Jubilee Bridge
Structural Condition Assessment Report
(Post Auckland Extreme Weather Events)

Panmure Basin, Lagoon Drive, Panmure

Job No. 21785

Issue Numbers and Revisions

Issue	Description	Author	Date
A	DRAFT	Jonah Tahir	17 July 2023
B	FINAL	Jonah Tahir	19 July 2023

Document Acceptance

Action	Signed	Author	Date
Prepared By		Jonah Tahir	19 July 2023
Reviewed by		Dmitri Mouravlev	19 July 2023
Approved by		Charles Cumming	19 July 2023
On behalf of		CLC Consulting Group Ltd	

© CLC Consulting Group Limited (unless CLC has expressly agreed otherwise with the Client in writing)
This report has been prepared by CLC Consulting Group Limited on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which the Client has not given its prior written consent, is at that person's own risk.

+IMPAC PREQUAL HEALTH & SAFETY ASSESSED
ENGINEERING NEW ZEALAND OFFICIAL MEMBER
ace new zealand association of consulting and engineering
Telarc. Registered Quality ISO 9001

Contents

Appendices

1. Introduction

1.1 Background

Jubilee Bridge is located in East Auckland; it closes the loop for the McCullough Walkway that circles the Panmure Basin. The bridge is heavily used by pedestrians, joggers, and bikers alike to travel/ exercise around the Panmure Basin.

Figure 1: Jubilee Bridge location (Source: Google Maps)

The Jubilee Bridge was constructed circa 1984 and is an asset owned by Auckland Council. The intended design life of the bridge is assumed to be 50 years. Auckland was subject to two extreme weather events, stormwater flooding (27 January to 2 February 2023) and then Cyclone Gabrielle (8 to 12 February 2023). In response to the two closely timed severe weather events, CLC was commissioned by Auckland Council to carry out a visual structural engineering condition assessment of the bridge.

1.2 Purpose of the Report

This visual structural condition assessment focuses on the structural condition of the bridge, identifies any resultant impacts from the recent weather events on the structural performance of the bridge (if any) and identifies any structural performance issues that require an action plan to remediate. This report will be used by Auckland Council to assist in making decisions on the required remedial actions to respond to the issues identified, with an overriding aim to ensure public safety when using the bridge is not compromised.

1.3 Existing Structural Drawings

We compared the observed as-built condition of the bridge against the build details shown on the structural drawings, which had been prepared by Kevin D. Kelly & Assoc (dated April – July 1983). The as-built condition of the bridge is relatively similar to the build details that were shown on the reviewed drawings. We note, however, that some improvements had been completed since the bridge was built, and these were identified as being around the abutment/ foundations areas as well as some of the salient structural plate connections. At some point, the bridge also appears to have been repainted.

1.4 Previous Reports.

The most recent Rapid Structure Assessment Report, by Auckland Council's in-house assessor (dated 31 January 2023), assesses the bridge to be generally in poor condition (Condition Grade – CG4), which is functioning but with extensive deterioration and renewal is required. We understand that Council has progressed with a replacement bridge design which is currently being tendered.

The Issues and Options Report prepared by Opus (dated September 2013) mentioned the bridge structure was in adequate condition but with an overall poor appearance. Many of the defects recorded were generally seen to be in their early stages of impact. Of particular concern was the moisture content of the main timber members. The painting of the bridge was foreseen to be the highest priority maintenance work to ensure the long-term durability of the bridge. There was also an earlier report from Blue Barn Consultants (mentioned in Opus's report); however, we do not have access to this earlier report.

2. Site Visits

A senior structural engineer from this office visited the site to conduct a visual structural condition assessment on the bridge on 23 February 2023. The easily accessible parts of the bridge were visually inspected to record the current conditions. The parts of the bridge that were not easily visible/ accessible (e.g., top parts of arches, the underside of the deck, external elevations, and base piers) were inspected by employing aerial surveys and photographs. This work was completed by a professional drone specialist, NZ Drones. NZ Drones are CAA Part 102 certified and employ Ultra-High Resolution (UHR) close visual inspection, which captures detailed graphical still images and video.

In addition to the visual and Drone Inspection mentioned above, Wilcon Sylvan Parks and Landscape Management (WSPLM) were engaged to undertake timber sampling investigations at specific locations using a Resistograph IML Resi F400-S measuring tool. These sampling investigations were carried out on 7 June 2023. Test locations were selected by our staff, considering the importance of the locations to the overall structural performance of the bridge but also balanced by considering the safety & accessibilities of the locations for the sampling investigations carried out by WSPLM personnel. The test locations were recorded in the WSPLM report dated 3 July 2023 (refer to Appendix B).

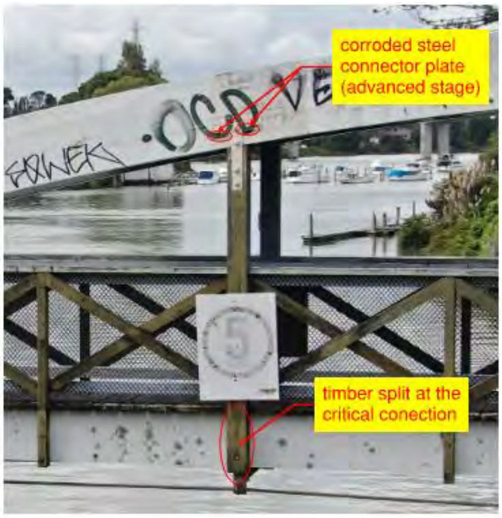
3. Findings from Visual Structural Assessment.

From our visual assessment, and in agreement with the previous reports, the bridge is assessed as in very poor condition. The ability of the bridge to function as intended has been reduced/ compromised by the many structural issues we observed during our site visit and which were confirmed by the detailed Drone survey footage.

3.1 Hangers

The timber hangers comprise 150x150 timber posts hung from the laminated timber arches and are used to support the main horizontal carriageway (decking) beams. As can be seen from Figure 2a, there are serious structural problems that have been observed:

- Splitting of timber has occurred at the bolted connections between the hangers and the main horizontal beams. These bolted connections are critical connections by which the main horizontal beams are supported by the top laminated arches, and the timber splits here can significantly reduce the capacities of these structural connections.
- The T-shaped structural steel plates at the top of the hangers have mild to advanced corrosion. Similar to the bolted connections at the bottoms of the hangers, these T-shaped steel plates are also critical to the overall structural performance of the bridge. The bridge deck would be at an increased risk of collapse if any of these steel plates were to fail.
- One of the timber hangers on the northern side of the bridge is showing signs of decay; see Figure 2b



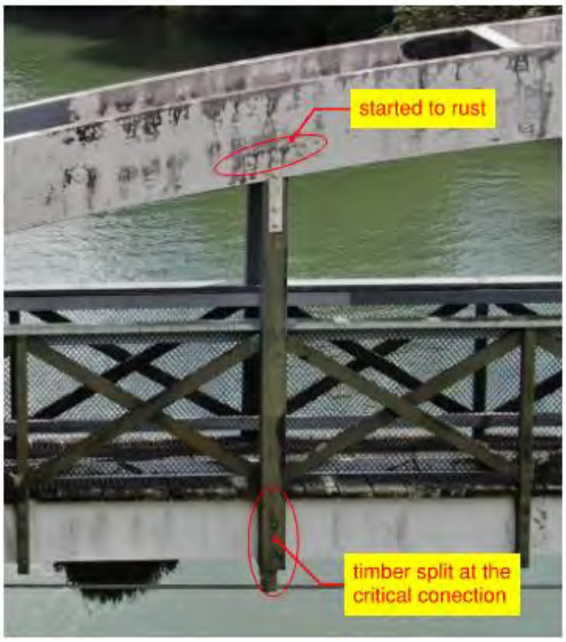


Figure 2a: Timber splits and corrosions at the hangers

Figure 2b: Condition of one of the hangers on the Northern side.

3.2 Main Laminated Timber Arches

The paint/ protective coating system of the main timber arches was observed as being in poor condition; the paint was flaky and stained. Areas of moulds are visible across most parts of the arch beams. Decayed and rotting timbers are also observed along the lengths of the arches. Without extensive invasive investigation and laboratory testing, the severity of the decayed timber impact is difficult to determine from inspection alone. See Figure 3a for the conditions of the main arches.

Figure 3a: Conditions of the laminated timber arches

The main timber arches are supported at each end by concrete abutments. It can be seen from Figure 3b that the bottom supports of these main arches are affected by water, which has been held at these locations due to the build-up of trapped debris comprising leaf litter and vegetation, causing the timber ends to be essentially in contact with the ground. From the information provided by the previous Opus report, the main timber arches are known to be treated to H3.2, which is not adequate when the bottoms of the main arches are in contact with the ground. The main timber arches should be treated to a min of H4 to meet the durability requirements. In lieu of treating the timber, the base areas need to be reconstructed such that entrapment of leaf litter and vegetation is prevented. Further in-depth investigation and laboratory testing of the leg areas of the arches is required to assess the degree/ extent of any decayed timbers.

Figure 3b: Support conditions of the main timber arches

3.3 Main Laminated Horizontal Beams

The main laminated horizontal beams were found to be in better condition compared to the timber arches. However, the paint/ coating system is showing signs of ageing; mouldy, discoloured areas are visible on areas of the beams (more apparent towards the west bank). Small areas of timber decay/ rot are also present.

Figure 4: Conditions of the laminated timber main beams

3.4 Plywood Diaphragms and Box beams

There are plywood diaphragms and box beams which make up each bracing unit, and these connect and provide lateral restraints between the two arches. All of these were seen to be in very poor condition. The external faces of the tanalised plywood panels were observed as in an advanced stage of decay, with numerous edges partially or fully detached from the supporting timber members. One of the bottom plywood diaphragms on the eastern end of the bridge was observed with a large hole in it. There was no longer any detectable protective paint coating visible.


Figure 5: Conditions of the plywood diaphragms and box beams

3.5 Barrier System – Handrails, Infills and Balustrades.

In general, the handrails are seen to be in poor to very poor condition. The paint/ coating system is damaged and no longer provides adequate protection. Rather than using pre-drilled screws to connect the handrails to the uprights, nails have been used instead. Some nails, positioned too close to the edge of the members & inserted into the side grains of the timbers, have caused the handrails to split. These splits, together with inadequate edge distances for some of the nails, compromise the structural integrity of the handrails to transfer loads to the uprights.

The 100x75 balusters are spaced at approximately 1.5 m crs; by inspection, the existing balusters are not adequate to resist the minimum barrier loads described in Table 3.3 AS/NZS 1170.1:2002. The structural capacities of the shorter balustrades closest to the main arches are also further compromised due to their inadequate bottom connections, see Figure 6.

The cross timber infills are found to be in fair/poor condition. We cannot verify their connections to the balustrades from the existing drawings.

Figure 6: Conditions of the timber handrails and balustrades

3.6 Timber Deck Boards

The timber decking boards were found to be in poor condition overall. The timber fibres at the surface of the boards were failing as the result of prolonged exposure to environmental conditions, ultraviolet and water damage. In some areas, it appeared that the inner layers of the boards were starting to be affected. On the underside of the boards, watermarks and mouldy conditions starting from the edges (gaps between the boards) were observed. This wet condition encourages fungi to grow and exacerbates the decay of the deck boards.

As mentioned in the previous Opus report, apart from resisting gravity load, these deck boards also contribute to the lateral load-resisting system of the bridge by acting compositely with the main horizontal beams. The boards' current state and unconfirmed connections to the main horizontal beams do not appear to be structurally adequate to provide the lateral load-resisting system for the bridge.

Figure 7: Conditions of the timber deck boards

3.7 Timber Piers & Diagonal Braces

Visually, it appears that there is an onset of timber decay, especially at the lower parts of the piers and diagonal braces, see Figure 8. Of particular concern is the detail of the bottom connection of the piers; the piers are not elevated off the steel plate to create a gap for the water to escape fast enough and keep the bottom of the piers dry. Due to this constant wetness, the bottom of the piers is starting to rot. Further, in-depth investigation and laboratory testing of the leg areas of the piers is required to assess the degree/ extent of any decayed timbers.

The upper parts of the piers, apart from the visible dampness and discolouration of the horizontal members, which is directly supporting the main deck beams, appear to be in better condition.

Figure 8: Conditions of the timber piers

3.8 Sway cable system

There are numerous structural issues with the sway steel cable system that have been observed:

- Some of the galvanised RHS steel beams to which the 26dia cables are anchored are in poor condition and showing signs of severe corrosion.

Figure 9: Conditions of RHS steel beams under the bridge

- Most of the U-shaped bolts and nuts of the sway cable system are severely corroded; one of the nuts could also be seen as almost completely detached.
- The cable themselves appeared to be very loose, bringing their ability to be engaged to restrain the bridge from lateral swaying in question, see Figure 11.
- Surface corrosion has started on the sway cable; see Figures 9 & 11.

Figure 10: Conditions U bolts and nuts

Figure 11: Conditions sway cables

3.9 Concrete abutments – post Auckland flood events.

There was no visible movement of the concrete abutments or ground directly supporting the abutments following the Auckland flood events in the last week of January 2023. There was a small landslip observed, which was off to the southern side of the western abutment. However, this was noted as being sufficiently detached from the abutment to have not raised any concern.

Figure 12: Conditions of the eastern bank of the bridge – Post Auckland flood event

Figure 13: Conditions of the western bank of the bridge – Post Auckland flood event

4. Findings from Recent Site Visit for Timber Samplings Investigation

The more recent site visit on 7 June 2023 was for the purposes of the timber sampling investigation works. Our staff and the WSPLM personnel who carried out the investigation managed to get to the bottom support of the timber arche on the Watene Road end via a steep slope filled with dense vegetation. However, due to the steep slope, we could not transfer the Resistograph testing equipment down to the abutment area. Therefore, only visual inspections and manual probing with a tool were done for some areas at the base of the main timber arches and piers. Access to the bottom of the main timber arches on the Lagoon Rd side was impossible without the appropriate safe access provisions.

Comparing the conditions of the base of the main timber arches that were observed during the recent site investigation and the previous site investigation back in 2013, it's apparent that the bottom of the main arches has deteriorated further, and decay is noticeably in a more advanced stage (see the comparisons in Figures 14-

15). We also observed that the timber piers supporting the main horizontal beams were at an advanced deterioration at the ends (refer to Figure 16).

Figure 14: Side-by-side comparison of the base of the main timber arches on the Watene Rd side – Southern arches.

Figure 15: Side-by-side comparison of the base of the main timber arches on the Watene Rd side – Northern arches.

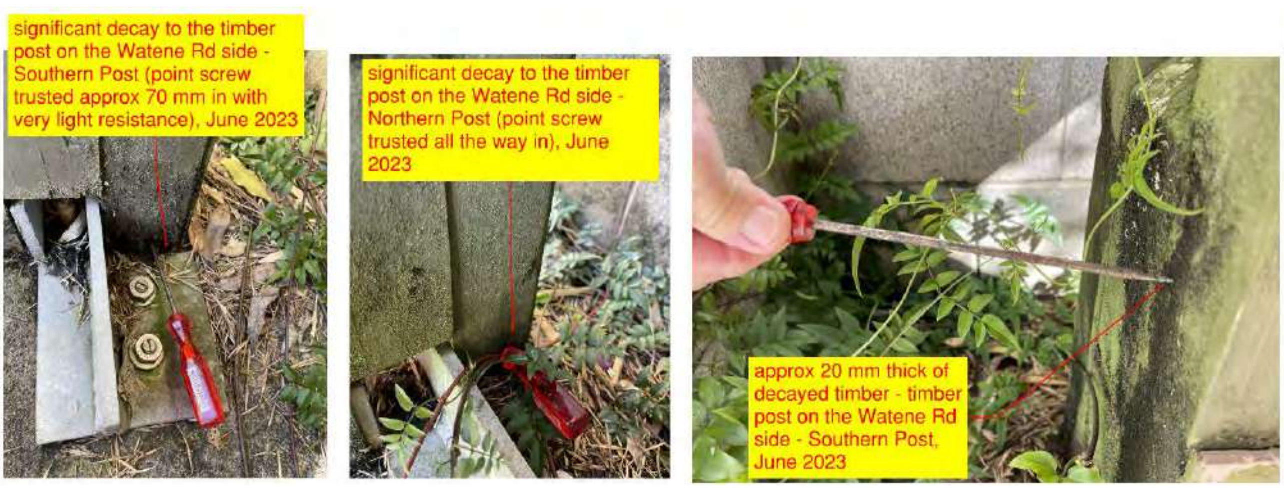


Figure 16: Conditions of timber posts supporting the main horizontal beam – Watene Road end.

Apart from the up-close visual investigation and manual probing mentioned previously, WSPLM did the Resistograph tests at several selected locations of the main timber arches and the main horizontal beam of the bridge (see Figure 17 for Resistograph test locations).

