2023 ACEC - Nancy Pauw Bridge

Project Summary

The glacial Bow River traces its way through the Rocky Mountains and the Town of Banff, in Canada's first national park. Spanning the Bow, in the heart of the community, is the new Nancy Pauw footbridge, fulfilling a 108-year dream for the town. Responding to the wish for natural materials and minimal intrusion, StructureCraft designed and built an unusually slender 80m clear span out of sustainable timber, a shallow high-thrust arch which appears effortless in this beautiful and pristine natural setting.

Figure 1 - Nancy Pauw Bridge spanning the Bow River in Banff, AB, Canada
Credit: Paul Zizka Photography

History and Background

Given its natural beauty among towering mountains, Banff is one of the most sought out tourist destinations in North America, visited by more than 4 million people annually. The town was established in 1883, and the national park a few years later. Through this town, which is very conscious of representing its place in the park, flows the lovely aquamarine, glacier-fed Bow River.

Across this river from the town centre lie hot springs and many natural attractions, as well as the world-renowned Banff Springs Hotel and golf course. Banff has always been a town determined to promote walking and cycling. Already by 1914, to make better connections, planners had in mind a footbridge to be located at Central Park, immediately adjacent to the town centre, 200 m upstream from the road bridge. But that wish was not to come true for over 100 years.

An attempt had been made to create this crossing in 2007, but the technical challenges were deemed too difficult, and the project was abandoned.

Figure 2 - The Town of Banff in Canada's first national park.
Credit: Paul Zizka Photography

However, a new opportunity recently arose through a private donation offered by the Wim and Nancy Pauw Foundation, along with funding by various levels of government, including the Town of Banff, who was the project client, procuring the bridge through a design-build competition. The new bridge is named after the late Nancy Pauw, a long time Banff resident and hiking/cycling enthusiast.

Figure 3 - The glacier-fed Bow River flanked on either side by parks and attractions.
Credit: StructureCraft

Figure 4 – Looking across the Bow from Central Park. Here the river slows, and its banks are quite low.
Credit: StructureCraft

Site Challenges

The Bow River is pristine, and carefully guarded by both Parks Canada and the town. Environmental concerns, both permanent and during construction, were paramount. The bridge needed to be a clear span to minimize impact on the river. It needed to be low profile with minimum slopes for user accessibility, and minimal ramping on either side to mitigate impact on the park lands. Yet it needed to give clearance for flood conditions and not alter the paths of the ever-present elk which freely cross the river here. And the banks of this glacier-fed river are never high.

The desire was for a bridge which was graceful, unobtrusive, and natural, fitting in with both the beautiful surroundings and the town's defined Rocky Mountain theme, which clearly suggests the use of wood and stone. Also essential was allowing users unimpeded views while crossing.

At this location, the river slows, and its banks are quite low. Thus the solution needed to be extremely slender, with an 80m clear span to avoid work in the river. And could this be done in timber, a natural and beautiful material, yet not as strong as steel?

And with such a slender span, what about vibrations and user comfort? This is a high-profile civic structure with up to 10,000 users per day.

Solution and Analysis

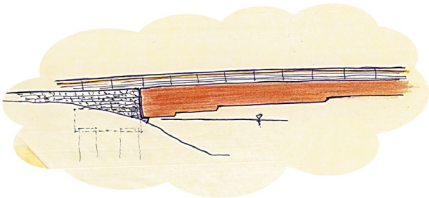


Figure 5 – Early sketch of the bridge and abutment.
Credit: StructureCraft

StructureCraft had been thinking about this site since the time of their earlier downstream bridge in 2013. The challenge was the low banks. The only solution, especially with timber, appeared to be a shallow arch. And with a 5% max slope at the abutments, and the required clearances, the arch could only have a rise:span ratio of about 1:20, inviting all the challenges of a very shallow arch structure.

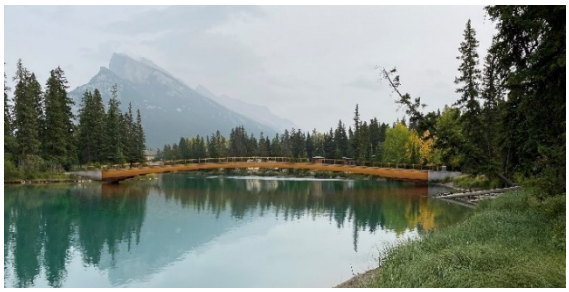


Figure 6 - Initial render of the clear span, low profile Nancy Pauw Bridge.
Credit: StructureCraft

These challenges include:

- non-linear behaviour
- potential for snap-through buckling
- large abutment thrusts
- susceptibility to unsymmetrical loading
- and difficulty with understanding the vibration characteristics.

To understand if this solution was possible, the first challenge needing investigation was soil conditions. Could the soils resist the enormous thrusts required, including the permanent dead load thrusts? These could increase over time due to creep in the timber structure and be magnified by non-linear effects (a kind of "ponding-like" instability). The soil profile was dense sedimentary but the complex effects needed to be confirmed through full soil-structure interaction analysis. By working with our geotechnical consultant and an experienced piling contractor, we chose a grouping of 5 - 1.1m diameter cast-augered concrete piles to resist the full unfactored 4000 kN thrust with minimal horizontal deflections (approx. 15mm including non-linear effects).

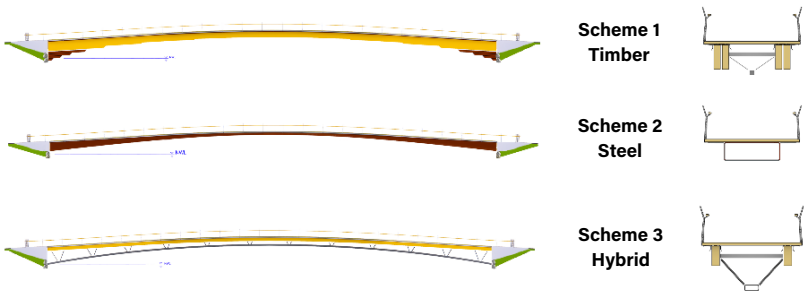


Figure 7 – Three low-profile options considered.
Credit: StructureCraft

Proportions of the structure were selected for elegance of form and efficiency. Two pairs of shallow tapered Douglas Fir girders were chosen. The dominant resisting mechanism is arch thrust, and for this the cross-section does not need to be deep. Diagonal steel bracing links the two pairs, creating the diaphragm to resist lateral movements.

Figure 8 - Sketch showing the low profile of the bridge in relation to the embankments.
Credit: StructureCraft

It was desired to create the natural form of a tapered arch, minimizing depth for greater clearance at midspan, and maximizing depth at abutments, much like the many beautiful stone arches of the past. But like the early stone arch designers we wanted to use the mass stiffness of the abutments to assist with the global structural action and unbalanced loading effects, essentially creating fixity at the supports.

Abutments consist of a 1.5m deep pile cap and the large diameter piles, 10m in length, socketed into the stiff soil. Tapered weathering steel "haunches" were anchored to the abutments both to add stiffness and to protect the timber from the river. Straps from the top of the timber were affixed to the concrete abutment, in this way creating the fixity. Fixity was also achieved at the midspan splice. The fixity helps structurally with buckling resistance and unbalanced effects, including vibration mode shapes.

