	Girders

FINDINGS AND CONCLUSIONS

The inspection, analytical findings and results are being delivered to the City in two formats: 1) a comprehensive, stand-alone, report for each bridge, and 2) a single large 3-ring binder report containing this summary and a compilation of all the individual bridge reports. We suggest that the stand-alone reports be placed in each bridge's individual file to ensure that future inspectors and load raters will be able to easily locate the contents, data, findings, and conclusions reported herein. Ideally, this will serve as a valuable resource to future engineers evaluating these bridges. The 3-ring binder report provides a single location for all reports and may better serve as a broadly-distributed tool for various stakeholders for capital planning, understanding of the overall conditions and issues, and costs related to the bridges.

Our inspectors found eight of the eleven bridges to be in fundamentally good structural condition, with only a few minor-to-moderate level defects – which for the most part can be addressed with improved maintenance. Four of these bridges, further discussed in the next paragraph, require a complete deck replacement. Three of the eleven bridges, however, will require special effort to improve the structural integrity of the deck system. Top priority is the 1931-built **Howard Street Bridge**. *This bridge needs to be replaced in its entirety due to severe deterioration of numerous primary structural components and evidence of undermining of one foundation (which has been temporarily reinforced*). The remaining two bridges deserving of immediate attention are the **North and South Suspension Bridges**. These bridges do not need replacement in their entirety, but have severely degraded components (deck) which require replacement and other components (floorbeams, girders, hanger cable anchor bolts) which need cleaning, painting, and in some cases, strengthening or replacement.

The four bridges we are recommending for deck replacement are the **Kardong Bridge, the East and West Wooden Bridges,** and the **Triangle Bridge**. Replacement concepts and costs have been developed for each of these bridges and are included in the individual bridge report. These bridges currently have wooden decks with short life spans and require a significant amount of upkeep. This is a good time to replace the wooden decks since they currently exhibit evidence that the planks are nearing the end of their lifespan. New wooden deck systems are expected to last four times longer than the older plank system, require essentially no up-keep, and are structurally more viable to support high-density pedestrian or light truck loads. Concrete decks are another possible replacement option but change the character of the bridge.

The southernmost **Theme Bridge** in the Riverfront Park has been identified by the City Park for replacement. This bridge is structurally fit to serve as a pedestrian bridge but cannot support heavy fire truck/emergency vehicles. The goal is to convert one of the Theme Bridges into a bridge that can provide emergency vehicle access into the park interior. A replacement concept and cost is included in this report.

The **Washington Bridge** was not inspected or analyzed strictly to evaluate its structural integrity. Rather, the goal was to develop ideas in which the western sidewalk could be widened to better accommodate pedestrian and bicycle traffic. Accordingly, several options were developed with unique improvements to the pathway width, and each with a corresponding cost. Please see the individual report for details.

The **Howard Street Bridge** has clearly reached the end of its service life. We realize this is not new information to the City. Accordingly, we concur that this bridge should be replaced - and replaced sooner rather than later. The dominant load on this bridge is the self weight of the concrete, and in time the bridge girders risk becoming excessively strained in an effort to support the bridge self weight without reserve capacity to support the live load (pedestrians). We believe that repair and retrofit is not the optimal solution at this point in the life cycle consideration of this bridge. While rehabilitation could cost less, depending on the desired goals, it would only provide a limited period of additional safety. In general, the greater the investment for rehabilitation, the greater the lifespan and functionality achieved. However, the work would, even under the best of circumstances, remain a temporary fix.

The Kardong Bridge, as already mentioned, should have the deck replaced at this time. In addition, we recommend that the platform at Pier 4 be closed to public use. The platform needs to be removed or fully retrofitted to a much more stable structural system in order to continue to remain in service.

Details of the underwater inspection of the bridge's in-water piers and streambed in the vicinity of these piers are reported in the Underwater Inspection Report provided in the stand-alone Kardong Bridge report. From a scour perspective, the important findings are:

1. Evidence of streambed scour up-stream of all three piers was noted and to be somewhat note-worthy. It is believed that this scour is a result of increase flow velocity resulting from streambed constriction caused by the large footings of piers 3, 4 and 5. The large boulders in the streambed cross-section may also contribute to local scour.

2. **No undermining to the visible footings or surrounding cofferdams was found in any of the in-water piers (Piers 3, 4 and 5).**

3. The pile tip and footing bottom elevations are unknown. In addition the stream-bed elevations at time of construction are unknown.

Scour investigations are more telling when a comparison of today's streambed configuration can be chartered against elevations and configurations from the past, thereby providing an opportunity to note trends in the streambed's on-going process of re-configuration over time. Such trends to note are: 1) migration of the thalweg (lowest point of streambed), 2) occurrence of local or general scouring versus aggregation to the streambed, and 3) at what rate these events are occurring.

Secondly, without knowing the bottom of footing elevations and the sheet piling tip elevations, we are not able to assess the level of concern appropriately applied toward the issue of scour and potential undermining. Accordingly, monitoring the condition of the stream bed is the most prudent approach to ensure the safety of the bridge.

We strongly urge that the City repeat this level of underwater bridge investigation every five years allowing this inspection to serve as the base line for future comparisons.

IMPROVEMENT PLAN

The bridge improvement plan includes conceptual level repair, replacement and/or widening details, and cost estimates. Table 3 below summarizes the estimated costs for the improvements of each bridge:

Table 3: Bridge Improvement Plan - Cost Estimate

Bridge Name	Type of Improvement	Approx. Cost
Kardong	Deck/Railing Replacement, Platform Removal	$1.1 million
Iron	*	$0
Centennial Trail	*	$0
Triangle Truss	Deck Replacement, Debris Removal, Slope Protection	$246,000 -$308,000
East Wooden	Deck Replacement	$409,000 -$528,000
West Wooden	Deck Replacement, Bearing Repair, Install Rip Rap, Footing	$239,000 - $307,000
North and South Suspension Bridges and Vaults	Deck Replacement, Floor-beam Repair/Replacement, Hanger Repair/Replacement, Vault Deck Replacement	$2.8 million
Howard St South	Bridge Replacement	$4.6 to $5.9 million
Washington St North	Pedestrian and Bike Bridge Widening	$340,000 - $1.6 million
Theme Stream	South Bridge Replacement, Replace Timber Railing	$1.0 million
Total		**$10.7 – 13.5 million**

**The recommendations for the Iron Bridge and Centennial Trail Bridge fall under general maintenance, and therefore are not included in the cost estimate for the capital improvements budget.*

The remaining lifespan of each bridge is discussed in the individual reports with some detail. For general planning purposes, we fully anticipate the bridges following implementation of this report's recommendations, to be in service as pedestrian bridges for another 50-75 -years, if moderately maintained, repaired as necessary, and cleaned and spot painted on occasion. Most important, continue to inspect and monitor the condition of the bridges so that action to preserve them is proactive.

The field portion of this project was completed during August and September 2014, and the report was submitted initially as a draft on November 14, 2014. This is the final report, dated December 31, 2014.

Please feel free to contact me or Marijean Frymoyer at the information below at anytime to discuss these bridges, this report, or for assistance in answering any additional questions.

Thank you for the opportunity to serve the City and citizens of Spokane, and for entrusting us to report on the structural integrity, safety, and needs of these unusual, interesting, and beautiful structures.

Sincerely,

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