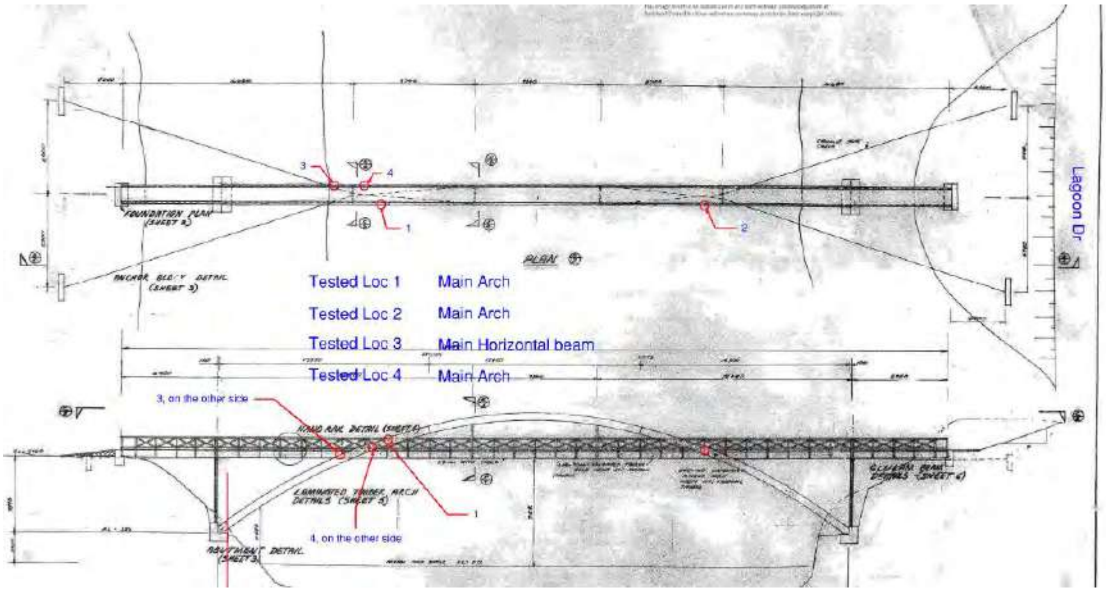


Figure 17: Resistograph test locations

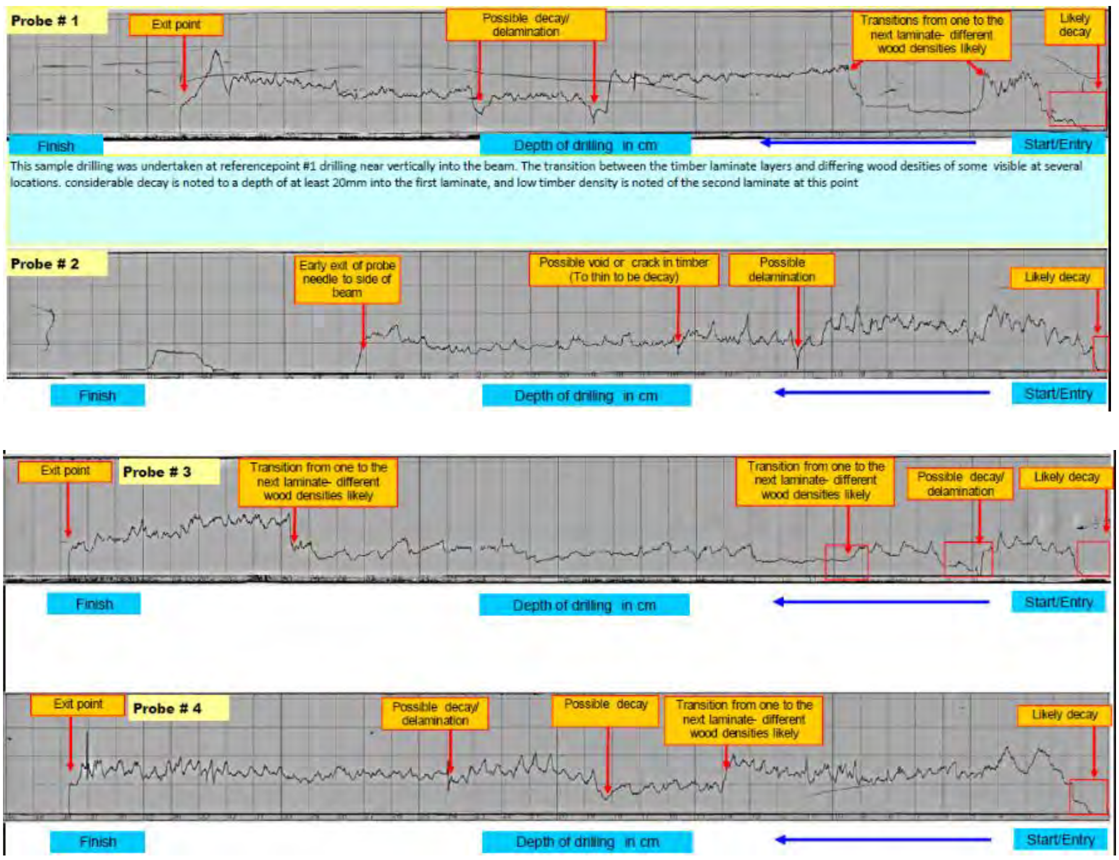


Figure 18: Resistograph test results and their interpretations.

As can be seen from Figure 18, the Resistograph test results were far from conclusive. Without taking cored samples of the timbers for proper laboratory tests, it is just too difficult to tell whether the less resistant parts of the timber were caused by decay, delamination, varying timber densities between the laminated timbers, imperfections or voids which were incumbent at the time of fabrication.

5. Discussion & Recommendation

Sections 3 & 4 of this report show that the bridge is in very poor condition, both structurally and visually (this can cause anxiety and nervousness to users when approaching the bridge). The bridge requires extensive remedial work as soon as practically reasonable to prevent the risk of collapse. The order of works required is as follows:

1. Replace the split timber hangers, including the T-Shaped steel plates where mild to advanced corrosions have been observed (refer to section 3.1 of this report). If visually acceptable, we suggest adding the new hanger adjacent to (or a certain distance away from) the existing split hanger without removing the existing one. This will provide structural redundancy to the bridge. This work should be done as soon as reasonably practicable (within one month from the date of this report). The bridge must be closed off for public use when this work is in progress.

2. Expose areas of timber members that are within the plywood diaphragms and box beams; these areas of the timber are the most susceptible to water and where moisture can become trapped and cause the most damage or decay to the timber. Additional probing with Resistograph may be required should the timber inside the plywood diaphragms & box beams display signs of deterioration. This work can only be carried out when the wind is calm under the supervision of a suitably qualified structural engineer. The bridge must remain closed for public use until the new plywood diaphragms & box beams (like for like, including their connections) are installed. (Note that the new plywood diaphragms & box beams will only be installed if the decision is made that the bridge is still feasible to be kept for a certain period of time until the new bridge is built. Before installing the new plywood diaphragm and box beams, areas of the main arches that are to be covered within the box beams are to be prepped and repainted). This work should be done as soon as reasonably practicable, ideally one month from the date of this report and will need to be carried out in stages; one bracing element at a time is to be removed and repaired before moving to the next.

3. Remove the rust stain/surface corrosion on the sway cables and recoat the cables with a zinc-rich compound. The remaining cable sway system needs to be examined (i.e., the corroded bolts, nuts, cleats & RHS beams). All the corroded bolts & nuts are to be replaced with HDG bolts, and all the corroded RHS beams and steel cleats are to clean and prepared for repainting with zinc-rich paints. Replace the corroded turn buckles and apply the correct tensioning to the sway cables (at their current state, the sway cables are loose, they won't provide efficient lateral restraints to the bridge). We recommend this work be done within three months from the date of this report.

4. Replace the entire balustrade. The current handrails and their nailed connections are in very poor condition; the cross timber infills are in fair to poor condition with unverifiable connections to the balustrades. By inspection, the uprights @ 1.5 m crs do not appear to be structurally adequate. (see Section 3.5). We recommend this work be done within six months from the date of this report.

5. Replace the timber decking (boards), including anti-slip measures, within six months from the date of this report.

6. Extend steel plates and add additional bolts at the base of the piers/posts supporting the main horizontal beams to compensate for the decayed timber ends at the very bottom of the piers. We recommend this work be done within six months from the date of this report.

7. Clean out the bridge abutment of all debris. This maintenance work should be inspected and maintained periodically, ideally every month.

8. Clean and prepare for painting including the repair of any damaged areas and then paint the timber arches and horizontal beams with an appropriate paint system. This work should be carried out within six to twelve months from the date of this report.

9. The existing signage noting a capacity limit for a maximum of 10 people on the bridge at a time, which is placed at each end of the bridge, is to remain and be made more prominent and noticeable. Clear vegetation and move signage into a closer position to the Bridge entry points.

We recommend for these remedial works be started as soon as reasonably practicable within the time frame suggested above. Based on the progression of the decays at the base on the main arches between 2013 – 2023, we estimate the bridge can remain safe for public use for the next five years upon the completion of the full scope of recommended remedials works. The condition of the arches, horizontal beams and piers are to be inspected by a qualified structural engineer on a three-monthly basis to monitor the progress of the decays or other deterioration, especially at the bases of the arches and piers.

6. Conclusion

The existing bridge, in its current state, cannot remain in service for the 11 years left of its 50 years of design life. Critical remedial works, as mentioned in Section 5 of this report, are required to avoid the risk of the bridge collapsing due to failures resulting from the defects that have been identified.

Due to the sheer enormity of the scope of works required and the ongoing requirements for an inspection and maintenance regime, it is more economical to as soon as practicable close the existing Bridge. This recommendation is made on the basis that the new replacement Bridge has been designed, consented and is currently being tendered for construction starting this year, 2023. The time required to complete the highest priority remedial works would likely overlap with the commencement of the new build of the replacement Bridge and during the period of remedial works the Bridge would need to be closed. Early notice of the closure and acceleration of the tender process should be encouraged.

7. Limitations

This report has been prepared for Auckland Council in relation to the Jubilee Bridge at Panmure Basin, Lagoon Drive, Panmure. This report has been prepared only for the use of our Client.

All other parties should seek their own professional advice in relation to the continuing validity of this report for their intended use. CLC Consulting Group Ltd will not accept any liability by any other person or entity other than Auckland Council in any way whatsoever in relation to this assessment.

Appendix A – Previous Reports

Rapid Structure Assessment Report

31/01/2023

Requester: Marcel Morgan **Assessor:** Nicky Aziz **Reviewer:** Ben Meadows

Description	Jubilee Bridge		
Asset Group	Bridge	**SAP ID**	1000585772
Site Description	Panmure Basin	**Condition Grade**	4
Address	Panmure Basin	**Local Board**	Maungakiekie-Tamaki

1. Summary

Marcel Morgan requested this report to assess the structure's condition after the recent flooding event in Auckland.

The structure is generally in poor condition (Condition Grade 4 - CG4), functioning but with extensive deterioration and renewal required. The structure can be used by members of the public after the proposed maintenance works have been completed, but considering other defects to the bridge, not in the long term. It was also noted that although there are no noticeable defects to the bridge due to recent flooding events, there appear to be new slips on each sides of the gulley (at both ends). The vertical cracks to the piles have also become more apparent than when previously inspected (2021).

2. Proposed Maintenance and Renewal Works

The following table summarises the works required to improve the structure to a good condition, and an indicative cost for the works is also included. The indicative costs do not include the cost of any building consent, contingency or project management costs.

S/N	Proposed Immediate and Maintenance Works	Cost Estimate ($)
1	Replace the broken non-slip mats	BAU
2	To engage a specialist Structural Engineer to assess the condition of the bridge every 6 months before the new bridge completed	TBC
		-

S/N	Proposed Renewal Works	Cost Estimate ($)
1	Monitor the condition of the bridge and the surrounding cliff/gulley during the construction stage of the new bridge.	TBC
		-

3. Condition Grade Table

Element Condition			
Element	**Material(s)**	**Condition**	**Comments**
Piles / Poles	Timber	4	Cracks visible
Post	Timber	3	
Bearer	Timber	4	Cracks visible
Joist	Timber	3	
Barrier	Steel	4	
Rails	Timber	4	Rotten
Decks	Timber	4	Non-slip mats damaged, also at their 'end of life'
Fixings	Galvanised Steel	3	
Abutments	Concrete	3	

APPENDIX A - PHOTOGRAPHS

 1. Timber piles show splitting	 2. Steel cable obstructed by vegetation
 3. Typical: Damage to non-slip mesh	 4. No erosion to the concrete footing
 5. New slips beside the bridge on the west end	 6. New slips beside the bridge on the east end

APPENDIX B – CONDITION GRADE MATRIX

ELEMENT	CONDITION GRADE – CG				
	CG1	**CG2**	**CG3**	**CG4**	**CG5**
	Very Good Condition	**Good Condition**	**Moderate Condition**	**Poor Condition**	**Very Poor Condition**
Estimated Proportion of life consumed	Up to 45%	Between 45% to 90%			90% to 100%
Structure	Sound structure.	Functionally sound structure.	Adequate structure, some evidence of foundation movement, minor cracking.	Structure functioning but with problems due to foundation movement. Some significant cracking.	The structure has serious problems, and concern is held for its integrity.
Maintenance	Well maintained and clean.	An increased maintenance inspection is required.	Regular and programmed maintenance inspections are essential.	Frequent maintenance inspections are essential—short-term element replacement/rehabilitation.	Minimum life expectancy, requiring urgent rehabilitation or replacement.
Customers	No customer concerns.	Deterioration causes minimal influence on occupational uses—occasional customer concerns.	Some deterioration is beginning to be reflected in minor restrictions on operational uses—customer concerns.	Regular customer complaints.	Generally not suitable for use by customers.

Auckland Council

Jubilee Footbridge Panmure

Issues and Options Report

Auckland Council

Jubilee Footbridge

Panmure

Issues and Options Report

Prepared By	Nick Broad Structural Assets Engineer	Opus International Consultants Ltd Takapuna Civil Level 1, 12 - 14 Northcroft St, Takapuna PO Box 33 1527, Takapuna, North Shore City 0740 New Zealand
Reviewed By	Ian Leach Principal Engineer - Bridge Structures	Telephone: +64 9 488 4570 Facsimile: +64 9 488 4571 Date: September 2013 Reference: 1-95477.00 NSR 013/057 Status: Final (Rev 0)
Approved for Release By	Matiul Khan Team Leader - Structural Asset Management	

© Opus International Consultants Ltd 2013

Contents

1 Executive Summary

This report focuses on the structural issues and the remedial solutions for Jubilee Footbridge. The purpose of this work and report is to allow the Owner, Auckland Council, to plan for the bridge's future whether they choose to repair the bridge or programme for replacement.

From the structural assessment the only regions of concern are the arch/deck beam connections, and the hanger/deck beam connections. These areas can (generally) be strengthened with the inclusion of steel plates and additional bolts. In their absence, the bridge is not capable of supporting the loads prescribed by the NZ loading standards.

The bridge structure was seen to be in an adequate condition during the detailed inspection but with a poor overall appearance. However many defects noticed were generally seen to be in their early stages. Of particular concern is the moisture content of the main timber members. The painting of the bridge is foreseen to be the most needed maintenance works required to ensure the long term durability of the bridge. Furthermore, it is also the most complicated and costly task due to the likely resource consent requirements. The removal of the deteriorated paint, the drying of the timber and the subsequent re-application of a protective coating is paramount to the satisfactory future performance of the structure. To achieve this full containment of the removed paint is highly likely to be required.

An indicative cost to complete the suggested repairs and remedial works has been prepared. At this stage, these costs are based on preliminary details which are considered feasible (the accuracy should be considered +/-40%). The expected cost to repair the bridge ranges from $320,000 - $595,000 whilst a full bridge replacement (like-for-like) is considered to be approximately $568,000.

Following the detailed inspection and the detailed structural analysis, the following recommendations are made:

» Apply a load restriction on the bridge immediately, "Bridge Limit Warning - No more than 10 people on the bridge at a time".
» Obtain confirmation on the required level of paint containment to meet resource consent. This will likely require a resource consent application to be prepared and lodged.
» The future of the footbridge, whether it is to be repaired or replaced, requires review by Auckland Council. This review and subsequent decision needs to be made within the next year to avoid costly deterioration of the structure.
» If repair is required, instigate the moderately urgent works within the next 6 months (section 6.3).
» Design the proposed strengthening measures for the connection details OR prepare design for a replacement structure.

If it is decided to keep the bridge, it is recommended that a resource consent application to discharge the deteriorated paint into the surrounding environment is sought from Auckland Council. If consent can be granted to avoid more costly containment measures, then it is recommended that all the suggested repairs contained in this report are completed in the suggested timeframes. This will enable the service life of the bridge to be extended by between 10-15 years from the date of this report.

If it is decided to replace the bridge, Auckland Council shall source funding, plan for and replace the bridge within the next two, to three years. If the bridge is to remain open whilst the replacement is planned, Auckland Council shall still complete the following items to ensure the safety of the users:

- Reinstate the holding down bolts to the main arch beams
- Reinstate the holding down bolts to the base of the pier legs
- Replace the (fractured) deck boards
- Improve the handrail fixing to main arch beam
- Replace the handrail mesh with a compliant alternative

Special inspections on the condition of the timber should be carried out at least at six month intervals to check that timber is not deteriorating at an unacceptable rate. During this time, it is recommended that Auckland Council source funding, plan and replace the bridge.

2 Introduction

2.1 Background

Jubilee Pedestrian Footbridge is an asset owned by Auckland Council. Following concerns about its condition the asset owner engaged Blue Barn Consultants to complete condition inspections to easily accessible parts of the bridge. The findings of their two reports recommended that a full inspection of the bridge should be undertaken together with a structural assessment to ascertain whether the bridge is able to sustain pedestrian loading in its current state.