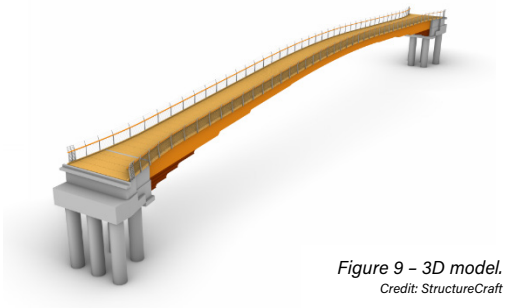


Figure 9 – 3D model.
Credit: StructureCraft

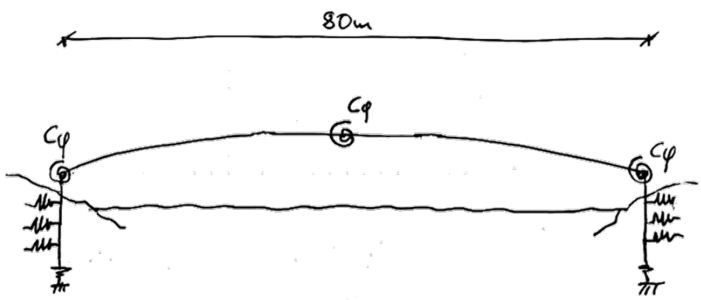


Figure 10 – Structural concept.
Credit: StructureCraft

Soil-structure interaction analysis indicated that thrusts were reduced by approximately 30% through this bending action at the abutments. Care was taken in studying upper and lower bound effects of the modelling assumptions.

Vibration Damping

Figure 11 - The completed bridge was measured using accelerometers prior to and after installation of the TMD.
Credit: StructureCraft

The most difficult aspect of slender bridge design is vibration performance. We had previous experience with our similar bridge downstream from this one using twin custom tuned mass dampers we had devised. But that was a propped cantilever design, not an arch.

With a shallow arch bridge, it was more difficult to predict the natural frequencies, and they were closer together, even compounding each other. A single central tuned mass damper was used, similar to the previous bridge, consisting of a simple mass of steel plates on a carriage suspended from cables stretched to four points on the girders. Visible, if you look for it. A unique feature of this design is that we were able to tune it to both walking (1.9 Hz 1st vertical) and jogging (2.4 Hz 1st torsional) frequencies. In the first case the mass moves vertically, and in the other it moves laterally, efficiently suppressing the large accelerations experienced initially in both modes.

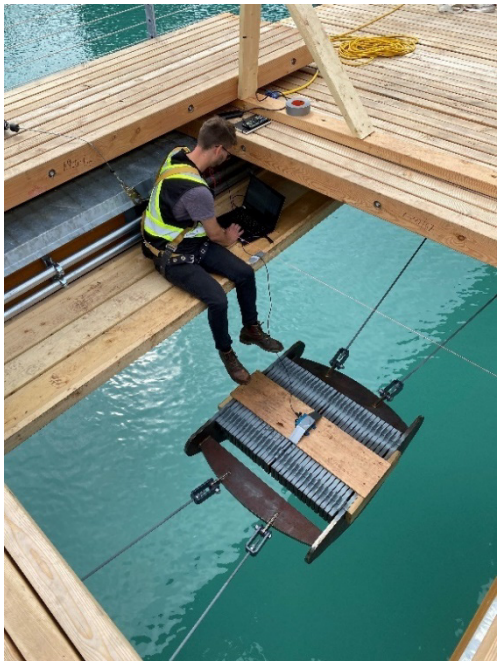


Figure 12 - Single central multi-modal tuned mass damper system.
Credit: StructureCraft

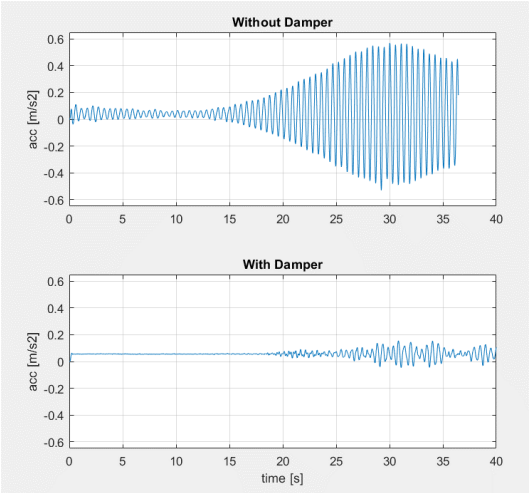
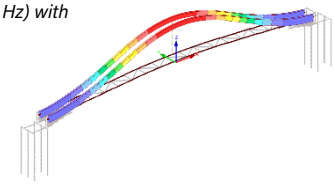


Figure 13 – Measured response to resonant input (1.9 Hz) with and without TMD.
Credit: StructureCraft



Guardrails and Decking

Bridge materials needed to be natural and durable. Great thought and care had been taken with the guardrail and decking system of the earlier downstream bridge, and it had performed very well in the 9 years preceding this bridge. So it became obvious to do the same again.

The tapered guardrail stanchions are hot-dip galvanized, and connected at the base to tabs which are welded to the heavy gauge flashing which protects the bridge girders. Continuous 6mm diameter stainless steel cables run through grommet protected holes in the stanchions and are prestressed to anchor stanchions at each end. The prestress force of 5kN was chosen to perform under the extremes of temperature the bridge would experience.

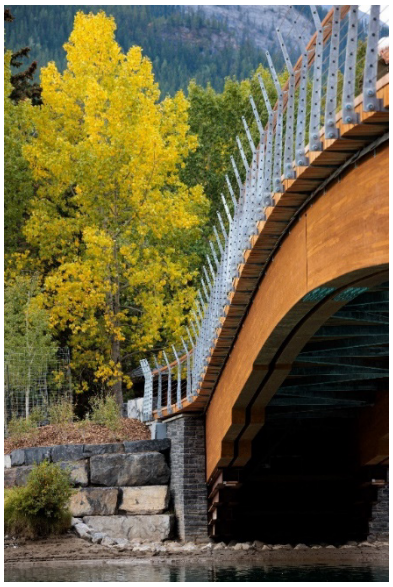


Figure 14
Credit: Paul Zizka Photography

Decking consists of spaced Douglas Fir timbers prestressed into 1m wide removable panels using galvanized rods and rubber spacers.

Figure 15 - Installation of conveniently replaceable timber deck panels.
Credit: StructureCraft

Fabrication and Installation

As with all longer span bridges, design must respect erection and fabrication considerations, and the site. How to least disturb river, national park, and town, considering seasonal issues and low/high water levels? Environmental impact assessments and approvals at numerous levels needed to be procured. All of these were managed under the design-build contract, and the client was very cooperative in assisting to ensure the critical timelines were met.

Piling was conducted in December, at low water but prior to deep freeze. Based on bore holes, it was expected that water would be present, and so Tremie concrete was specified, requiring extra quality control. Abutments were formed and poured in April, before water levels started to rise.

The 8m long tapered weathering steel haunches, complete with 35mm diameter rebar embeds, were surveyed and cast in at this time. These act not only to stiffen the span, but as receivers for erection of the timber bridge girders.

Figure 16 - Weathering steel "haunches" ready to receive bridge sections. *Credit: StructureCraft*

For spanning the river, two erection schemes were considered: first as two sections, and second, as three sections. The second option had the advantage of shorter glulam pieces, reducing shipping costs, and allowing a larger number of supplier options. But it wasn't preferable structurally, with two moment splices required, and more erection complexity. So the first was chosen, with two sections and a central tight-fitting thrust pin, which was later fixed using straps. Although each section was heavier, the reach was less, and allowed us to stay within the capacity of the available cranes. It required two cranes, but erection could be done in one day, with greater certainty.

Figure 17 – South section ready for install. Note central pin connection and straps for moment continuity.
Credit: Paul Zizka Photography

To minimize handling of large pieces, the 8 - 40m+ long tapered glulam pieces were fabricated and coated at the glulam plant. The only cuts left for the site were the notches for the steel pin pieces, which were finalized very carefully from the 3D model to as-built conditions. The girders were transported directly to site and assembled into the two half-bridge sections in preparation for erection. Erection weight for each section was 32,000 kg.

Figure 18 – Bridge sections were erected concurrently.
Credit: Paul Zizka Photography

Figure 19 – A central pin locks the two bridge sections together. *Credit: Paul Zizka Photography*

By its nature the shallow arch design demands extremely tight tolerances. Small horizontal displacements create large vertical movements, and the bridge geometry was critically dependent on a tight fit.