2.2 Purpose

This report focuses on the structural issues and remedial solutions for Jubilee Footbridge. The purpose of this work and report is to allow the Owner, Auckland Council, to plan for the bridges future, whether they choose to repair the bridge or programme for replacement.

2.3 Previous Reports

A previous email report, dated 25/11/1998, presumed to be addressed to the owner's representative at the time, discusses the ineffectiveness of the lateral support cables. The report also mentions that City Design (former Auckland Council in-house structural engineers) looked into the possibility of moving the anchor points to improve their efficiency but was unable to identify a suitable location. The report concludes that the addressee should reassure the residents that the cables are safe.

2.4 Existing Drawings

Existing drawings by Kevin D. Kelly and Associates have been used in this study. It is not known whether these drawings are design drawings or as-built drawings. However, during the site inspection (15 August 2013) no significant discrepancies were noted suggesting the drawings may cautiously be treated as as-built issue.

3 Evaluation of the Life Span of the Bridge

Jubilee Footbridge was built in 1984 with an intended design life of 50 years (assumed). The remaining life of a bridge is however dependent on its maintained condition. An attempt has been made to estimate the remaining life of Jubilee Footbridge by taking the design life and current condition into consideration.

3.1 Issues

According to the bridge drawings, the material used for the main arch beams is No1 Framing, Radiata Pine treated to H3.2. The Roads and Traffic Authority of NSW and the NZ Timber Federation describe this material as a non-durable material and in its untreated state has expected service life of 5 years in a Hazard Class 3 (H3) environment. However, due to its availability and ability to be treated, its use in bridging applications has become common practice. However, the RTA of NSW recommends that the material is treated to a minimum of H4 in bridging applications (Roads and Traffic Authority of NSW, 2008). This highlights that the treatment level used at the time, design, specification and construction, is questionable.

3.1.1 Treatment

The glulam beams themselves were manufactured by McIntosh Timber Laminates in the early 1980's who have identified that the treatment level used is H3.2 (Griffiths, 2013). If the bridge was designed for the durability requirements of today, this timber would be expected to last a minimum of 50 years if suitably specified. However, the use of this material to this treatment level would need to be justified with the use of a protective coating system, good detailing at the time of construction and regular maintenance of the coating system.

Following a discussion with a McIntosh representative (Griffiths, 2013) it is understood that the preservative treatment used for the main arches is Copper Chrome Arsenic (CCA) whilst the preservative used for the original carriageway beams (main horizontal beams) was Ammoniac Copper Citrate (ACC). According to Griffiths the industry noticed relatively soon after the introduction of the ACC product, that it was not providing the hazard class rating it was intended to. As a result, the treatment manufacturer was liable for the replacement of the members. As such, the carriageway beams were replaced circa 1994 with new beams.

3.1.2 Detailing Issues

Generally speaking, any areas affected by site procedures such as cutting, drilling, nailing etc. that compromise the factory applied timber treatment shall be addressed. Following our site inspections we deduced that this was not addressed adequately at the time of construction. This is particularly evident where the handrail posts have been attached to the main beam with vertical spiking nails.

Page et al (2004) say that nails inserted vertically into exposed horizontal surfaces (such as the case with the arch beams/hand rail connections and carriageway beam/deck plank connections) should be avoided at all costs, as this method tears the wood open, promotes entry of water and can generate iron sickness[1]. From site observations such iron sickness is apparent at these areas. Given

[1] Iron sickness, or Nail sickness is a poorly understood chemical interaction between the ferrous metals and the timber

that the damage to the timber treatment appears not to have been specifically addressed, the timber has deteriorated as if it were not treated at all due to the increased hazard class exposure.

3.1.3 Apparent Lack of Maintenance

From the apparent visual condition of the bridge and from the aforementioned reports prepared by Blue Barn Consultants, the maintenance does not appear to have been sufficient to ensure the longevity of the bridge.

Some localised areas appear to have been neglected. One example is the arch beam bearing. It is understood from previous reports (and photos contained within) that the timber at these locations was buried in dirt and leaf litter. This type of micro climate (dirt against timber) is known to increase the hazard class substantially. The reason for this is that H3 timber protection is generally treated to prevent the growth of fungi when wet. But when in direct contact with soil, which is full of bacteria and fungi spores, deterioration soon develops and flourishes as if not treated at all as it is not treated against direct attack from this source. Hence the deteriorated condition we see today at these locations.

3.2 Expected Life Span of Bridge

Generally speaking, it appears that the design life of the bridge, apart from main horizontal beams, was intended to be 50 years. From this the remaining life of the bridge is 21years [1984+50-2013=21]. In its unmaintained state we would expect that the bridge would reach the end of its useful life sooner than this. It is not possible to put an exact date when the bridge will become unsafe as the type of deterioration for this type of bridge can vary considerably. It is likely that the inappropriate timber protection and poor detailing (of connections and bearing areas) will result in local failure of the bridge long before 21 years and the structure will become unsafe for use without remedial action.

Without regular monitoring inspections of the structure, it is not possible to determine a time frame where the deterioration will render the bridge unsafe for use. Based on what was observed during the detailed bridge inspection (refer section 5), the bridge is anticipated to become unsafe within the next few years.

4 Summary of the Detailed Structural Assessment

A detailed structural assessment was completed to understand the bridge's ability to meet the present day standards. The detailed structural assessment report has been included in Appendix A – Structural Assessment. The procedure, loads, findings and recommendations have been summarised below.

The structure was modelled using software program Lusas and simulated its performance under the following AS/NZS 1170 load cases; self-weight, pedestrian and wind loading and their combinations

The load ratio (ratio of load effect to capacity) for the main structural components was determined. The findings are as follows.

4.1 Main Horizontal Beams

Three of the five load cases that were considered resulted in load ratios that are in excess of unity[2] for the main horizontal beams. The most severe load case combines wind loading with pedestrian traffic, followed by the pedestrian only load case, and then the vertical wind load only case. The regions that are distressed are localised and limited to the splicing detail (of the horizontal beams) and connection detail between the main horizontal timber beam and arch beam.

Although the load ratios exceed unity it is only marginally so for the pedestrian only load case (10% in excess) and vertical wind only load cases (3% in excess), but more so for the combined wind and pedestrian load case (34% in excess). The minimum material strengths were used to determine the capacity of the sections and will in likelihood exceed these strengths; this however cannot be quantified without destructive testing. The condition of the timber at the connection detail was also assessed as part of the on-site investigation and considered to be fair to good; however one of the reasons for limiting the material strength is to account for possible latent defects in the timber.

It is therefore concluded that the capacity of the main timber beams are adequate for pedestrian load taken in isolation, but not for combined wind and pedestrian loading, specifically at the arch main beam connection detail.

4.2 Main Arch Beams

The main arch beams have a maximum load ratio that is less than unity for all the load cases under consideration along its length. Similar to the main horizontal beams the combined load case that includes both wind and pedestrian loading results in the highest load ratios.

The main arch beams are adequate for all the load cases under consideration.

4.3 Pier Columns

The pier columns have a maximum load ratio that is less than unity for all the load cases under consideration along its length. The load case which combines wind and self-weight, results in the highest load ratios.

---

[2] A result of greater than unity (1.0) indicates that the member under consideration is excessively loaded.

4.4 Hangers

The hangers are locally distressed in the load cases that include transverse wind load. The maximum load ratio for the load case that includes transverse wind and gravity are 7% in excess of unity and the capacity is therefore not adequate (bottom of the hangers).

The connection detail between the hangers and the arch beams are moment resisting, and increase the moment capacity of the hangers substantially in this area (moment capacity of the connection detail is doubled at the top of the hangers). The bending moment capacity of the connection detail at the bottom of the hangers is only marginally increased by the torsion capacity of the main horizontal beam and could be further increased by duplicating the connection detail at the top.

4.5 Dynamic Behaviour

Jubilee Bridge is a slender timber structure that is relatively lively, because the live load is comparatively large when compared to the dead load. The natural frequency, without the lateral cable supports, has been determined (first and second modes of vibration are 0.96 Hz, and 2.26 Hz) and is below 2.5 Hz in the lateral direction. This means that in certain situations the bridge could be performing at a level below what most pedestrian users would consider comfortable. Although beyond the scope of this assessment it is suggested that detailed analysis and comparison with the current following design criteria should be considered for this frequency range (British Standard, 1978; ENV1992-2,1996; NBCC, ONT83, ISO/DIS 10137, 1995). The proposed additional analysis would provide confidence that the structure meets current serviceability standards. The motion induced by pedestrian traffic depends on the amount of traffic and the type of activity that the users are undertaking. The effectiveness of the lateral cable support therefore needs to be further investigated.

4.6 Summary

Based on the structural assessment the only regions of (static) concern are the arch/deck beam connections, and the hanger/deck beam connections.

The capacity of the deck (main) beams can be increased (in-plane) at the connection detail by the inclusion of plates and additional bolts. The out-of-plane bending capacity of the hanger/beam connection detail can be increased by the addition of flat plate sections to the outside of the hangers.

Further work is also recommended to investigate the dynamic behaviour of the structure including how this may be improved possibly by modification of the lateral cable restraints.

5 Detailed Bridge Inspection

Prior to the inspection phase, the detailed bridge structural assessment and modelling was completed. This allowed the areas with a high load to capacity ratio to be identified and was particularly useful insofar that the inspectors were able to pay extra attention to these highly loaded areas. Please refer to section 4 for further details of the structural assessment work.

5.1 Inspection Methodology

A detailed bridge inspection was completed 15 August 2013. Areas not usually easily accessible were accessed with the use of ropes and climbing equipment, by a suitably qualified abseiling inspector (and support team).

In addition to the climbing inspector an inspection of the easily accessed area was completed. This includes both bearing areas of the timber arches and the pier legs. The bearings of the horizontal glulam beams were not accessible and therefore only a superficial inspection completed. The findings of the inspections have been captured using New Zealand Transport Agency's (NZTA) bridge inspection reporting tool, the S6 form. This form uses extent and severity of defects for determining the condition of key features of bridging infrastructure. The completed S6 form is included in Appendix C – NZTA Bridge Inspection Report –S6.

Figure 5-1 View of Inspector from west bank

5.2 Key Inspection Observations

The bridge structure was seen to be in average condition during the detailed inspection but with a poor overall appearance. However many defects noticed were generally seen to be in their early stages. Of particular concern is the moisture content of the main timber members. At present, the moisture content appears[3] to be greater than the design level and the hazard class level permits. The timber used to make the main elements is treated in H3.2. However, this hazard class is typically used in exterior structural applications where the timber can readily dry naturally. During the inspection of Jubilee Bridge it was observed that the timber cannot readily dry naturally due moisture trapped within the paint system.

The paint system was intended to preserve the timber by preserving the moisture content to guarantee its longevity. However the breakdown of the paint has meant that water has entered the timber through the cracks and flakes in the paint system. The water has been allowed to enter the timber freely but cannot exit easily due to the remainder of the paint system. This will raise the hazard class the timber is exposed to closer to H4. This means the timber is not adequately protected against fungal attack and deterioration is likely to accelerate if not suitably addressed. This is a key issue which needs to be addressed to preserve the bridge.

5.3 Testing

The onsite testing consisted of timber sampling and resistograph testing. The testing was completed by Wilcon Sylvan Parks and Landscape Management. This contractor was onsite for testing should any areas of suspect timber be noticed during the detailed inspection. The general condition of the timber was found to be reasonably good and the decision was made that excessive drilling would be counter-productive to the bridge. As such, only two areas were justified for testing. The first was to assess the condition of the timber in the main arch where hangers meet the arch. The edge spacing of the lower bolts in the arch appears to be questionable (i.e. too close to the free edge), as such the test was to prove that the timber was sound. A core was taken using an incremental drill and the 10mm cavity was plugged using a 10mm dowel secured in place using an epoxy resin. The timber was found to be sound. Refer Figure 5-2 for a photo of the core removed.

Figure 5-2 5mm core of timber to assess condition of timber

The second test was to understand the level of decay in the main arch where the vertical spiking of nails had introduced water into the main arch. The purpose of the test was to determine the extent (depth) of the affected timber. The drilling was on a skew to the vertical to ensure any decay deeper in the timber element was identified. Following the use of the Resistograph test it was found that the affected timber was only on the uppermost layer which is what we see visually.

[3] Moisture content testing not completed

Notwithstanding this, the affected timber should be treated and protected to prevent further ingress of water.

A copy of the Resistograph test is contained in Appendix D – Inspection Test Results.

6 Suggested Maintenance

This section outlines the suggested maintenance that is required to prolong the life of the Asset or to remedy inadequate details.

There are several defects that were noticed during the inspection of varying urgency. These have been categorised as urgent and moderate depending on the nature of the defects.

6.1 Do-nothing approach

The decision to follow a do-nothing approach can be made for a variety of reasons, which may include cost, value of alternatives and other agendas the Owner, Auckland Council, may have.

This bridge is understood to play a key role in the community and is the only link in the McCulloch Walkway spanning the mouth to the Panmure Basin. The only easily accessible detour on foot is approximately 3km in length.

Although a decision to do-nothing may be considered, it is vital that the client understands the consequences of this approach. Without adequate and timely maintenance of the key issues identified the bridge will soon become unfit for use and will need to be closed. Refer section 3.2 for further details.

We cannot recommend a do-nothing approach.

6.2 Urgent Repairs (within 3 months)

Some defects have been identified as requiring urgent attention. This is due to the safety of the users and the stability of the bridge in general.

6.2.1 Holding down bolts – main arch beams ($1,250).

The galvanised M20 nuts to the holding-down bolts into the concrete abutment were seen to be in a poor condition. In some areas the structural washers between the nut and the bracket had failed by completely owing to corrosion. This has meant that the nut is proud of the bracket and in some instances a 15mm gap has resulted in loss of clamping action. Until an alternative detail can be designed, stainless steel washers and nuts should be installed taking care to separate dissimilar metals[4].

6.2.2 Holding-down bolts – base of pier legs ($500).

As with the main arch beams these bolted connections were in poor condition. Further deterioration to this connection has meant that one nut has completely failed. Until an alternative detail can be designed, stainless steel washers and nuts should be installed taking care to separate dissimilar metals[5]

[4] Professional engineering advice shall be sought prior to any work on these details
[5] Professional engineering advice shall be sought prior to any work on these details

6.2.3 Deck – timber boards ($750).

The timber deck planks were seen to be in a fair to poor condition. During the inspection several boards (less than 5%) were noticed as being significantly more flexible than the adjacent boards. From the lack of stiffness is it possible to infer that some of these boards have fractured. These 'fractured' boards should be replaced.

6.3 Moderately Urgent Repairs (within 6 months)

6.3.1 Glulam Timber Elements – painting system ($76,000- 376,000).

The glulam timber is in need of a new coating system. The glulam timber was painted with Everdure distributed by International Protective Coatings during construction. It is understood that the bridge has been overcoated subsequently since it was built, although the system is not known. At present the protective coating is damaged and split allowing the ingress of water and this needs to be rectified. It is recommended that all of the paint systems are removed and the bare timber exposed. This shall be completed in the dryer summer months (i.e. February or March). Once all the timber is exposed it shall be left to dry for a period of no less than 28 days. The issue with painting over the existing systems is that the water in the timber becomes trapped. The issue with this is that this hazard class is greater than what it was originally treated for and decay will progress. At present areas of timber under the paint were seen to be, damp to wet. However it appears that decay has yet to flourish.

Fungus struggles to establish/grow in dry timber (moisture below 20%) so once the paint is removed and the timber is dry a new coating system should be installed.

However, the bridge will need to be closed during this operation and from what was observed during the detailed inspection this is a heavily used pedestrian bridge. This will require public consultation whereby the bridge condition and necessity of task is explained.

6.3.2 Arch beam bearings ($11,000).

The bearing detail requires load transfer through the timber concrete interface. This detail has not been protected and debris such as leaf litter has accumulated resulting in a higher hazard classification than the timber was originally treated to. As such the timber was seen to be in a moderate state of decay. To overcome this situation a revised detail needs to be designed and retro fitted to prevent further loss of section to the timber arch.

6.3.3 Pier – bearings and decayed timber ($4,000).

This detail requires load transfer through a M20 bolt passing through the vertical timbers and a steel bracket. The bracket is secured to the concrete shelf and no allowance was made to elevate this connection off of the shelf. As with the arch beam bearings, leaf litter and soil has accumulated at the base of the pier legs. As a result the top of the galvanised U-bolt securing the steel bracket into the concretes shelf has been has severely corroded. To overcome this situation a revised detail needs to be designed and retro fitted to ensure load transfer to the piers and the abutment shelves.

The timber at the base of the eastern pier was seen to be in a poor condition. The timber members have suffered loss of section at the base approximately 50mm (vertically). Whilst the load is transmitted though the bolted connection 150mm above this decay the ability of this connection will soon become compromised if the decay progresses and weakens the timber adjacent to the bolt. This should be included in the detailed design of the revised bearing detail.

6.3.4 Diaphragms - Ply box beams ($15,000).

The box beams between the main arch beams were seen to be in a poor condition. The nature of the defect varied from beam to beam but the general theme was the condition of the ply material and the connection between the ply and bracing timber. These should be replaced like-for-like with completely new materials to meet the present durability requirements (stainless steel fixings, H4 timber).

6.3.5 Deck – timber boards ($15,000).

In addition to the replacement of the fractured boards discussed in Urgent Work, all the remaining deck boards shall be replaced. Generally, the timber deck planks were seen to be in a fair to poor condition and nail slip between the deck and the carriageway beams was observed. These boards contribute to the bridge's lateral stiffness and should be replaced. The connection detail is not stated on the construction drawings and the current connection detail is visibly inadequate to ensure that the carriageway beams act compositely. The fixings of the deck planks shall be sufficient to ensure the two carriageway beams are 'locked in' and act compositely without damaging or allowing the horizontal deck planks to deteriorate.

The original timber hazard class appears to have been inadequate. This should be considered in the deck replacement.

6.3.6 Abutment - drainage system ($2,000).

The eastern bearing shelf of the main arch beams has been cut into the hillside and at present (rain) water can collect at this level which effects the base of the main timber arch beams. Presently there are two dish drains that appear to have been installed at the time of construction. However, these were seen to be blocked with leaf litter and plant debris. As such, a revised detail of a positive drainage system needs to be installed to allow the bearing shelf to drain freely and naturally.

6.3.7 Handrail - fixing to arch beams ($4,000).

From the construction drawings it appears that the handrail details for the section where pedestrians walk through the arch was overlooked. The currently installed solution is aesthetically pleasing but does not appear to be sufficiently robust. Furthermore the nailed connection of the vertical timbers to the arch has created an entry point for water into the glulam. Localised areas of severe decay were seen at these locations. However, onsite testing using a resisitograph has identified that the depth of decay appears to be no greater than the length of the nails used. This form of decay can be referred to as a form of nail sickness (refer to section 3.1.2). A revised detail needs to be designed and retro fitted to ensure adequate load transfer from the top rail to the supporting members. According to the schedule of quantities the original protective paint system is Dulux Timbercryl with a 10-15 year service life.

6.3.8 Handrail – chain-link mesh ($7,000).

The installed mesh does not meet the Building Code requirements for safety from falling as the mesh is too coarse. A compliant mesh shall be installed.

6.3.9 Cross bracing – galvanised brackets ($4,000).

The brackets are showing early signs of corrosion. This should be treated before significant loss of section occurs. The as-built drawings show that the steel work was to be coated with Devran 224 which is currently distributed by International Protective Coatings (not clear if this has been installed). The protective system shall either be compatible with this system, or it should be completely removed.

6.4 Suggested Maintenance Programme

1. Urgent repairs – complete as necessary (0-3 months).
2. Moderately urgent repairs that do not require closure to public e.g. repair and install retrofit bearing details (0-6 months).

    1. Design of measures
    2. Consultation with public and mail drops

3. Repairs that require closure to the public (0-1 year).

    1. Close bridge to public
    2. Remove all paint systems
    3. Remove timber deck planks
    4. Remove any traces of the paint system
    5. Dry glulam
    6. Paint glulam
    7. Paint cable deviators
    8. Install new ply box beams
    9. Install new deck planks
    10. Install plates to bolted connection between arch and horizontal beams
    11. Upgrade handrail
    12. Open to public

6.5 Required Work Identified by Structural Assessment

Based on the structural assessment the only regions with inadequate strength are the arch/deck beam connections and the hanger/deck beam connections.

The capacity of the main deck beams (carriageway beams) can be increased (in-plane) at the connection detail by the inclusion of plates and additional bolts. The out-of-plane bending capacity of the hanger/deck beam connection detail can be increased by the addition of flat plate sections to the outside of the hangers.

This work shall be completed within 12 months unless it is decided to post the bridge with load restrictions, e.g. “Bridge Limit Warning - no more than 10 people on the bridge at a time”.

7 Repair and Maintenance Costs

An indicative cost to complete the suggested repairs and remedial works has been prepared. These cost estimates are either based on rates for the cost of construction (adjusted for inflation) or by estimating the hours, material and plant required. At this stage these costs are based on preliminary details considered which have been considered feasible, as such the accuracy of these estimates is expected to be +/-40%. For the estimate to be refined, the detailed design and the specification of material are required. Allowances for the design fee and obtaining resource consent have been included in the estimates.

The painting system is the single, most difficult task that needs to be completed. This is due to the complexity of the containment system needed to contain the removed paint and to contain the new paint. The estimated cost of the containment system is based on experience of previous work of a similar nature also requiring a similar level of containment.

A summary of the cost estimates are presented below in Table 7-1.

Table 7-1 Summary of repair costs

Item	Brief description of task	Rough order cost estimate
1.	Design, detailing and specifications for repairs	$ 50,000
2.	Resource Consent application	$ 30,000
3.	Holding down bolts – main arch beam reinstatement (section 6.2.1)	$ 1,250
4.	Holding-down bolts – base of pier legs (section 6.2.2)	$ 500
5.	Replace 'fractured' timber deck boards (section 6.2.3)	$ 750
6.	Timber arch base plates	$ 11,000
7.	Pier legs	$ 4,000
8.	Timber Deck	$ 15,000
9.	Abutment drainage system	$ 2,000
10.	Ply diaphragm box beams	$ 15,000
11.	Handrail connection detail	$ 4,000
12.	Handrail mesh	$ 7,000
13.	Painting Handrail	$ 14,000
14.	Paint cross bracing brackets	$ 4,000
15.	Strengthening of connection between arch and horizontal beam	$ 17,000
16.	Strengthening of connection between arch and hanger	$ 3,500
17.	Painting - Handrails	$ 14,000
18 a.	Painting preparation – no containment required	$ 25,000
18 b.	Painting preparation –containment required (range)	$ 75,000 - $350,000
19.	Painting – Main timber elements apply paint	$ 27,000
20.	Contractors P & G	$ 25,000
Total – Resource Consent granted to discharge into surrounding environment		**$270,000**
Total – Full containment required for painting preparation (range)		**$320,000 - $595,000**

8 Replacement Costs

8.1 Like-for-Like Replacement (Glulam Timber)

The schedule of quantities (prepared by Downer and Company Limited) for the original bridge construction was used to understand the cost to construct the bridge. This data was used to determine the present day estimated replacement cost by considering the present day cost of material, plant and labour. This process ensures the cost to replace the structure best reflects what currently stands. There is an assumption that this data is correct and the construction came in on budget.

The original schedule of quantities provides detailed quantities for the materials, the purchase price of materials, the man hours (and rates) and the plant (and rates) required.

Please note that the present day replacement cost provided does not take into consideration of any further elements that may be required for the bridge to be considered compliant to the current statutory requirements such as the Building Code and the Building Act.

Due to escalation of costs, additional costs for demolition, support of services and design fees, the original figure of $67,994 has risen to $568,000. A summary of the items is presented in Table 8-1.A copy of the full schedule which presents the detailed breakdown (presumed) to have been used in the construction of the bridge and the present day rates for those items is presented in Appendix E – Original Schedule of Quantities.

Table 8-1 Summary of original estimated cost to construct

Item	Engineer Estimate (Kevin D. Kelly & Associates) 1983	Contractors Estimate (Downers and Co Ltd) 1983	Opus Estimate (based on Downers and Co Ltd) 2013
Preliminary and general	$ 6,121	$ -	$ -
Excavation	$ 5,667	$ 3,206	$ 25,315
Concrete	$ 2,940	$ 2,636	$ 7,396
Reinforcing	$ 742	$ 1,116	$ 2,982
Carpentry	$ 10,582	$ 11,649	$ 46,059
Metal Work	$ 5,409	$ 5,599	$ 29,534
Painting	$ 760	$ 2,690	$ 13,231
Laminated timber supply	$ 12,726	$ 17,045	$ 98,180
Erection	$ 15,000	$ 11,931	$ 28,139
Contingency	$ 2,000	$ 1,011	$ 4,418
Margin	$ 6,000	$ -	$ -
Demolish Bridge			$ 60,000
Temporary support of services during construction			$ 100,000
Allowance for estimating errors			$ 52,746
Allowance for design of Bridge			$ 100,000
Total estimate	**$ 67,947**	**$ 56,883**	**$ 568,000**

Please note some items have not been included in the estimate. These largely pertain to professional service fees and regulatory processing fee such as: consultation, building consent fees, resource consent fees.

9 Discussion

9.1 Keep the Bridge

9.1.1 Option one

If resource consent can be granted avoiding the costly containment then it is recommended that all the suggested repairs contained in this report, including the strengthening are completed in the suggested timeframes. This has an expected cost of $270,000 (if declined, repairs and maintenance with full containment is expected to cost between $320,000 -$595,000).

Following the successful lodgement and issue of the Resource Consent Application, the detailed design of the remedial work, the strengthening solutions and the specification of materials, needs to be completed. It is advisable not to start this work until the resource consent has been granted and the specific requirements are known. This will ensure all the conditions can be adequately addressed from the onset.

Following the completion of the suggested repairs and the strengthening of the identified connection details, a producer statement (PS1) stating that the bridge is capable of carrying the stated loads (at the time of issue) can be produced and supplied to Auckland Council.

The remaining useful life of the bridge once all the suggested maintenance work has been completed largely depends on the performance and future maintenance of the paint system itself. A correctly specified and applied paint system is expected to provide a period between applications of between ten to fifteen years. However to achieve this, the paint system will require periodic cleaning using low pressure water washing to remove surface contaminates (such as salt spray and animal droppings).

9.1.2 Option two

Alternatively, in conjunction with regular six-monthly inspections, it is possible to progress a lower level of repairs to the bridge. These repairs will primarily focus on the safety of the users and the overall stability of the bridge. It should be noted that areas generally affecting the longevity of the bridge (such as painting) are not included. As such, the timber elements of the bridge will still continue to deteriorate. If at a later date, the Owner chooses to complete the remainder of the tasks, the level of maintenance work required will most likely have increased, primarily owing to the increased decay of the timber.

It is possible that the bridge may perform for a period greater than five years, however, only the regular bridge inspections will reveal the true length of time when the bridge is no longer fit for use.

Areas that could be considered in this option are:

» Apply a load restriction on the bridge immediately, “Bridge Limit Warning - No more than 10 people on the bridge at a time”.
» Design, detailing and specifications for the appropriate repairs
» Reinstate the holding down bolts to the main arch beams
» Reinstate the holding down bolts to the base of the pier legs
» Replace the all deck boards

- Design and install new base plate details to the main arch beams
- Design and install new base plate details to the pier legs beams
- Install a positive drainage system to the eastern abutment shelf
- Replace the ply box beams
- Improve the handrail fixing to main arch beam
- Replace the handrail mesh with a compliant alternative

This work is expected to cost $60,000 -70,000 depending on what the Owner chooses to implement.

9.2 Replace the Bridge

If it is decided to replace the bridge, Auckland Council shall source funding, plan for and replace the bridge within the next two to three years.

If the bridge is to remain open whilst the replacement is planned, Auckland Council shall still complete the following items to ensure the safety of the users:

- Apply a load restriction on the bridge immediately, "Bridge Limit Warning - No more than 10 people on the bridge at a time".
- Design, detailing and specifications for the appropriate repairs
- Reinstate the holding down bolts to the main arch beams
- Reinstate the holding down bolts to the base of the pier legs
- Replace the (fractured) deck boards
- Improve the handrail fixing to main arch beam
- Replace the handrail mesh with a compliant alternative

The above work is expected to cost $18,500 (excluding the replacement works itself).

Furthermore to the above points, Auckland Council shall ensure that the bridge is inspected six monthly by a suitably qualified and experienced professional to identify any areas of accelerated deterioration.

9.3 Painting Issues

The painting of the bridge is foreseen to be the most important, the largest, the most complicated and costly task. Owing to the reasons discussed earlier the need for the removal of the deteriorated paint, the drying of the timber and the subsequent re-application of a protective coating is paramount.

It is expected that resource consent will be required in order to complete the painting operation. Experience has proven that full containment is highly likely to be required. Notwithstanding this, there is an opportunity that resource consent may be granted to discharge the paint material directly into the surrounding environment. The requirements can only be confirmed by preparing and submitting a Resource Consent Application to the Auckland Council Planners.

Full containment requires any material, be it water, the removed paint or the new coating system, to be captured and removed from site thus preventing any foreign material from entering the water course. Containment is typically achieved using scaffolding encapsulated in plastic (commonly seen on construction sites as white 'shrink wrap'). The issue with this method for Jubilee Bridge is the high wind loading that will be applied to the structure potentially causing instability.

We know from the detailed structural assessment that the bridge is reasonably sensitive to high wind conditions. Add to this, the containment system and the wind forces could be sufficiently high to cause structural failure[6]. This may be mitigated by phasing of works and completing the work, area by area therefore increasing the cost.

Another option potentially available is to discharge the deteriorated material directly into the watercourse below and attempt to contain within floating booms or provide little or no containment. There is a possibility that a Resource Consent may be granted by Auckland Council to do this. However, it is not possible to ascertain whether this method will be considered to be acceptable to the Auckland Council Planners or not. Furthermore, this option may require laboratory testing to identify the toxicity of the paint to understand whether it will not adversely harm the environment. Owing to this reasons, this option has been included as a lower bound option for Jubilee Footbridge but can only be considered viable following the lodgement of a Resource Consent Application.

[6] The exact load paths of such a system on the bridge structure have not been assessed.

11 Conclusions

11.1 Condition

Although Jubilee Footbridge is currently in an average condition however it is in need of major repairs and maintenance to meet its assumed design life of 50 years.

The repairs have been categorised as urgent and moderately urgent to enable Auckland Council to schedule the physical works, while making a decision on the future of Jubilee Bridge.

The most costly single repair item is repainting. This is not a cosmetic remediation and could potentially be very expensive depending on the level of containment that is prescribed following the Resource Consent Application. The bridge should ideally be repainted within the next year as moisture is currently trapped and causing decay. Delay will compromise the viability of the bridge.

11.2 Structural assessment

Based on the structural assessment that has been conducted as part of the investigation areas have been identified that require strengthening. The arch/deck beam connection detail and the hanger/deck beam connection detail require strengthening to accommodate design loads as prescribed by the AS/NZS Structural Design Actions – General Principals (NZS1170.0.2002). Strengthening may be avoided by installing weight limit signs at both ends of the bridge.

11.3 Replacement

The replacement cost of Jubilee Bridge has also been estimated and is presented in section 8 and is $568,000.

A like-for-like replacement of the bridge may not be the best solution to provide a crossing. This is largely due to the choice of timber as the main load carrying material. An alternative bridge, with alternative materials can provide a service life of 100 years which also provide lower operating costs over the structures life (i.e. lower maintenance costs). Suitable materials such as steel can provide this level of service. However, bridges built with steel, with these spans are typically more expensive. With reference to the recently designed steel through truss bridge designed as part of the Auckland Manukau Eastern Transport Initiative, the construction cost, for the steel structure alone, is in the range of $1.5-2.0m.

A full bridge replacement using alternative materials (such as steel) would have the advantage of giving the crossing a 100 year design life in addition to complying with all appropriate design codes, standards and specifications.

11.4 Summary of options

There are several alternatives that the Owner may choose to progress, each with their own benefits, associated costs, merits and disadvantages. Options range from limited selected remedial works, to full replacement with alternative design solutions. Understandably, the lesser options are likely to limit the remaining useful life span of the bridge as the bridge continues to deteriorate with time. The options have been summarised in Table 11-1.

Table 11-1 Summary of options

Option	Prerequisite requirements	Expected life span	Estimated Cost
Selected repairs excluding painting	Standard consenting requirements	<5years	$50,000 -$75,000
Repairs including painting with no containment	Resource consent granted allowing discharge into surrounding environment	10-15 years	$270,000
Repairs including painting with containment	Standard consenting requirements	10-15 years	$320,000 - $595,000
Replacement like-for-like	Standard consenting requirements	<50 years	$568,000
Replacement alternative structure (Steel Truss)	Replacement alternative structure	<100 years	$1.5 -2.0m
Replacement alternative structure (Cable stayed)	Replacement alternative structure	<100 years	$2.5 – 3.0m

12 Recommendations

The following recommendations have been made.

12.1 Repairs affecting safety

It is strongly suggested that following work is implemented within the next three months as a matter of safety:

- Apply a load restriction on the bridge immediately, “Bridge Limit Warning - No more than 10 people on the bridge at a time”.
- Undertake all the urgent repairs (section 6.2) which include; holding down bolts to main arch beams and to the base of the pier legs, and replace the fractured deck boards. This work is expected to cost $2,500 -$3,000.

12.2 Decide on the future of the bridge

The future of the footbridge, whether it is to be repaired or replaced, requires review by Auckland Council. This review and subsequent decision needs to be made within the next year to avoid costly deterioration of the structure.

If it is decided to replace the bridge, concept designs of alternative crossing structures should be completed. Following this, a detailed economic analysis can be completed to determine the merit of each of those alternative solutions considering the capital costs and the on-going maintenance costs.

12.3 Apply for resource consent

If it is decided to keep the bridge, it is recommended that further work is carried out such as a Resource Consent Application to discharge material in a safe manner into the surrounding environment can be submitted to Auckland Council as soon as practical. This will confirm the required level of paint containment.

13 References

Griffiths, O., 2013. *Mr* [Interview] (23 July 2013).
Kevin D Kelly and Associates, 1983. *Mt Wellington Borough Council Arch Footbridge Drawings.* Auckland: Self Published.
Page, O. W. a. D., 2004. *Stop The Rot,* Wellington: Department of Conservation.
Roads and Traffic Authority of NSW, 2008. *Timber Bridge Manual Bridge Engineering,* Canberra: Roads and Traffic Authority of NSW.