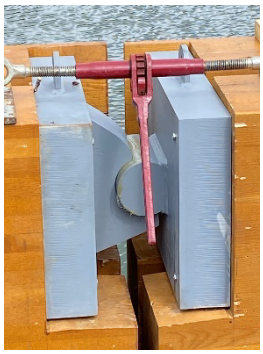


Figure 20 – Close up of central pin.
Credit: StructureCraft

Erection of the bridge sections concurrently (with activation of arch thrust) was carried out in a matter of hours, and horizontal and vertical deflection measurements, even after set was achieved, were smaller than anticipated. Interestingly, "set" was experienced, by those standing close by, as a series of faint creaks and groans, as the beams and joints found their load path into tight compression.

Conclusion

The Town of Banff is thrilled to have their 108-year-old dream come true. The new footbridge crossing is now prized as a beautiful accent in this most picturesque setting and will be a popular connector for both townsfolk and the many visitors for generations to come. This incredibly slender span (span:depth > 65) using natural materials is without precedent and was delivered to a delighted client under budget and ahead of schedule using a clean, all-inclusive design build delivery model.

Figure 21 – User experience was a most important design goal. At the Grand Opening, hundreds walked, jogged, and jumped on the bridge.
Credit: StructureCraft

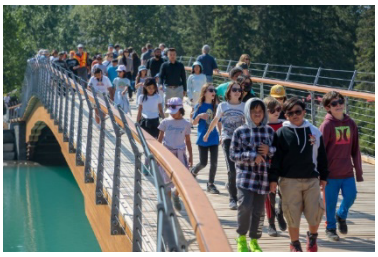
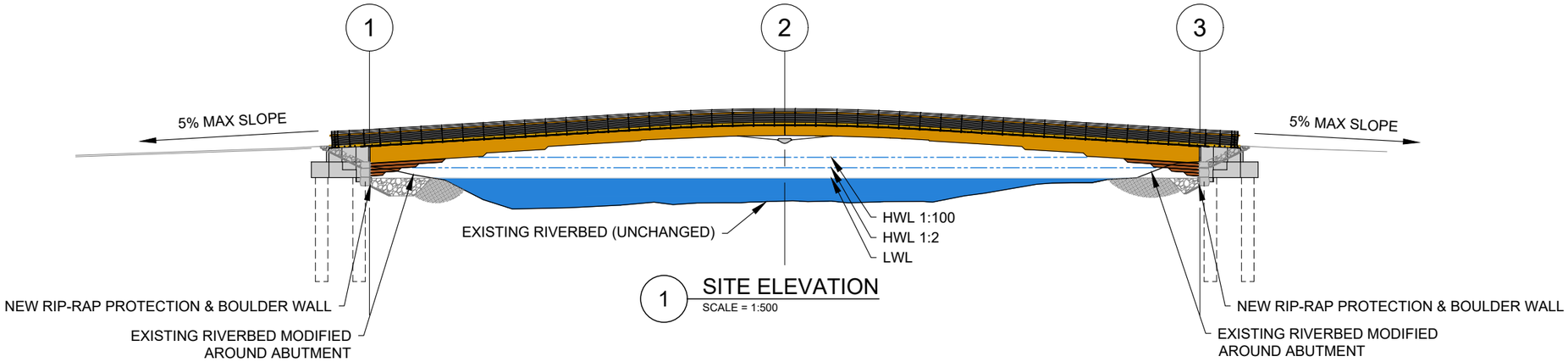


Figure 22 – Among the first to cross the new community bridge were the Banff Elementary School students.
Credit: Town of Banff



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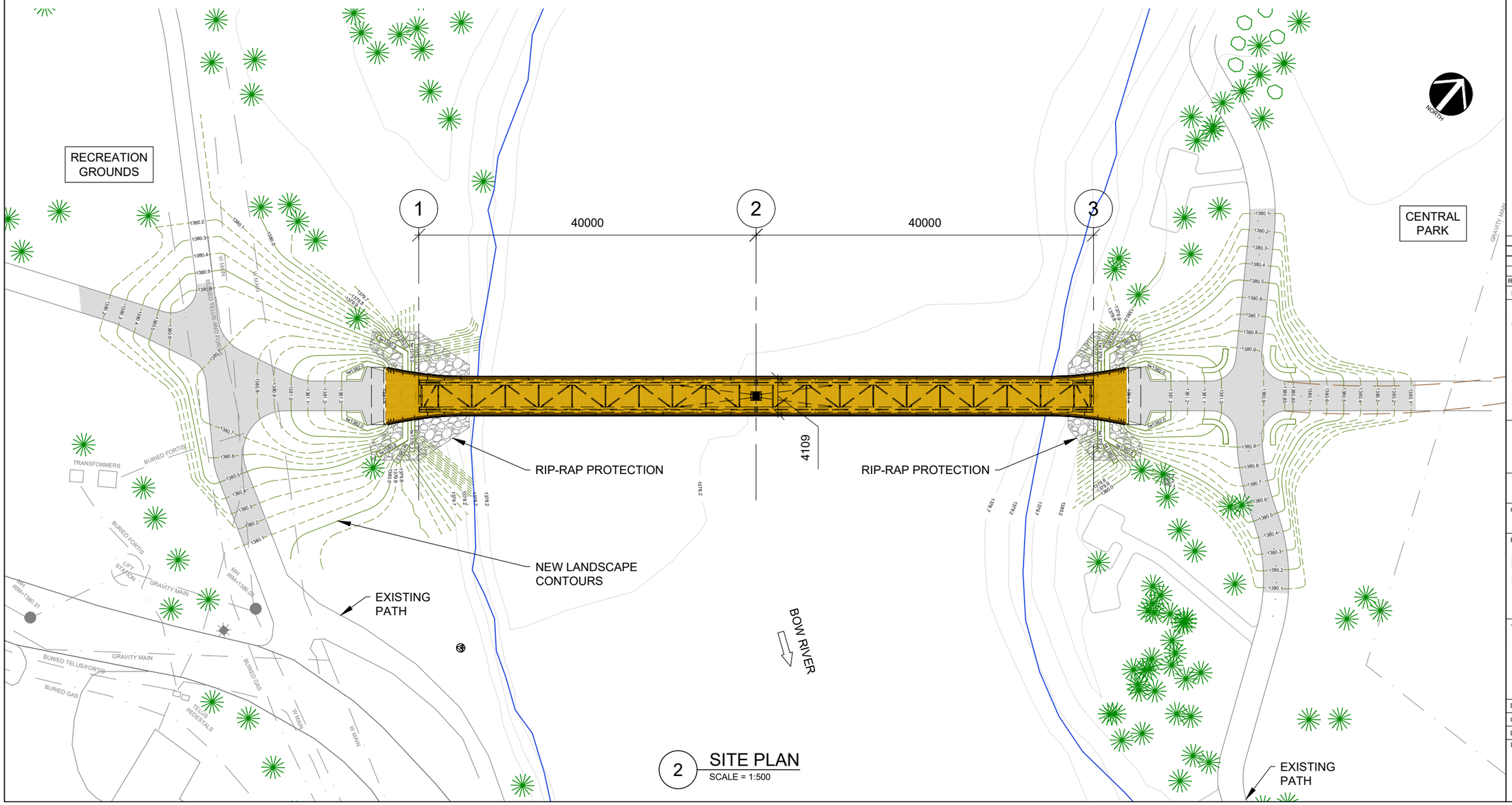