14 Appendices

14.1 Appendix A – Structural Assessment Report

Auckland Council – Jubilee Bridge Panmure

Structural Assessment Report

Auckland City Council

Jubilee Bridge Panmure – Structural Assessment

Prepared By

Johan Klopper
Structural Asset Management Engineers

Reviewed By

Ian Leach
Principal Structures Bridge Engineer

p.p.

Jim Baker
Structural Assets Engineer / Associate

Approved for release

Matiul Khan
Structures Asset Management Team Leader

Opus International Consultants Limited
12-14 Northcroft Street, Takapuna
Level 1, North Shore City 0622
PO Box 33 1527
New Zealand

Telephone: +64 9 488 4570
Facsimile: +64 9 355 4571

Date: September 2013

Reference: 1-95477.00
Status: Final

© Opus International Consultants Limited 2012

Contents

1 Introduction

Jubilee Bridge is located at the entrance to the Panmure Basin and provides a link in the McCulloch Walkway which circles the Basin. The Bridge, opened in 1984, serves pedestrians only and can be reached from Watene Road and Lagoon Drive.

This report briefly describes the methodology that was followed in the structural assessment of the Jubilee Bridge and presents the results. The aim of the assessment was to rate the individual superstructure components (determine the load ratio) and eventually comment on the overall structural integrity of the superstructure.

2 Description of the Laminated Arch Bridge

Jubilee Bridge can be described as a Laminated Arch Bridge with a total length of 60m. The two main arch members support two continuous horizontal beams running through the arch. The central main span of the arch (46m) divides the horizontal beams into approximately five spans of equal lengths, 9.25m. There are two 6.9m approach spans on either side of the main arch spans.

The approach spans and main laminated arches are founded on slab footings. The narrow bridge is laterally restrained with cables to the North and South side of the bridge at both sides. Figure 2.1 presents a basic layout of Jubilee Bridge.

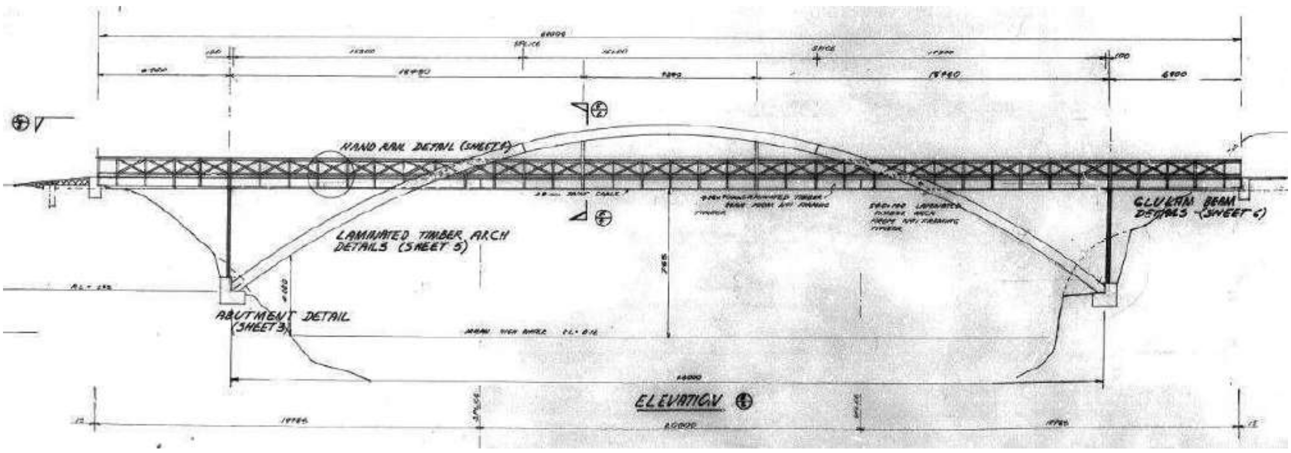


Figure 2.1 Basic Layout of Jubilee Bridge

2.1 Strengthening and Modifications

No strengthening or modifications has been made to the bridge since it was opened (30 June 1984). The main horizontal beams were however replaced in the 1990's as a result of inadequate timber treatment that was applied to the original beams (refer to the investigation and options report). The drawings that were obtained from Auckland Council (Kevin D. Kelly and Associates, Dwg No 3226) was regarded as as-built drawings. We have subsequently confirmed this with on-site measurements.

3 Information provided by Auckland City Council

Auckland Council has provided the following data and information for the assessment:

(i) Detailed drawings of the Jubilee Bridge by Kevin D. Kelly and Associates (12/04/1983) Dwg No. 3226, six sheets.

(ii) Parks, Sports, and Recreation, Jubilee Bridge Structural Testing by Blue Barn Consulting Limited (15/03/2013).

(iii) Auckland Council – Panmure Basin Pedestrian Bridge – Resistograph timber decay assessment by Wilcon Sylvan Parks and Landscape Management (17/01/2013).

(iv) Structures Inspection Record by Blue Barn Consulting Limited (20/11/2012).

(v) Asset Development and Business Support Central Structures Inspections by Blue Barn Consulting Limited (29/11/2012).

4 Load Assessment

The structural assessment entailed determination of the load effects as a result of various load cases. These have been compared to the capacities of the individual super structure elements.

4.1 Assessment Criteria

The Third Edition Bridge Manual (SP/M/022, NZ Transport Agency) is specifically tailored to vehicle bridges. It was therefore considered necessary to use the Structural Design Actions guide (NZS1170) for loadings. Section 7 of the Bridge Manual (NZ Transport Agency) was however used for guidance to rate the super structure elements.

The arch bridge was assessed using the following load effects from the NZ structural design actions – General Principles (NZS1170.0.2002):

- E_d = [1.2G, 1.5Q]. Permanent and imposed action,
- E_d = [1.2G, W_u, Q]. Permanent, wind and imposed action, and
- E_d = [0.9G, W_u]. Permanent and wind action reversal.

BS5400 (Steel, Concrete and Composite Bridges, Specification for Loads) supplemented by BD37/01 has been used to calculate the wind load. Two additional load cases were added and the load cases with pedestrian loading were altered. The load cases with live load and wind were limited to wind gusts of 35.0m/s following the recommendation of the British Standard, whereas wind effects without live load present were allowed to include gusts of up to 44.6m/s (NZS1170:2:2002).

The assessment did not include seismic actions. It was however determined that the load effects as a result of seismic actions is less severe than that of the local effects of New Zealand wind speeds.

4.1.1 Geometry and Section Properties

The main arches, longitudinal beams, hangers, and pier columns (superstructure elements) have rectangular cross sections and the sectional properties can therefore be calculated accurately.

The cross sections (or sectional properties) were included in the modelling software (***Lusas***), based on the drawing dimensions. No cross sectional loss was assumed (as-new condition). Figure 4.1 is a model representation of Jubilee Bridge

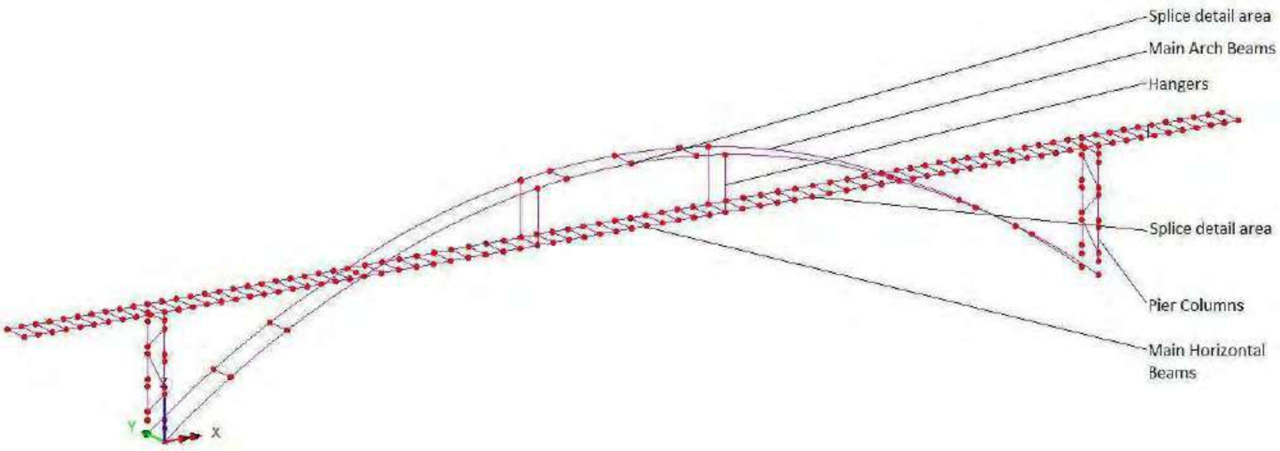


Figure 4.1 Model representation of Jubilee Bridge

4.1.2 Material Properties

The timber properties as presented in Table 2.2 of the Timber Design Standard NZS3603:1993 was used. The detailed inspection (15/08/2013) revealed that the condition of the timber is average-good. There were localised areas of decay, however these were not considered to warrant a reduction in the overall capacity/strength of the timber.

4.1.3 Loads

(a) Dead Load

Self-weight of the timber bridge was assumed to coincide with Radiata Pine (12% moisture content) and has a unit weight of 4.6kN/m^3 according to Table A.1, NZS1170.1:2002.

(b) Live Load

The live load on the bridge can be best described in Table 3.1 section C3, Reference values of imposed floor actions (NZS1170:1:2002), and comprises a uniformly distributed load of 5.0kN/m or a point load of 4.5kN.

(c) Impact Load

An impact load factor of 1.5 was used for live loading as described in section 4.1.

(d) Wind Load

The design wind speed was determined in accordance with NZS1170.2:2002. This wind speed translates to a force applied to the side of the bridge taking the reference area (only one of the two parallel beams to account for the effect of shielding) into consideration.

(e) Other Lateral Loads

The tension in the lateral cable supports was taken into consideration in the parametric model used to determine the load effects on the bridge. The lateral point load as a result of tension in the cable was equal to the wind load reaction at this point.

(f) Longitudinal Loads

No longitudinal loading was applied to the bridge.

4.1.4 Analysis Models

A 3-dimensional computer model was developed in ***Lusas*** (a structural analysis software package capable of undertaking both frame and finite element analyses) to determine the load effect on the superstructure elements of Jubilee Bridge.

4.2 Assumptions

Based on the available information the following assumptions were made in the assessment:

(i) The abutments at the approach spans and arch support are pin supported. They are thus fixed in translation and allow rotation of the supported beams.
(ii) The main arches and longitudinal beams are continuous at joints and thus capable of transferring moments.
(iii) The drawings will be regarded as, as-built drawings.

5 Results

Each of the main structural components was rated. The worst possible load effect along the length of the main structural components was determined by considering areas where the bending moments (in-plane and out-of-plane) reach maximum values. Since the capacity of the elements remains unchanged along its length considering the worst possible load effect resulted in a conservative approach.

Based on the criteria for combined bending and axial action (section 3.5 NZS3603:1993) the loading ratio should not exceed unity[1].

$$\left(\frac{M_y^*}{\emptyset M_{ny}}\right) + \left(\frac{N_c^*}{\emptyset N_{ncy}}\right) \leq 1.0 \quad (equation\ 1)$$

Tables 5.1 to 5.4 present the load ratio for the main structural components in Jubilee Bridge. Only the maximum load effects along the element lengths are presented and the exact location of the highly stressed areas can be identified using the element numbers in the tables and the model representation in Figure 5.1.

[1] Load effects, bending or axial, will result in longitudinal stresses, whereas shear forces will result in shear stresses. Stress is a tensor and can be summed using vector algebra. Based on the material characteristics of the structural members the characteristic strength (NZS3603:1993) for design should ideally not be exceeded.

Table 5.1 Load ratio of Main Horizontal beams

		1.2G+1.5Q				1.2G+Trans. Wind (LB)+Q					1.2G+Vert. Wind (LB)+Q				0.9G+Trans. Wind (UB)					0.9G+Vert. Wind (UB)			
	Element	Fx	Fz	My	load ratio	Fx	Fy	Fz	My	load ratio	Fx	Fz	My	load ratio	Fx	Fz	Fy	My	load ratio	Fx	Fz	My	load ratio
	125	-3.30	22.80	41.17	**1.06**	-117.41	14.50	16.56	28.99	**1.08**	-2.60	18.56	33.54	**0.86**	-185.45	2.93	23.30	3.86	**0.63**	-0.76	7.14	12.94	**0.33**
	133	-3.40	22.80	41.17	**1.06**	112.52	19.40	16.56	30.83	**1.23**	-2.68	18.56	33.54	**0.86**	184.55	2.93	31.30	6.70	**0.89**	-0.78	7.14	12.94	**0.33**
	177	-3.20	0.54	-18.30	**0.38**	-11.16	12.10	0.39	-13.31	**0.41**	-2.53	0.44	-14.88	**0.31**	-15.15	0.06	19.40	-2.36	**0.27**	-0.75	0.16	-5.69	**0.12**
	184	-3.44	-0.20	-18.30	**0.37**	6.31	12.20	-0.13	-13.26	**0.41**	-2.70	-0.16	-14.88	**0.30**	14.25	0.00	19.60	-2.29	**0.28**	-0.11	-0.04	-5.69	**0.11**
	227	-3.40	-22.80	41.17	**1.06**	-117.48	-14.50	-16.56	29.01	**1.08**	-2.68	-18.56	33.54	**0.86**	-185.45	-2.93	-23.30	3.90	**0.63**	-0.78	-7.14	12.94	**0.33**
	479	3.98	18.36	24.60	**0.69**	-111.10	17.30	13.38	19.96	**0.88**	3.13	14.98	20.10	**0.56**	-183.48	2.45	28.00	6.62	**0.73**	0.91	5.86	7.95	**0.22**
	685	-3.44	0.20	-18.30	**0.37**	-11.31	-12.10	0.13	-13.31	**0.41**	-2.71	0.16	-14.88	**0.30**	-15.15	0.00	-19.40	-2.36	**0.27**	-0.79	0.04	-5.69	**0.12**
	722	-3.20	0.20	-18.30	**0.37**	6.47	-12.20	0.13	-13.26	**0.41**	-2.53	0.16	-14.88	**0.30**	14.25	0.00	-19.60	-2.29	**0.28**	-0.75	0.04	-5.69	**0.12**
	798	4.10	-18.36	24.60	**0.69**	-111.02	-17.30	-13.38	19.96	**0.88**	3.22	-14.98	20.10	**0.56**	-183.48	-2.45	-28.00	6.62	**0.73**	0.92	-5.86	7.95	**0.22**
	831	3.98	-18.36	24.60	**0.69**	116.90	-14.40	-13.38	15.98	**0.86**	3.13	-14.98	20.10	**0.56**	184.53	-2.45	-23.40	0.14	**0.68**	0.90	-5.86	7.95	**0.22**
	879	-3.26	-22.80	41.17	**1.06**	112.62	-19.40	-16.56	30.85	**1.23**	-2.57	-18.56	33.54	**0.86**	184.55	-2.93	-31.30	6.74	**0.90**	-0.76	-7.14	12.94	**0.33**
	1116	4.10	18.36	24.60	**0.69**	116.98	14.40	13.38	15.98	**0.86**	3.22	14.98	20.10	**0.56**	184.53	2.45	23.40	0.14	**0.68**	0.92	5.86	7.95	**0.22**
	1193	4.52	0.52	-18.24	**0.38**	43.02	0.37	0.40	-14.72	**0.40**	3.59	0.44	-14.94	**0.31**	66.25	0.12	0.60	-4.80	**0.25**	1.10	0.22	-6.01	**0.12**
	1201	4.52	0.52	-18.24	**0.38**	-36.38	-0.19	0.40	-12.00	**0.30**	3.59	0.44	-14.94	**0.31**	-64.95	0.12	-0.30	-0.36	**0.11**	1.10	0.22	-6.01	**0.12**
	1208	4.53	-0.52	-18.24	**0.38**	43.02	-0.37	-0.40	-14.72	**0.40**	3.59	-0.44	-14.94	**0.31**	66.25	-0.12	-0.60	-4.80	**0.25**	1.10	-0.22	-6.01	**0.12**
	1216	4.53	-0.52	-18.24	**0.38**	-36.38	0.19	-0.40	-12.00	**0.30**	3.59	-0.44	-14.94	**0.31**	-64.95	-0.12	0.30	-0.36	**0.11**	1.10	-0.22	-6.01	**0.12**
Splice detail (steel cover plates)	778	4.10	1.17	-14.24	**0.31**	-29.22	-11.50	0.86	-11.03	**0.32**	3.22	0.96	-11.63	**0.25**	-50.66	0.18	-18.70	-2.97	**0.21**	0.93	0.40	-4.56	**0.10**
	785	4.11	0.21	-14.48	**0.31**	-48.91	-12.30	0.16	-11.13	**0.36**	3.23	0.18	-11.82	**0.25**	-82.56	0.06	-20.00	-2.88	**0.28**	0.93	0.10	-4.63	**0.10**
	843	4.01	1.17	-14.24	**0.31**	35.12	-12.10	0.86	-9.73	**0.31**	3.15	0.96	-11.63	**0.25**	51.72	0.18	-19.70	-0.85	**0.17**	0.91	0.40	-4.56	**0.10**
	850	4.00	0.21	-14.48	**0.31**	54.81	-11.70	0.16	-9.98	**0.35**	3.14	0.18	-11.82	**0.25**	83.62	0.06	-19.00	-0.99	**0.24**	0.90	0.10	-4.63	**0.10**
	1108	4.00	-0.15	-14.50	**0.31**	-48.99	12.30	-0.11	-11.06	**0.36**	3.14	-0.12	-11.84	**0.25**	-82.58	-0.02	20.00	-2.75	**0.28**	0.90	-0.04	-4.66	**0.10**
	1224	4.53	-7.46	-12.77	**0.29**	40.32	-1.82	-5.43	-10.88	**0.33**	3.60	-6.08	-10.45	**0.24**	61.85	-0.99	-2.96	-4.29	**0.23**	1.10	-2.37	-4.25	**0.10**
	1225	4.54	-13.54	0.82	**0.06**	36.83	-2.53	-9.84	-1.14	**0.13**	3.60	-11.02	0.63	**0.05**	56.25	-1.76	-4.11	-2.75	**0.19**	1.10	-4.26	0.15	**0.02**
	1232	4.51	-7.46	-12.77	**0.29**	-33.69	-1.27	-5.43	-7.80	**0.25**	3.58	-6.08	-10.45	**0.24**	-60.55	-0.99	-2.06	0.73	**0.15**	1.10	-2.37	-4.17	**0.09**
Splice detail (timber bolt connection)	778	4.10	1.17	-14.24	**0.87**	-29.22	-11.50	0.86	-11.03	**0.92**	3.22	0.96	-11.63	**0.71**	-50.66	0.18	-18.70	-2.97	**0.62**	0.93	0.40	-4.56	**0.28**
	785	4.11	0.21	-14.48	**0.87**	-48.91	-12.30	0.16	-11.13	**1.01**	3.23	0.18	-11.82	**0.71**	-82.56	0.06	-20.00	-2.88	**0.76**	0.93	0.10	-4.63	**0.28**
	843	4.01	1.17	-14.24	**0.87**	35.12	-12.10	0.86	-9.73	**0.93**	3.15	0.96	-11.63	**0.71**	51.72	0.18	-19.70	-0.85	**0.60**	0.91	0.40	-4.56	**0.28**
	850	4.00	0.21	-14.48	**0.87**	54.81	-11.70	0.16	-9.98	**1.04**	3.14	0.18	-11.82	**0.71**	83.62	0.06	-19.00	-0.99	**0.77**	0.90	0.10	-4.63	**0.28**
	1108	4.00	-0.15	-14.50	**0.87**	-48.99	12.30	-0.11	-11.06	**1.00**	3.14	-0.12	-11.84	**0.71**	-82.58	-0.02	20.00	-2.75	**0.75**	0.90	-0.04	-4.66	**0.28**
	1224	4.53	-7.46	-12.77	**0.87**	40.32	-1.82	-5.43	-10.88	**0.95**	3.60	-6.08	-10.45	**0.71**	61.85	-0.99	-2.96	-4.29	**0.64**	1.10	-2.37	-4.25	**0.29**
	1225	4.54	-13.54	0.82	**0.26**	36.83	-2.53	-9.84	-1.14	**0.43**	3.60	-11.02	0.63	**0.21**	56.25	-1.76	-4.11	-2.75	**0.55**	1.10	-4.26	0.15	**0.07**
	1232	4.51	-7.46	-12.77	**0.87**	-33.69	-1.27	-5.43	-7.80	**0.68**	3.58	-6.08	-10.45	**0.71**	-60.55	-0.99	-2.06	0.73	**0.32**	1.10	-2.37	-4.17	**0.28**
beam/arch connection	125	-3.30	22.80	41.17	**1.10**	-117.41	14.50	16.56	28.99	**1.17**	-2.60	18.56	33.54	**0.90**	-185.45	2.93	23.30	3.86	**0.73**	-0.76	7.14	12.94	**0.35**
	133	-3.40	22.80	41.17	**1.10**	112.52	19.40	16.56	30.83	**1.34**	-2.68	18.56	33.54	**0.90**	184.55	2.93	31.30	6.70	**1.03**	-0.78	7.14	12.94	**0.35**
	227	-3.40	-22.80	41.17	**1.10**	-117.48	-14.50	-16.56	29.01	**1.17**	-2.68	-18.56	33.54	**0.90**	-185.45	-2.93	-23.30	3.90	**0.73**	-0.78	-7.14	12.94	**0.35**
	879	-3.26	-22.80	41.17	**1.10**	112.62	-19.40	-16.56	30.85	**1.34**	-2.57	-18.56	33.54	**0.90**	184.55	-2.93	-31.30	6.74	**1.03**	-0.76	-7.14	12.94	**0.35**

Note: Red indicates areas where load exceeds capacity

Table 5.2 Load ratio of Main Arch beams

		1.2G+1.5Q				1.2G+Trans. Wind (LB)+Q						1.2G+Vert. Wind (LB)+Q				0.9G+Trans. Wind (UB)						0.9G+Vert. Wind (UB)			
	Element	Fx	Fy	Mz	load ratio	Fx	Fy	Fz	My	Mz	load ratio	Fx	Fz	Mz	load ratio	Fx	Fy	Fz	My	Mz	load ratio	Fx	Fy	Mz	load ratio
	20	-183.00	-2.06	-39.22	**0.39**	-172.17	-1.46	-5.73	-12.90	-28.69	**0.58**	-157.27	-1.65	-32.18	**0.33**	-90.50	-0.18	-9.23	-20.70	-9.72	**0.55**	-67.30	-0.49	-11.16	**0.12**
	57	-178.40	27.04	55.70	**0.62**	-104.43	19.75	-10.90	-21.00	40.69	**0.86**	-152.83	22.11	45.57	**0.51**	13.95	3.71	-17.70	-34.00	4.83	**0.76**	-64.55	7.55	15.57	**0.18**
	58	-178.40	-27.04	55.70	**0.62**	-167.23	-19.75	7.14	-15.80	40.69	**0.80**	-152.83	-22.11	45.57	**0.51**	-88.05	-3.71	11.50	-25.50	10.47	**0.67**	-64.55	-7.55	15.57	**0.18**
	91	-182.60	-1.00	-39.62	**0.39**	-136.78	-0.74	5.48	5.72	-28.99	**0.42**	-156.77	-0.83	-32.51	**0.32**	-35.01	-0.16	8.82	9.22	-2.18	**0.25**	-66.90	-0.31	-11.28	**0.12**
	92	-182.60	-0.09	-39.62	**0.38**	-136.77	-0.05	5.48	5.72	-28.99	**0.41**	-156.77	-0.07	-32.51	**0.32**	-35.00	0.03	8.82	9.22	-2.18	**0.25**	-67.00	0.00	-11.28	**0.12**
	93	-182.70	0.72	-39.62	**0.39**	-136.87	0.55	5.48	6.82	-28.99	**0.43**	-156.97	0.60	-32.52	**0.32**	-35.08	0.15	8.82	11.00	-2.03	**0.28**	-67.08	0.24	-11.29	**0.12**
	95	-183.00	2.06	-39.22	**0.39**	-172.17	1.46	5.73	-13.00	-28.69	**0.58**	-157.27	1.65	-32.18	**0.33**	-90.40	0.18	9.23	-20.80	-9.72	**0.55**	-67.30	0.49	-11.16	**0.12**
	287	-182.70	-0.74	-39.62	**0.39**	-142.10	-0.56	-3.44	5.97	-28.99	**0.41**	-156.97	-0.61	-32.52	**0.32**	-42.53	-0.16	-5.52	9.61	-9.12	**0.29**	-67.08	-0.24	-11.29	**0.12**
	288	-182.70	0.17	-39.62	**0.38**	-142.09	0.13	-3.70	5.97	-28.99	**0.41**	-156.87	0.15	-32.52	**0.32**	-42.52	0.04	-5.94	9.61	-9.12	**0.29**	-67.08	0.07	-11.29	**0.12**
	289	-182.60	0.99	-39.62	**0.39**	-141.99	0.73	-3.97	5.23	-28.99	**0.40**	-156.77	0.82	-32.51	**0.32**	-42.44	0.16	-6.37	8.42	-8.97	**0.27**	-66.90	0.31	-11.28	**0.12**
	303	-182.70	-0.74	-39.62	**0.39**	-136.85	-0.56	-5.47	6.82	-28.99	**0.43**	-156.97	-0.61	-32.52	**0.32**	-35.05	-0.16	-8.82	11.00	-2.02	**0.28**	-67.08	-0.24	-11.29	**0.12**
	304	-182.70	0.17	-39.62	**0.38**	-136.86	0.13	-5.47	6.82	-28.99	**0.43**	-156.87	0.15	-32.52	**0.32**	-35.05	0.04	-8.82	11.00	-2.02	**0.28**	-67.08	0.07	-11.29	**0.12**
	305	-182.60	0.99	-39.62	**0.39**	-136.76	0.73	-5.47	5.72	-28.99	**0.42**	-156.77	0.82	-32.51	**0.32**	-34.97	0.16	-8.82	9.23	-2.17	**0.25**	-66.90	0.31	-11.29	**0.12**
	310	-178.40	-27.04	55.70	**0.62**	-104.43	-19.75	10.90	-21.00	40.69	**0.86**	-152.83	-22.11	45.57	**0.51**	13.95	-3.71	17.70	-34.00	4.81	**0.76**	-64.55	-7.55	15.57	**0.18**
	640	-180.70	11.21	-24.54	**0.35**	-169.20	8.17	-7.14	14.10	-17.91	**0.57**	-155.10	9.17	-20.10	**0.29**	-89.03	1.50	-11.50	22.80	-1.52	**0.55**	-66.03	3.13	-6.88	**0.11**
	660	-178.40	27.04	55.70	**0.62**	-167.23	19.75	-7.14	-15.80	40.69	**0.80**	-152.83	22.11	45.57	**0.51**	-88.05	3.71	-11.50	-25.50	10.49	**0.67**	-64.55	7.55	15.57	**0.18**
	695	-182.70	-0.18	-39.62	**0.38**	-142.06	-0.14	3.70	5.97	-28.99	**0.41**	-156.87	-0.16	-32.52	**0.32**	-42.46	-0.04	5.94	9.61	-9.11	**0.29**	-67.08	-0.07	-11.29	**0.12**
	696	-182.70	0.72	-39.62	**0.39**	-142.06	0.55	3.44	5.97	-28.99	**0.41**	-156.97	0.60	-32.52	**0.32**	-42.47	0.15	5.52	9.61	-9.11	**0.29**	-67.08	0.24	-11.29	**0.12**
splice (steel plates)	405	-163.50	-0.33	-14.08	**0.54**	-109.46	-0.21	-0.03	2.09	-10.02	**0.47**	-139.86	-0.25	-11.26	**0.45**	-9.73	0.03	-0.05	3.40	0.55	**0.19**	-58.93	-0.04	-3.36	**0.17**
	406	-163.50	0.33	-14.08	**0.54**	-109.46	0.21	0.03	2.09	-10.02	**0.47**	-139.86	0.25	-11.26	**0.45**	-9.73	-0.03	0.05	3.40	0.55	**0.19**	-58.93	0.03	-3.35	**0.17**
	1036	-163.50	-0.33	-14.08	**0.54**	-139.66	-0.21	0.16	1.44	-10.02	**0.50**	-139.86	-0.25	-11.26	**0.45**	-58.53	0.03	0.27	2.34	-3.22	**0.28**	-58.93	-0.03	-3.35	**0.17**
	1037	-163.50	0.33	-14.08	**0.54**	-139.66	0.21	-0.16	1.44	-10.02	**0.50**	-139.86	0.25	-11.26	**0.45**	-58.53	-0.03	-0.27	2.34	-3.22	**0.28**	-58.93	0.04	-3.36	**0.17**
splice (timber connection)	405	-163.50	-0.33	-14.08	**0.62**	-109.46	-0.21	-0.03	2.09	-10.02	**0.47**	-139.86	-0.25	-11.26	**0.52**	-9.73	0.03	-0.05	3.40	0.55	**0.10**	-58.93	-0.04	-3.36	**0.18**
	406	-163.50	0.33	-14.08	**0.62**	-109.46	0.21	0.03	2.09	-10.02	**0.47**	-139.86	0.25	-11.26	**0.52**	-9.73	-0.03	0.05	3.40	0.55	**0.10**	-58.93	0.03	-3.35	**0.18**
	1036	-163.50	-0.33	-14.08	**0.62**	-139.66	-0.21	0.16	1.44	-10.02	**0.52**	-139.86	-0.25	-11.26	**0.52**	-58.53	0.03	0.27	2.34	-3.22	**0.23**	-58.93	-0.03	-3.35	**0.18**
	1037	-163.50	0.33	-14.08	**0.62**	-139.66	0.21	-0.16	1.44	-10.02	**0.52**	-139.86	0.25	-11.26	**0.52**	-58.53	-0.03	-0.27	2.34	-3.22	**0.23**	-58.93	0.04	-3.36	**0.18**

Table 5.3 Load ratio of Pier Columns

	1.2G+1.5Q				1.2G+Trans. Wind (LB)+Q					1.2G+Trans. Wind (LB)+Q				0.9G+Trans. Wind (UB)					0.9G+Vert. Wind (UB)			
Element	Fx	Fz	Mz	load ratio	Fx	Fz	My	Mz	load ratio	Fx	Fz	Mz	load ratio	Fx	Fz	My	Mz	load ratio	Fx	Fz	Mz	load ratio
196	-41.65	0.01	0.06	**0.13**	-20.77	1.45	1.92	0.03	**0.26**	-33.96	0.01	0.05	**0.11**	9.59	2.30	3.05	-0.02	**0.34**	-11.40	0.00	0.02	**0.04**
886	-42.60	-0.12	0.01	**0.13**	-56.95	-7.68	-2.73	0.02	**0.59**	-34.83	-0.10	0.01	**0.10**	-46.73	-12.02	-4.32	0.02	**0.81**	-11.89	-0.03	0.00	**0.04**
907	-42.41	0.01	0.00	**0.12**	-48.99	1.75	-2.73	0.01	**0.41**	-34.66	0.01	0.00	**0.10**	-34.46	2.76	-4.32	0.01	**0.52**	-11.81	0.00	0.00	**0.03**
914	-42.60	0.12	-0.01	**0.13**	-5.35	-7.50	-2.73	0.01	**0.44**	-34.83	0.10	-0.01	**0.10**	34.88	-11.98	-4.33	0.02	**0.79**	-11.89	0.03	0.00	**0.04**
935	-42.41	-0.01	0.00	**0.12**	-12.99	1.73	-2.73	0.00	**0.30**	-34.66	-0.01	0.00	**0.10**	22.74	2.76	-4.33	0.01	**0.50**	-11.81	0.00	0.00	**0.03**
1267	-41.55	-0.16	-0.09	**0.14**	-31.60	-0.15	-1.27	0.05	**0.21**	-33.84	-0.13	-0.08	**0.11**	-7.58	-0.08	-2.01	0.18	**0.22**	-11.27	-0.05	-0.03	**0.04**
1295	-41.71	-0.19	0.09	**0.14**	-28.96	-8.49	1.92	0.05	**0.48**	-34.00	-0.15	0.07	**0.12**	-3.26	-13.23	3.05	0.00	**0.62**	-11.39	-0.05	0.02	**0.04**
1298	-41.55	0.16	0.09	**0.14**	-28.80	0.05	-1.28	0.19	**0.22**	-33.84	0.13	0.08	**0.11**	-3.14	-0.08	-2.02	0.21	**0.21**	-11.27	0.05	0.03	**0.04**

Table 5.4 Load ratio of Hangers

	1.2G+1.5Q				1.2G+Trans. Wind (LB)+Q						1.2G+Vert. Wind (LB)+Q				0.9G+Trans. Wind (UB)						0.9G+Vert. Wind (UB)			
Element	Fx	Fy	Mz	load ratio	Fx	Fy	Fz	My	Mz	load ratio	Fx	Fy	Mz	load ratio	Fx	Fy	Fz	My	Mz	load ratio	Fx	Fy	Mz	load ratio
606	41.69	-0.47	0.37	**0.25**	21.62	-0.37	-3.92	2.94	0.26	**0.38**	34.08	-0.41	0.33	**0.21**	-8.56	-0.12	-6.37	4.80	0.06	**0.42**	11.65	-0.18	0.17	**0.08**
618	41.30	-0.47	-0.82	**0.30**	21.23	-0.37	-3.92	-6.87	-0.53	**0.61**	33.69	-0.41	-0.69	**0.25**	-8.85	-0.12	-6.37	-11.20	-0.02	**0.74**	11.36	-0.18	-0.28	**0.09**
631	41.30	0.16	0.82	**0.29**	21.23	0.05	-3.92	-6.87	0.53	**0.80**	33.69	0.09	0.69	**0.24**	-8.85	-0.12	-6.37	-11.20	0.01	**1.07**	11.36	-0.06	0.28	**0.09**
1249	41.30	-0.47	-0.82	**0.30**	38.99	-0.37	-3.09	-5.91	-0.72	**0.81**	33.69	-0.41	-0.69	**0.25**	19.95	-0.12	-5.03	-9.58	-0.33	**1.01**	11.36	-0.18	-0.28	**0.09**
1262	41.30	0.16	0.82	**0.29**	38.99	0.05	-3.09	-5.91	0.72	**0.81**	33.69	0.09	0.69	**0.24**	19.95	-0.12	-5.03	-9.58	0.33	**1.01**	11.36	-0.06	0.28	**0.09**