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REV.	DESCRIPTION	DATE

ISSUED

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CLIENT
TOWN OF BANFF

PROJECT
NANCY PAUW FOOTBRIDGE, BANFF

TITLE
GENERAL ARRANGEMENT

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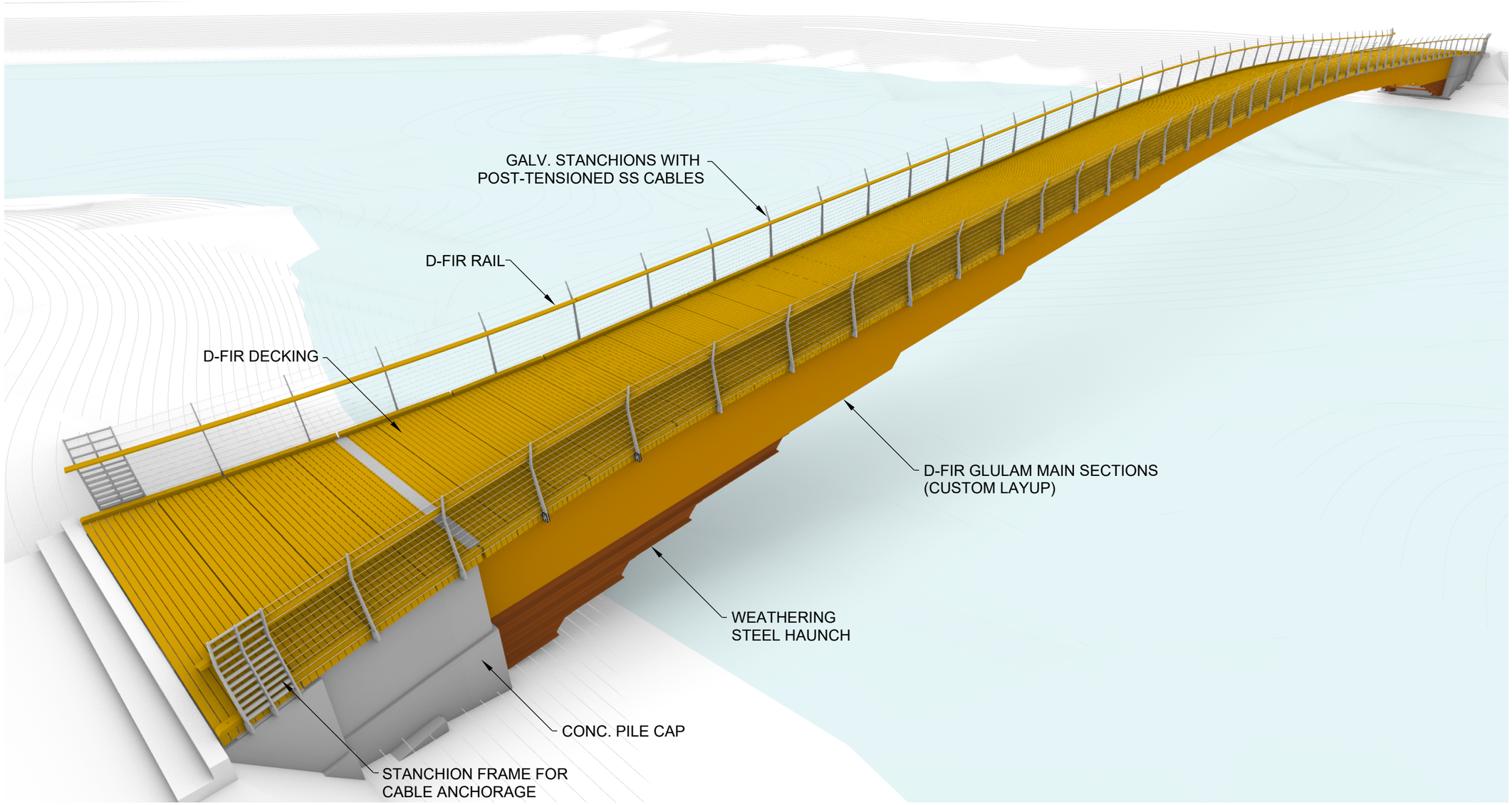

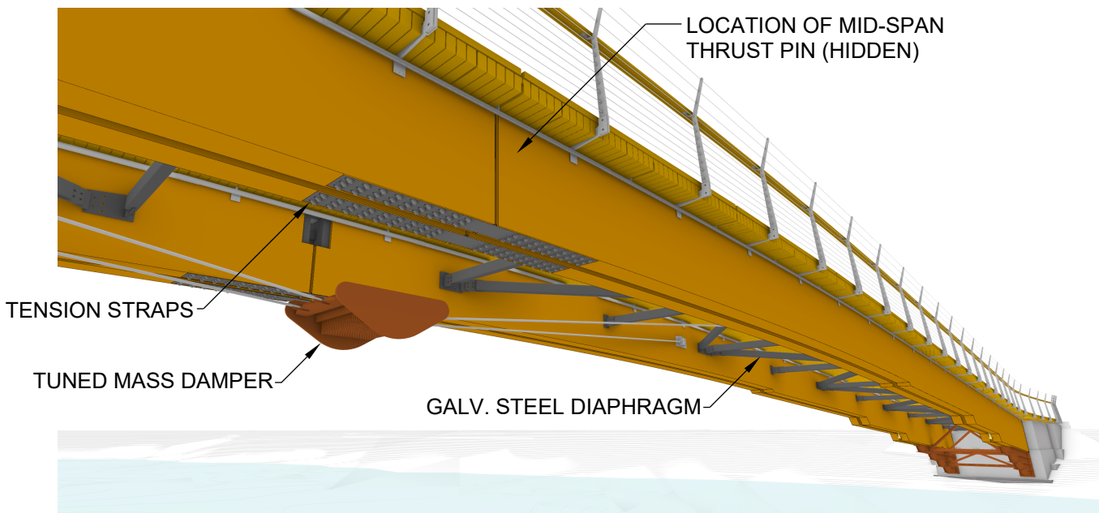

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CLIENT
TOWN OF BANFF

PROJECT
NANCY PAUW
FOOTBRIDGE, BANFF

TITLE
BRIDGE COMPONENTS
DIAGRAM

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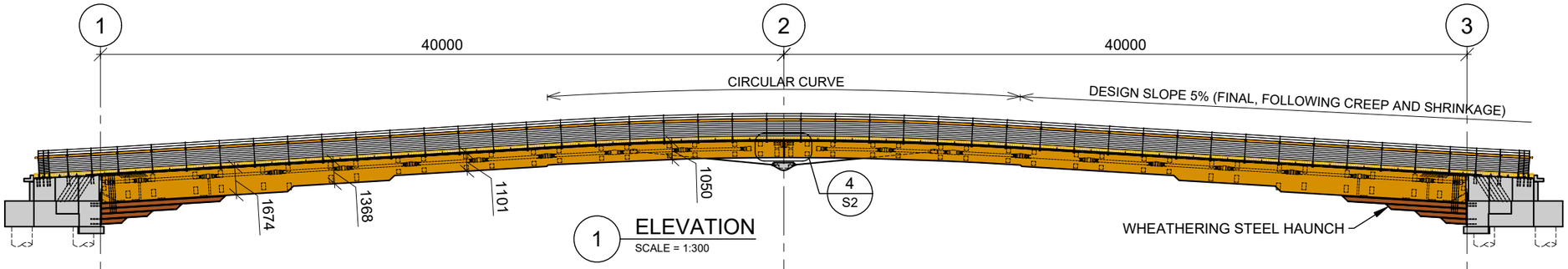

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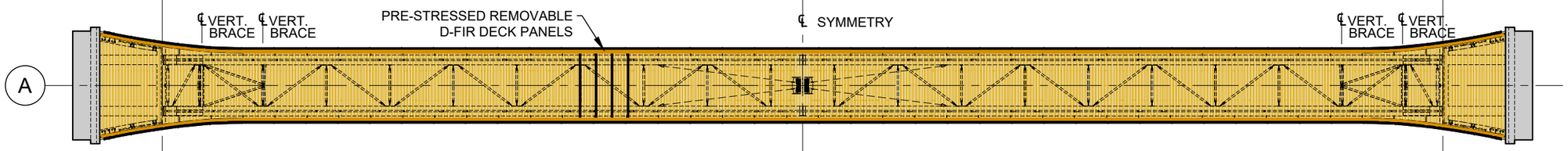