Table 5.5 Load Ratio for Bolt connection between Main Horizontal Beams and Arch Beams

A	1.2G			1.5Q			Trans. Wind (LB)			S
(m^2)	F_x (kN)	F_y (kN)	M_y (kNm)	F_x (kN)	F_y (kN)	M_y (kNm)	F_x (kN)	F_y (kN)	M_y (kNm)	(kPa)
0.000707	-0.6	3.903	7.07	-2.8	18.9	34.11	-115	0.2	0.93	198400
A	**Vert. Wind (LB)**			**Trans. Wind (UB)**			**Vert. Wind (UB)**			**S**
(m^2)	F_x (kN)	F_y (kN)	M_y (kNm)	F_x (kN)	F_y (kN)	M_y (kNm)	F_x (kN)	F_y (kN)	M_y (kNm)	(kPa)
0.000707	-0.2	2	3.62	-185	0.4	1.44	-0.33	3.24	5.87	198400

		1.2G+1.5Q			1.2G+Trans. Wind (LB)+Q			1.2G+Vert. Wind (LB)+Q			0.9G+Trans. Wind (UB)			0.9G+Trans. Wind (UB)		
Bolt	(m)	S_a (kPa)	S_m (kPa)	load ratio	S_a (kPa)	S_m (kPa)	load ratio	S_a	S_m	load ratio	S_a	S_m	load ratio	S_a	S_m	load ratio
1	0.218	5436	61757	**0.34**	31065	46270	**0.39**	4423	50305	**0.28**	44319	13381	**0.29**	1466	16755	**0.09**
2	0.088	5436	24754	**0.15**	31065	18546	**0.25**	4423	20163	**0.12**	44319	5363	**0.25**	1466	6716	**0.04**
3	0.218	5436	61757	**0.34**	31065	46270	**0.39**	4423	50305	**0.28**	44319	13381	**0.29**	1466	16755	**0.09**
4	0.218	5436	61757	**0.34**	31065	46270	**0.39**	4423	50305	**0.28**	44319	13381	**0.29**	1466	16755	**0.09**
5	0.088	5436	24754	**0.15**	31065	18546	**0.25**	4423	20163	**0.12**	44319	5363	**0.25**	1466	6716	**0.04**
6	0.218	5436	61757	**0.34**	31065	46270	**0.39**	4423	50305	**0.28**	44319	13381	**0.29**	1466	16755	**0.09**
maximum load ratio				**0.34**			**0.39**			**0.28**			**0.29**			**0.09**

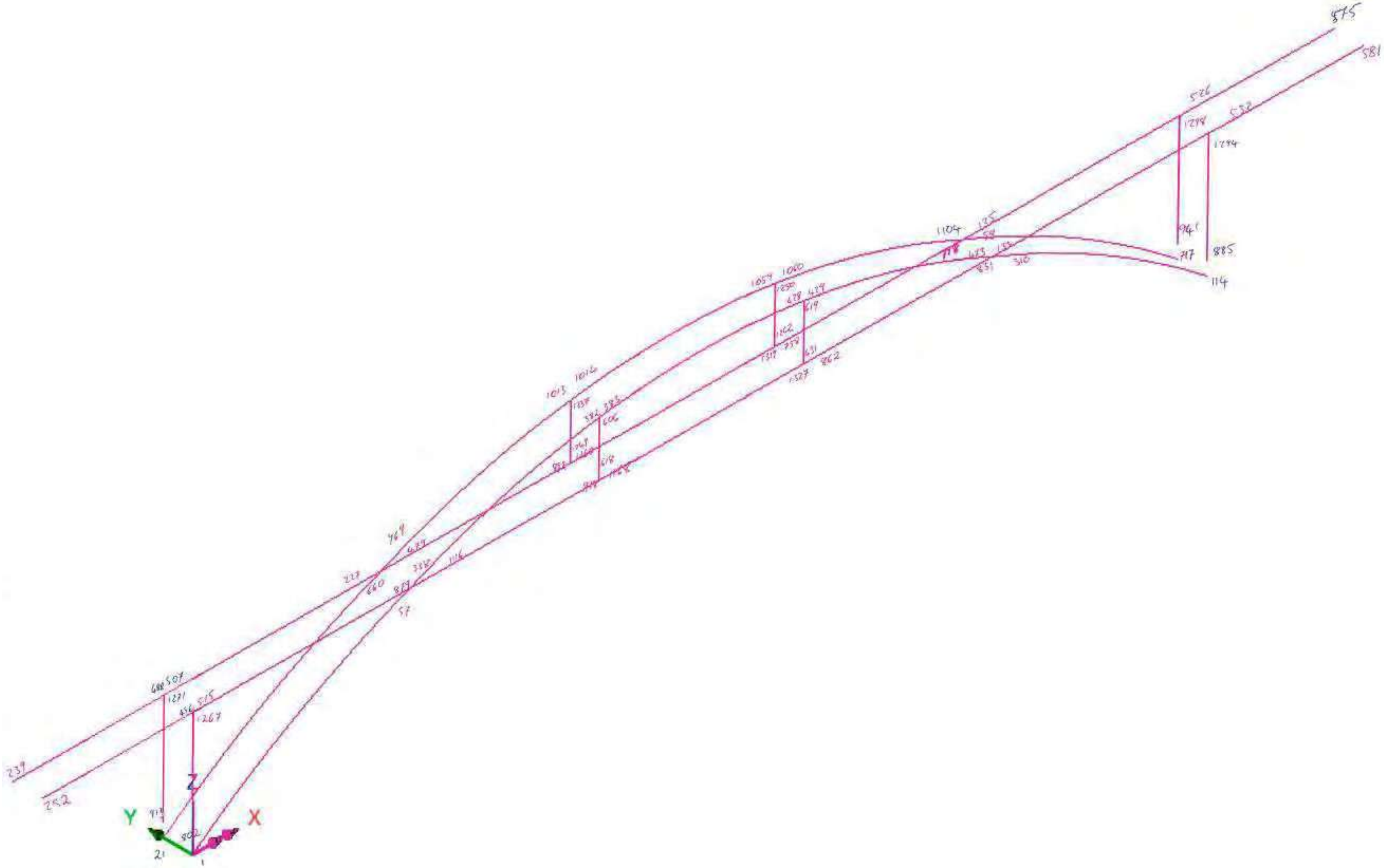


Figure 5.1 Isometric Lusas model showing global axis and selected elements from Table 5.1 to 5.4

6 Conclusion and Discussion of Results

Jubilee Bridge is a slender timber structure that is relatively lively, because the live load is comparatively large when compared to the dead load. The natural frequency, without the lateral cable supports, has been determined (first and second modes of vibration are 0.96 Hz, and 2.26 Hz) and is below 2.5 Hz in the lateral direction. Although beyond the scope of this assessment it is suggested that detailed analysis and comparison with the design criteria should be considered for this frequency range (British Standard, 1978; ENV1992-2,1996; NBCC, ONT83, ISO/DIS 10137, 1995). The motion induced by pedestrian traffic depends on the amount of traffic and the type of activity that the users are undertaking. The effectiveness of the lateral cable support therefore needs to be further investigated. The natural response as a result of pedestrian loading would only become a concern in the event of crowd loading, which should be avoided.

The load ratio (ratio of load effect to capacity) for the main structural components was determined and will be briefly discussed:

- Three of the five load cases that were considered resulted in load ratios that are in excess of unity for the main horizontal beams. The most severe load case combines wind loading with pedestrian traffic, followed by the pedestrian only load case, and then the vertical wind load only case. The regions that are distressed are localised and limited to the splicing detail (of the horizontal beams) and connection detail between the main horizontal timber beam and arch beam.

  Although the load ratios exceed unity it is only marginally so for the pedestrian only load case (10% in excess) and vertical wind only load cases (3% in excess), but more so for the combined wind and pedestrian load case (34% in excess). The minimum material strengths were used to determine the capacity of the sections and will in likelihood exceed these strengths this however cannot be quantified without destructive testing. The condition of the timber at the connection detail was also assessed as part of the on-site investigation and considered to be fair to good; however one of the reasons for limiting the material strength is to account for possible latent defects in the timber.

  It is therefore concluded that the capacity of the main timber beams are adequate for pedestrian load taken in isolation, but not for combined wind and pedestrian loading, specifically at the arch main beam connection detail.

- The main arch beams have a maximum load ratio that is less than unity for all the load cases under consideration along its length. Similar to the main horizontal beams the combined load case that includes both wind and pedestrian loading results in the highest load ratios.

  The main arch beams are adequate for all the load cases under consideration.

- The pier columns have a maximum load ratio that is less than unity for all the load cases under consideration along its length. The combined load case that only include wind and weight results in the highest load ratios.

- The hangers are locally distressed in the load cases that include transverse wind load. **The maximum load ratio for the load case that includes transverse wind and gravity are 7% in excess of unity and the capacity is therefore not adequate (bottom of the hangers).**

  The connection detail between the hangers and the arch beams are moment resisting, and increase the moment capacity of the hangers substantially in this area (moment capacity of the connection detail is doubled at the top of the hangers). The bending moment capacity of the connection detail at the bottom of the hangers is only marginally increased by the torsion capacity of the main horizontal beam and could be further increased by duplicating the connection detail at the top.

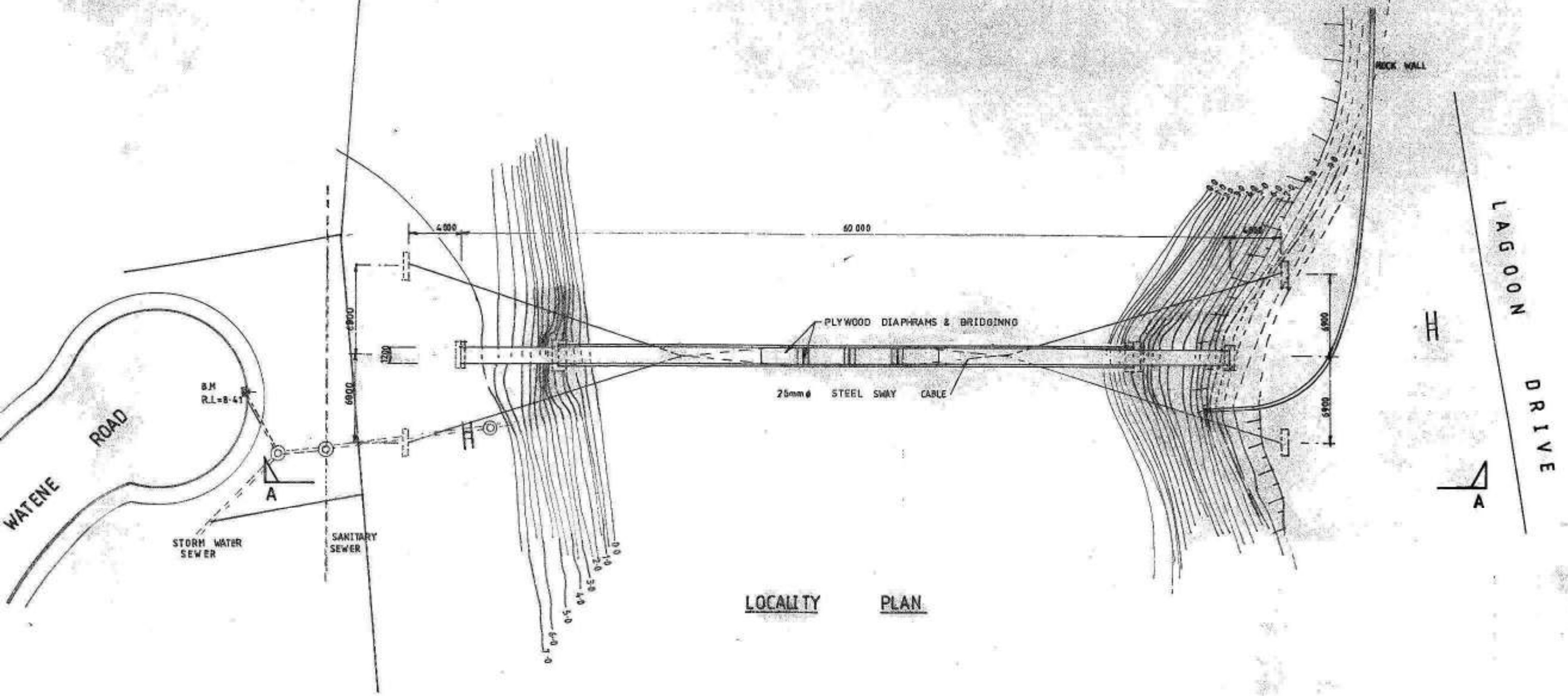
Based on the structural assessment the only regions of (static) concern are the arch/deck beam connections, and the hanger/deck beam connections.

The capacity of the deck (main) beams can be increased (in-plane) at the connection detail by the inclusion of plates and more bolts. The out-of-plane bending capacity of the hanger/beam connection detail can be increased by the addition of flat plate sections to the outside of the hangers.

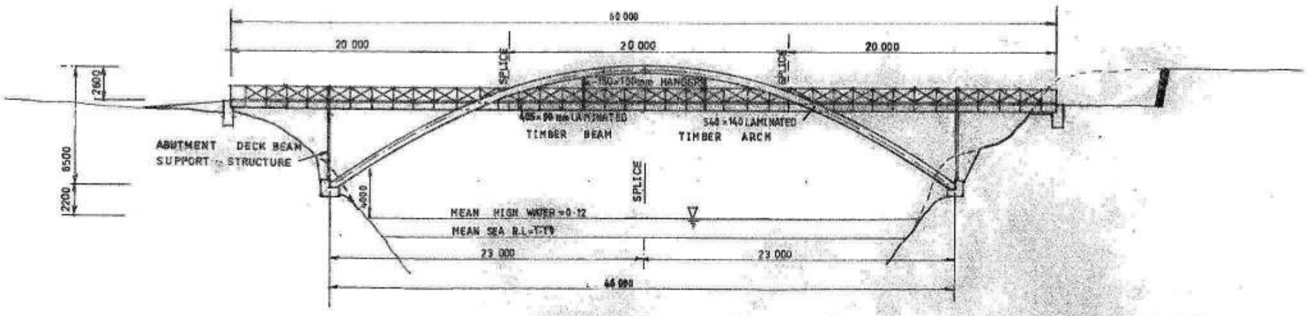
14.2 Appendix B – Drawings

© Auckland Council Archives

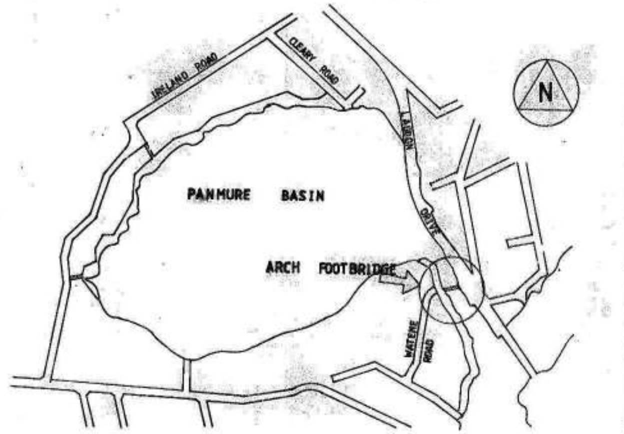
This image is not to be reproduced in any form without acknowledgement of Auckland Council Archives and where necessary permission from copyright holder



LOCALITY PLAN



ELEVATION A—A



DATUM - OLD AUCKLAND DATUM

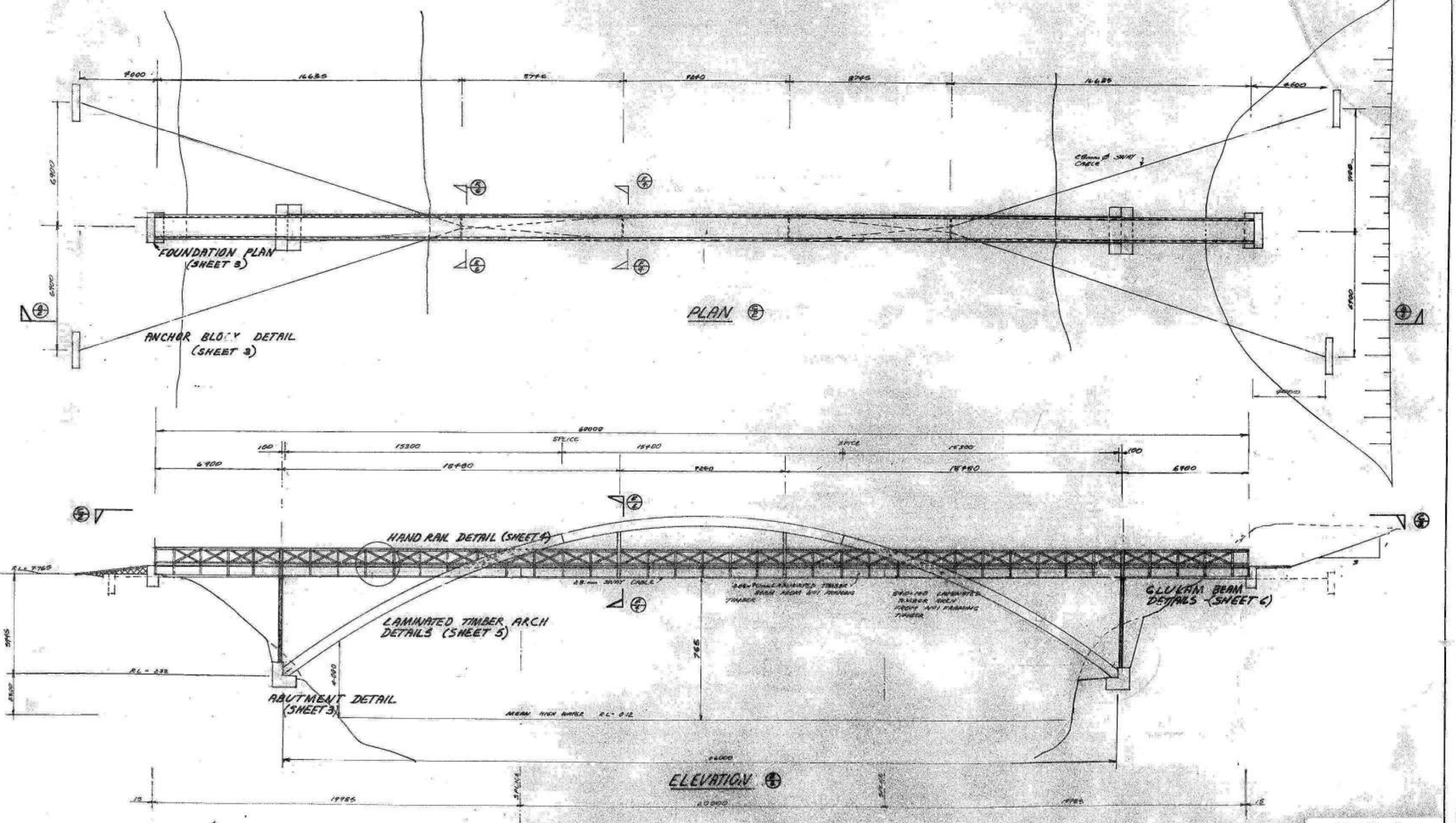
DRAWING No. 3226
SHEET 1 OF 6 SHEETS

MOUNT WELLINGTON BOROUGH COUNCIL ARCH FOOTBRIDGE

kevin d. kelly & assoc.