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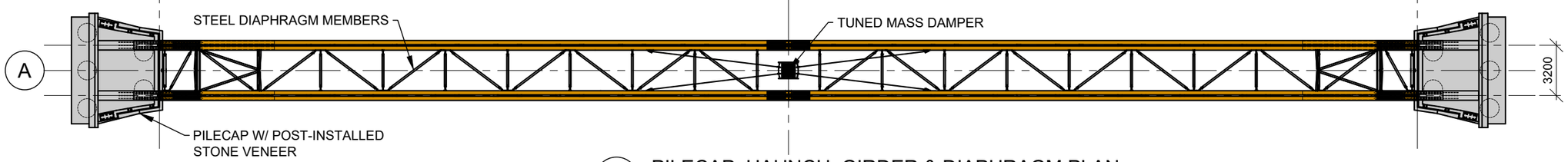

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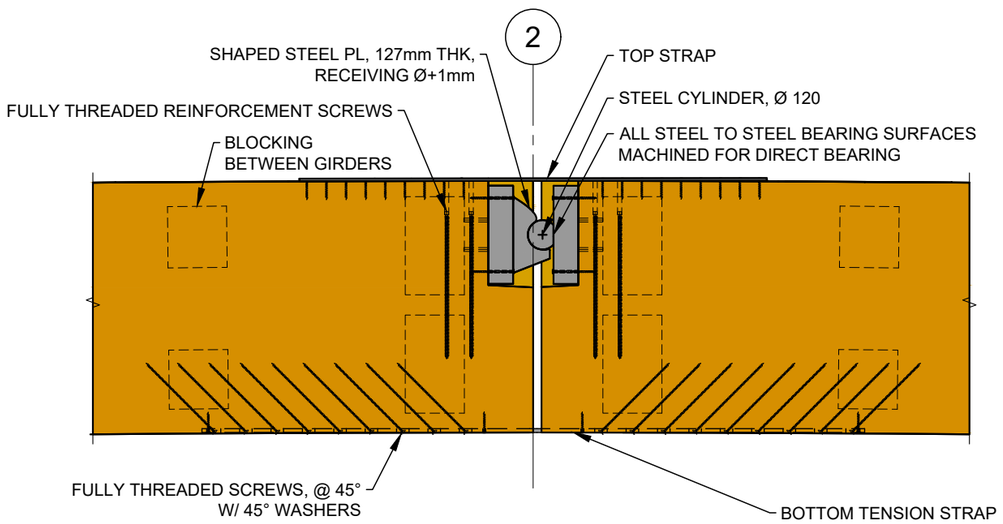

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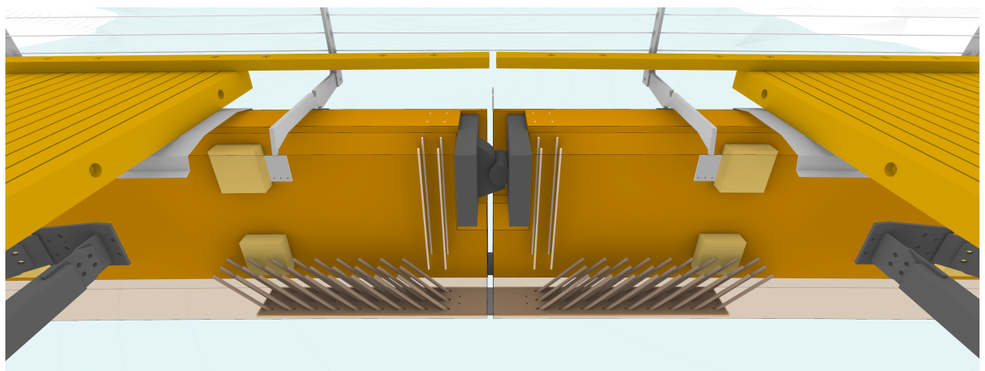

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PROJECT
NANCY PAUW FOOTBRIDGE, BANFF

TITLE
BRIDGE GEOMETRY & MID-SPLICE

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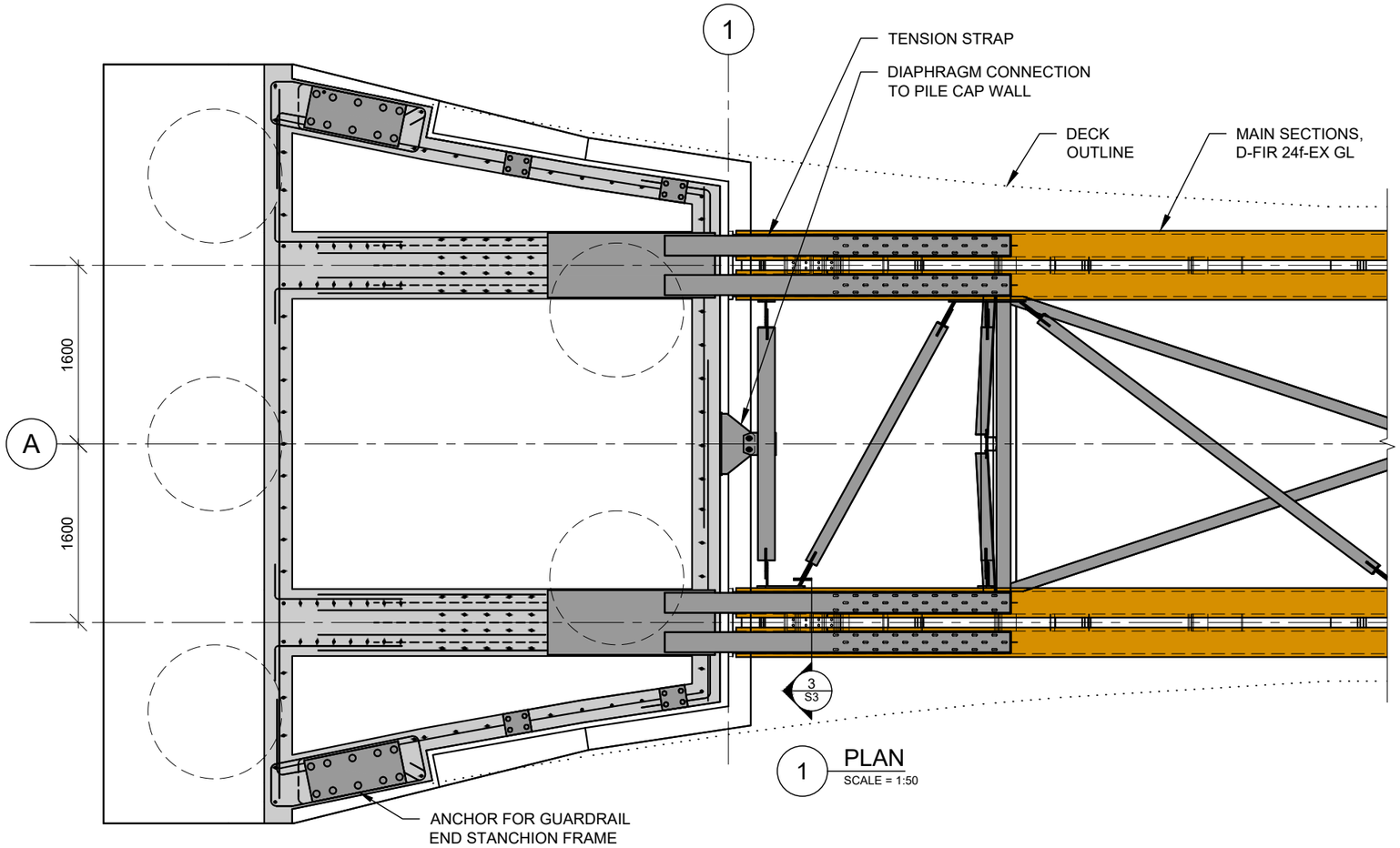

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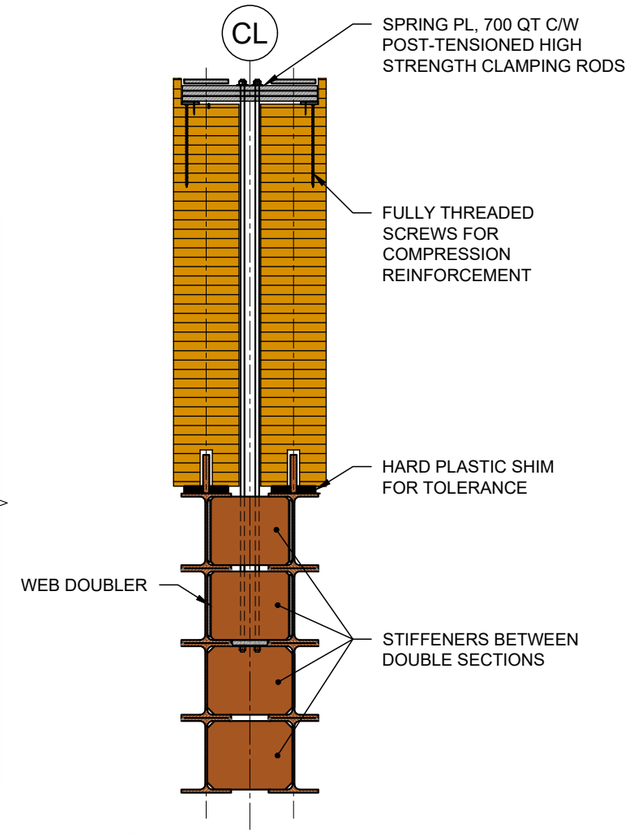

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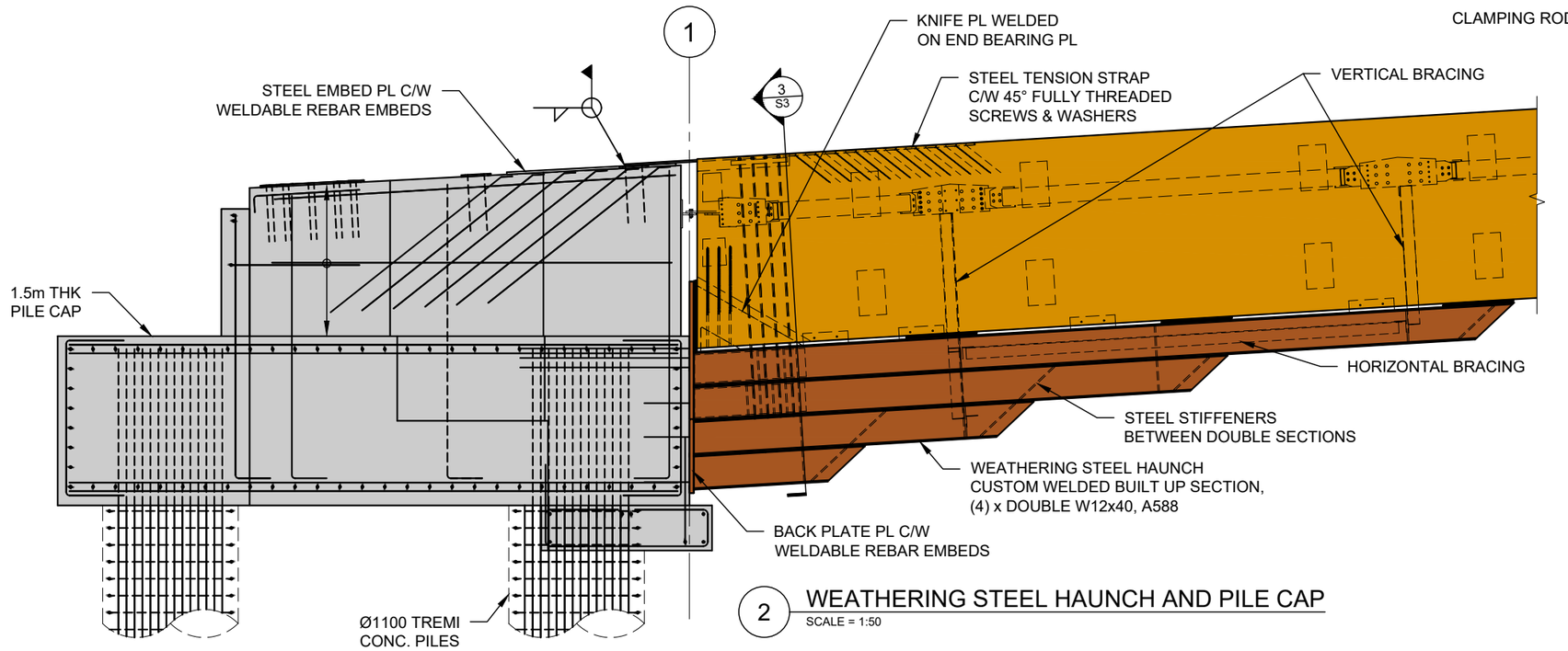

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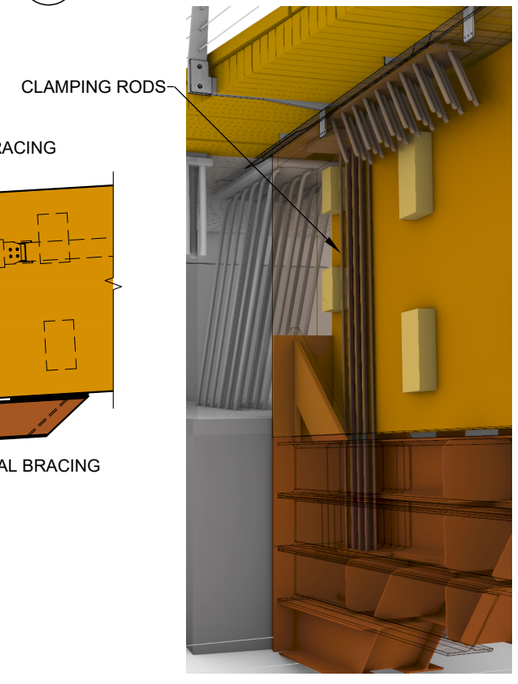

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CLIENT
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PROJECT
NANCY PAUW
FOOTBRIDGE, BANFF

TITLE
ABUTMENT & STEEL
HAUNCH DETAILS

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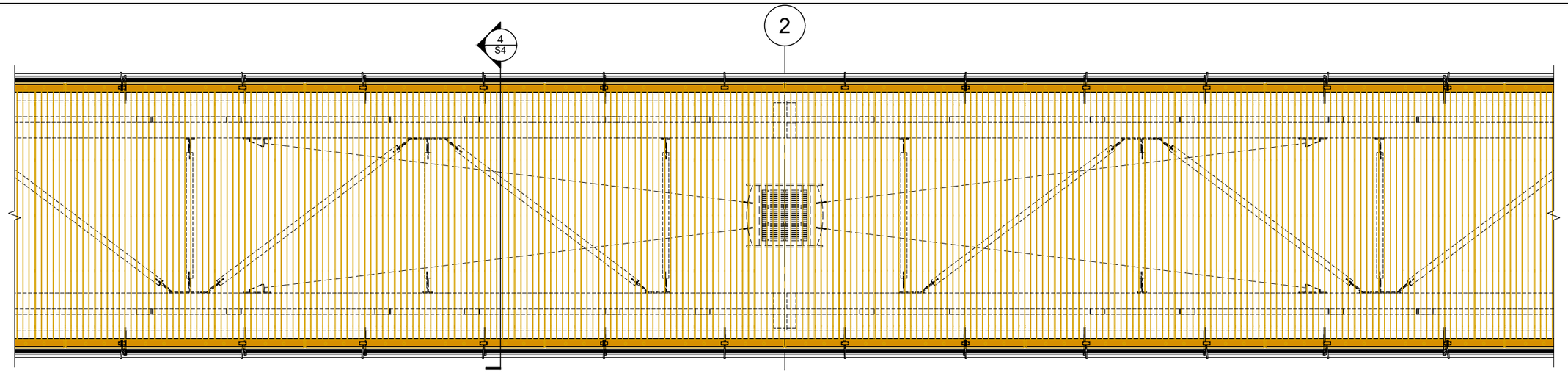

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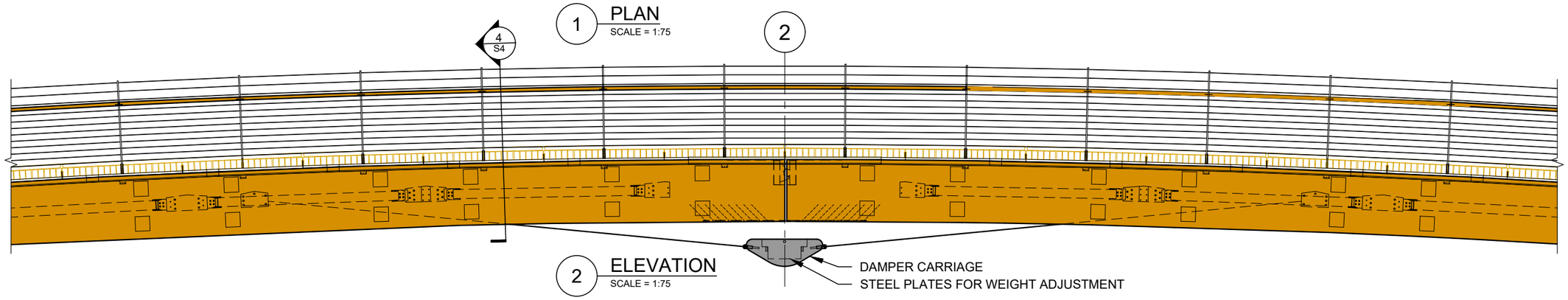

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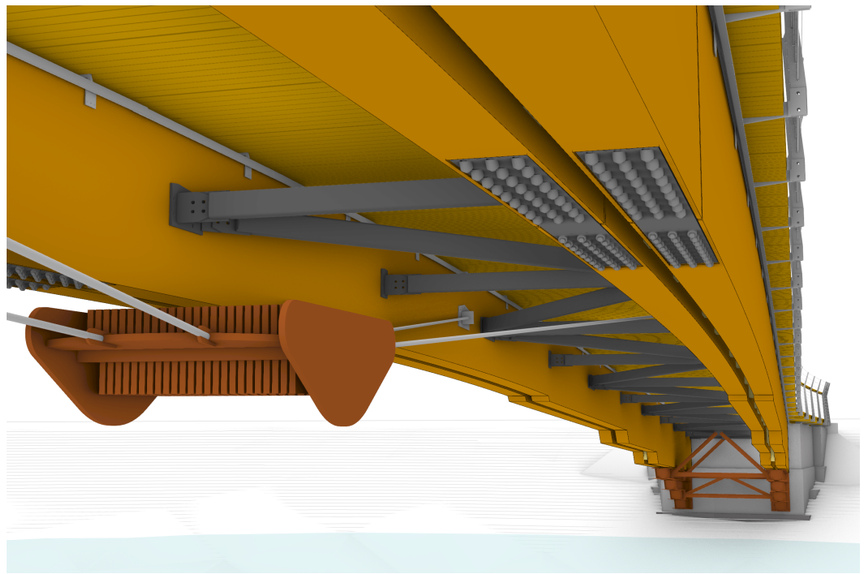

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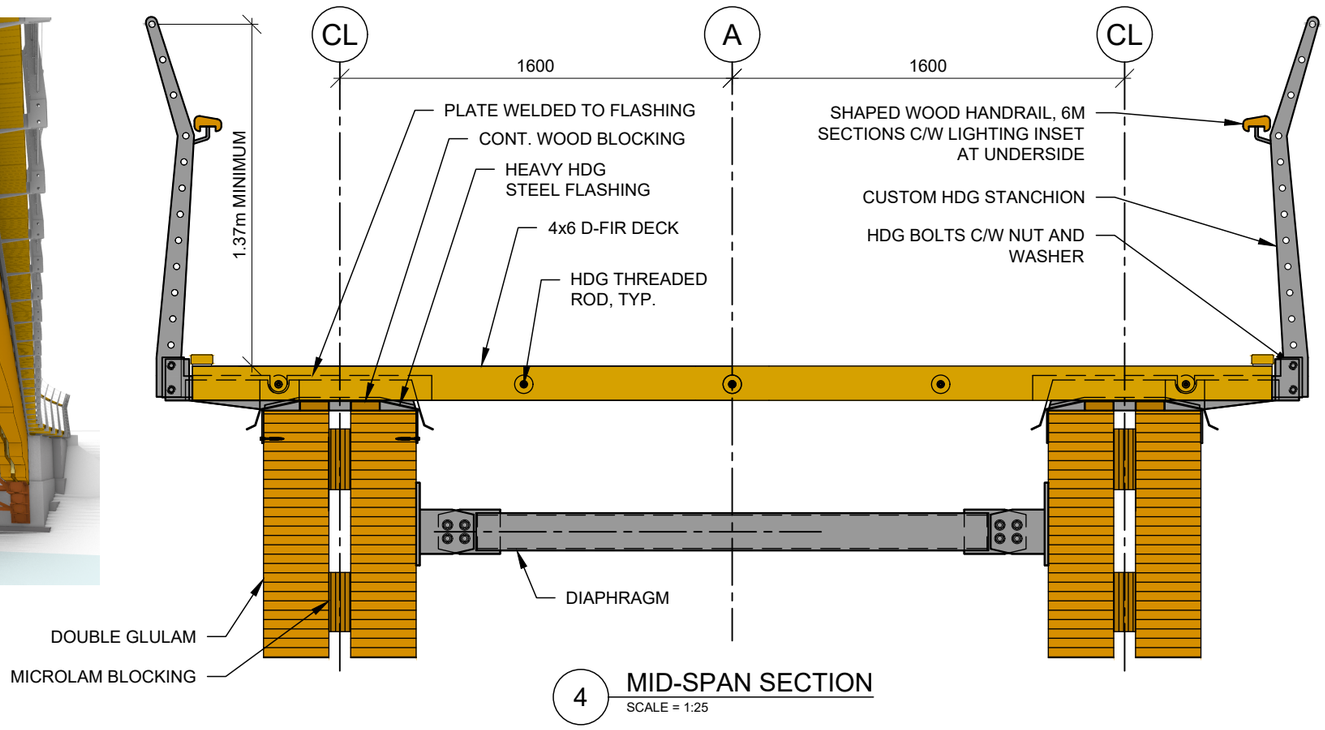

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CLIENT
TOWN OF BANFF

PROJECT
NANCY PAUW
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TITLE
DECK, RAILING & TMD
DETAILS

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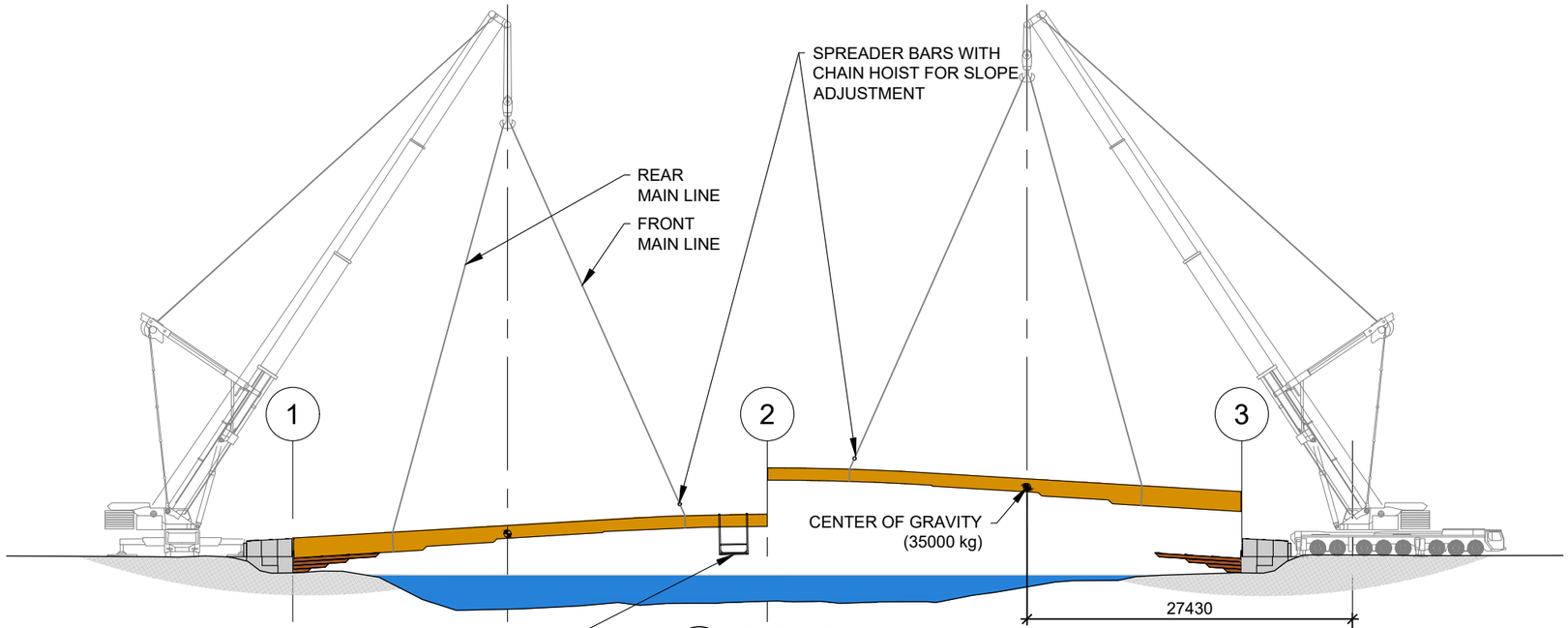

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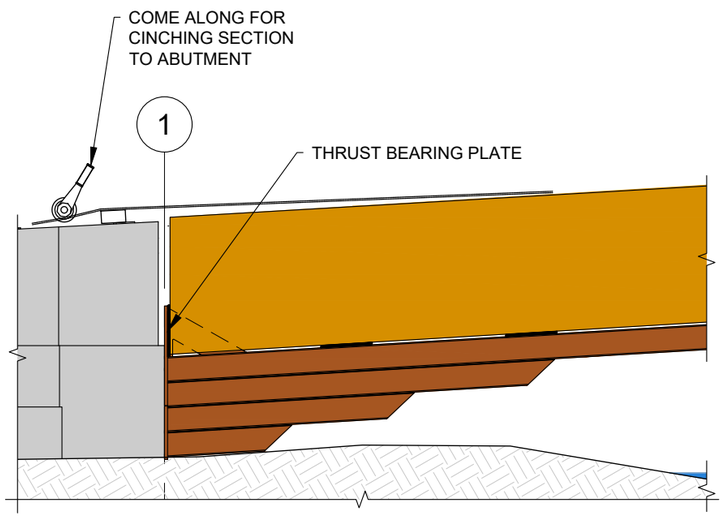

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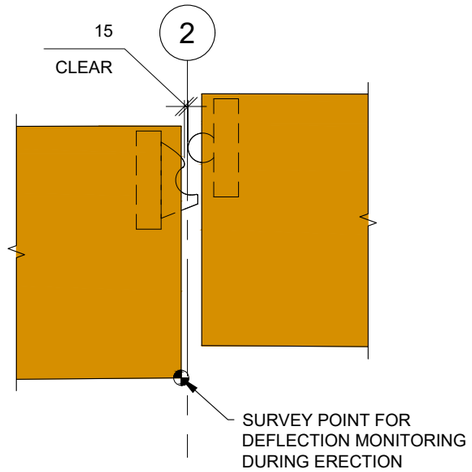

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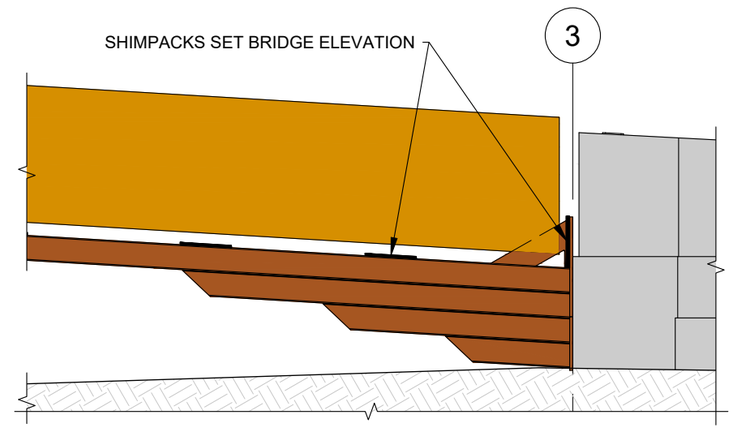
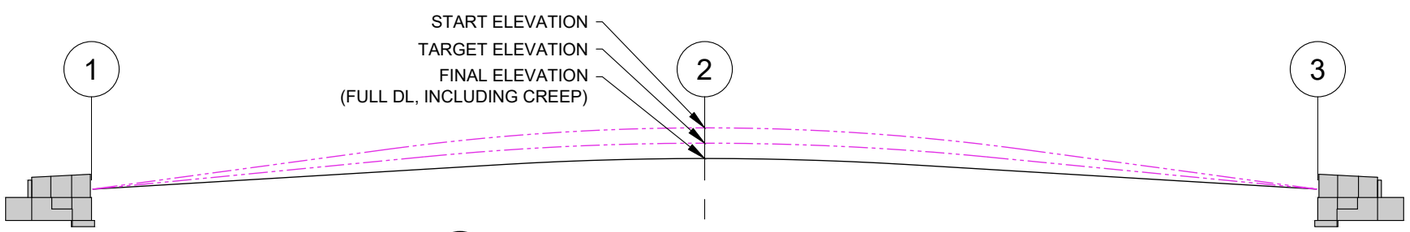


4 NORTH ABUTMENT ELEVATION
SCALE = 1:75



5 CONSTRUCTION STAGE ELEVATIONS
SCALE = NTS

ERECTION PROCEDURE:

1. Lift South bridge section first, with tip slightly above Start Elevation.
2. Cinch haunch end tightly into bearing plate with come-along.
3. Cinch bridge section end down to haunch with pre-stressed rods to allow workers to proceed onto span.
4. Place North bridge section, engaging central pin to south section prior to final lowering.
5. Do a test lowering to engage with shim pack at north abutment Thrust Bearing Plate
6. Measure centre span elevation to achieve Target Elevation and add shims at North Abutment as required.
7. Confirm Target Elevation

REV.	DESCRIPTION	DATE

ISSUED

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CLIENT
TOWN OF BANFF

PROJECT
NANCY PAUW
FOOTBRIDGE, BANFF

TITLE
ERECTION
PROCEDURE

DRAWN: BOG
CHECKED: LT/GE
DATE:
JOB No. S402
REVISION
DWG. No.
E1