Drawn P. G
Date 12 / 4 / 83
Scale 1 / 200 1 / 20
Job No. 363
Sheet / of sheets

© Auckland Council Archives
Auckland Council
This image is not to be reproduced in any form without acknowledgement of Auckland Council Archives and where necessary permission from copyright holder.



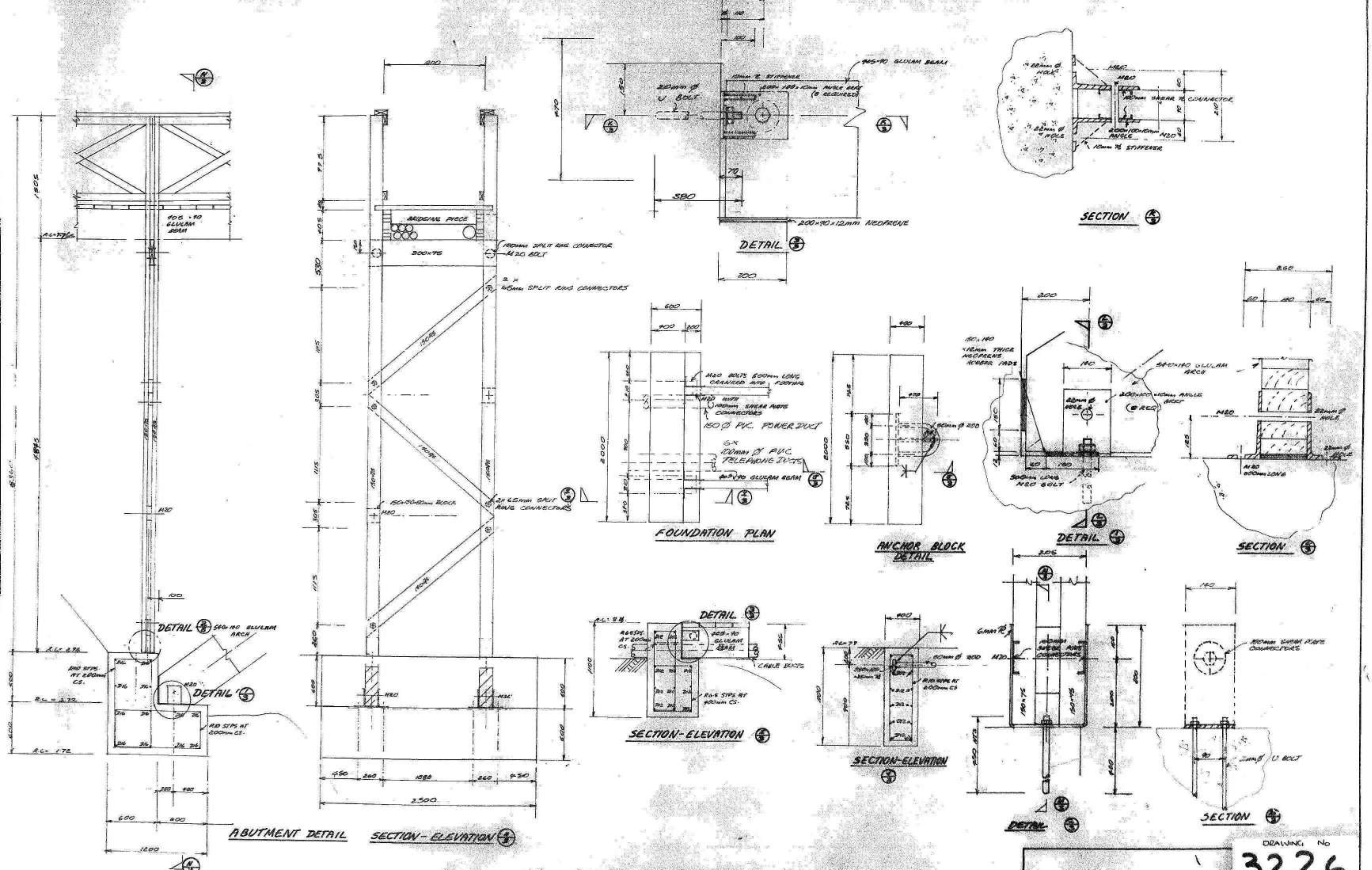
MOUNT WELLINGTON BOROUGH COUNCIL ARCH FOOTBRIDGE

kevin d. kelly & assoc.

DRAWING No. 3226

SHEET 2 OF 6 SHEETS

Job No. 363



MOUNT WELLINGTON BOROUGH COUNCIL ARCH FOOTBRIDGE

kevin d. kelly, & assoc.

Job No. 363

DRAWING No 3226

SHEET 3 OF 6 SHEETS

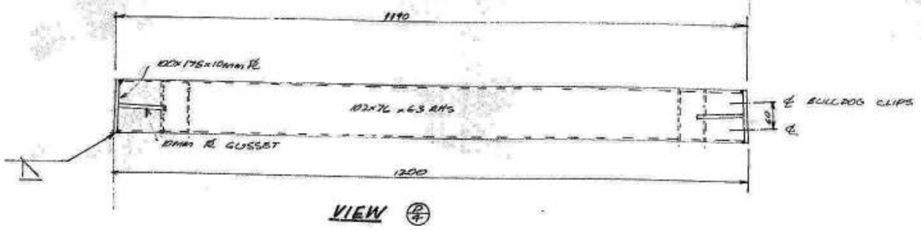
© Auckland Council Archives
Auckland Council
This image is not to be reproduced in any form without acknowledgement of Auckland Council Archives and where necessary permission from copyright holder.

NOTES

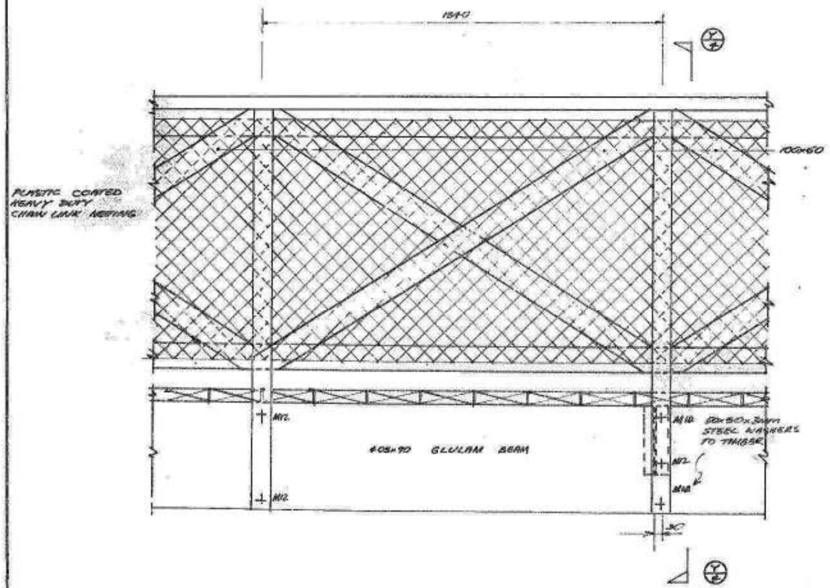
1) STEEL WORK, BRACKETS, NUTS AND BOLTS TO BE HOT DIP GALV. AND PAINTED

2) PAINT SYSTEM
   a) LIGHTLY SAND - BLAST GALV
   b) APPLY 1 COAT DEVRAN 201 PRIMER OR EQUAL
   c) APPLY 2 COATS DEVRAN 224 FINISH OR EQUAL
   - ALL PAINTING DONE TO MANUFACTURES REC.

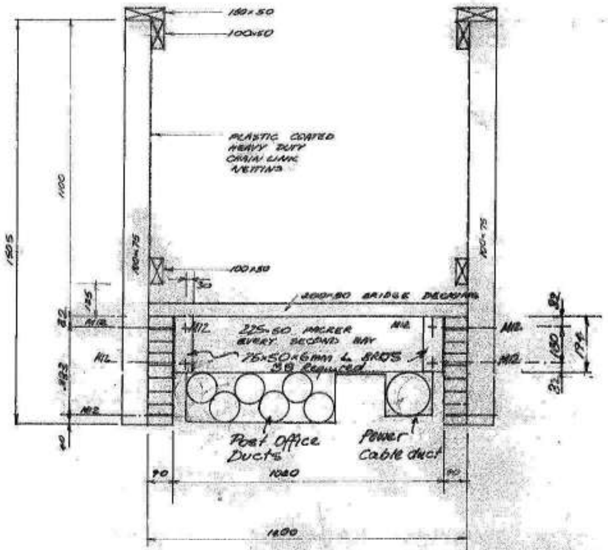
3) ALL DAMAGED PAINT WORK TO BE TOUCHED UP ON SITE (INCLUDING BOLTTHREADS)



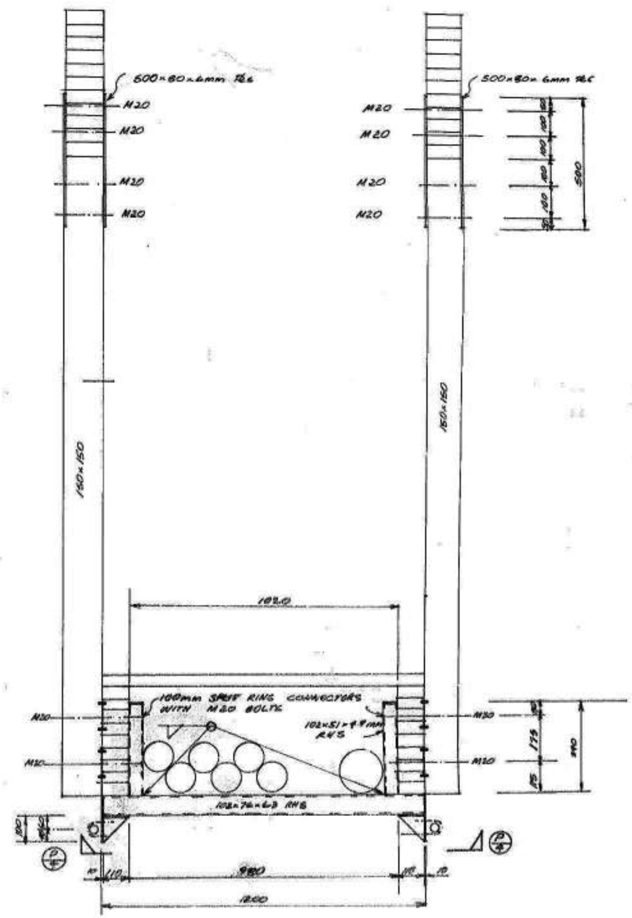
VIEW



HAND RAIL DETAIL



SECTION



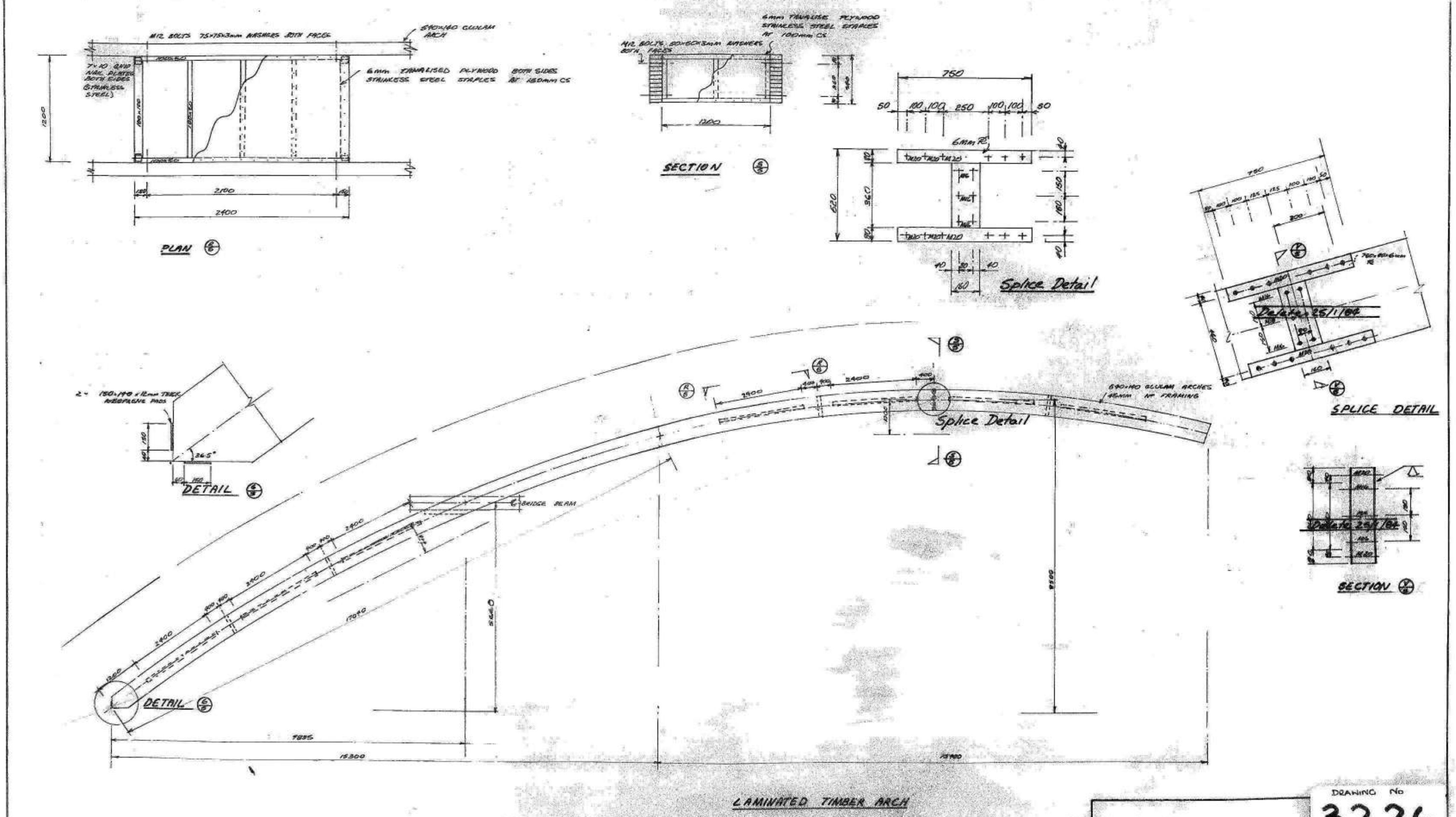
SECTION

© Auckland Council Archives
Auckland Council
This image is not to be reproduced in any form without acknowledgement of Auckland Council Archives and where necessary permission from copyright holder.

Project Engineer	Amendments		
MOUNT WELLINGTON BOROUGH COUNCIL ARCH FOOTBRIDGE	kevin d. kelly & assoc. registered engineers	Drawn	Job No. 363
		Date 21/7/80	Sheet 4 of
		Scale 1:10	

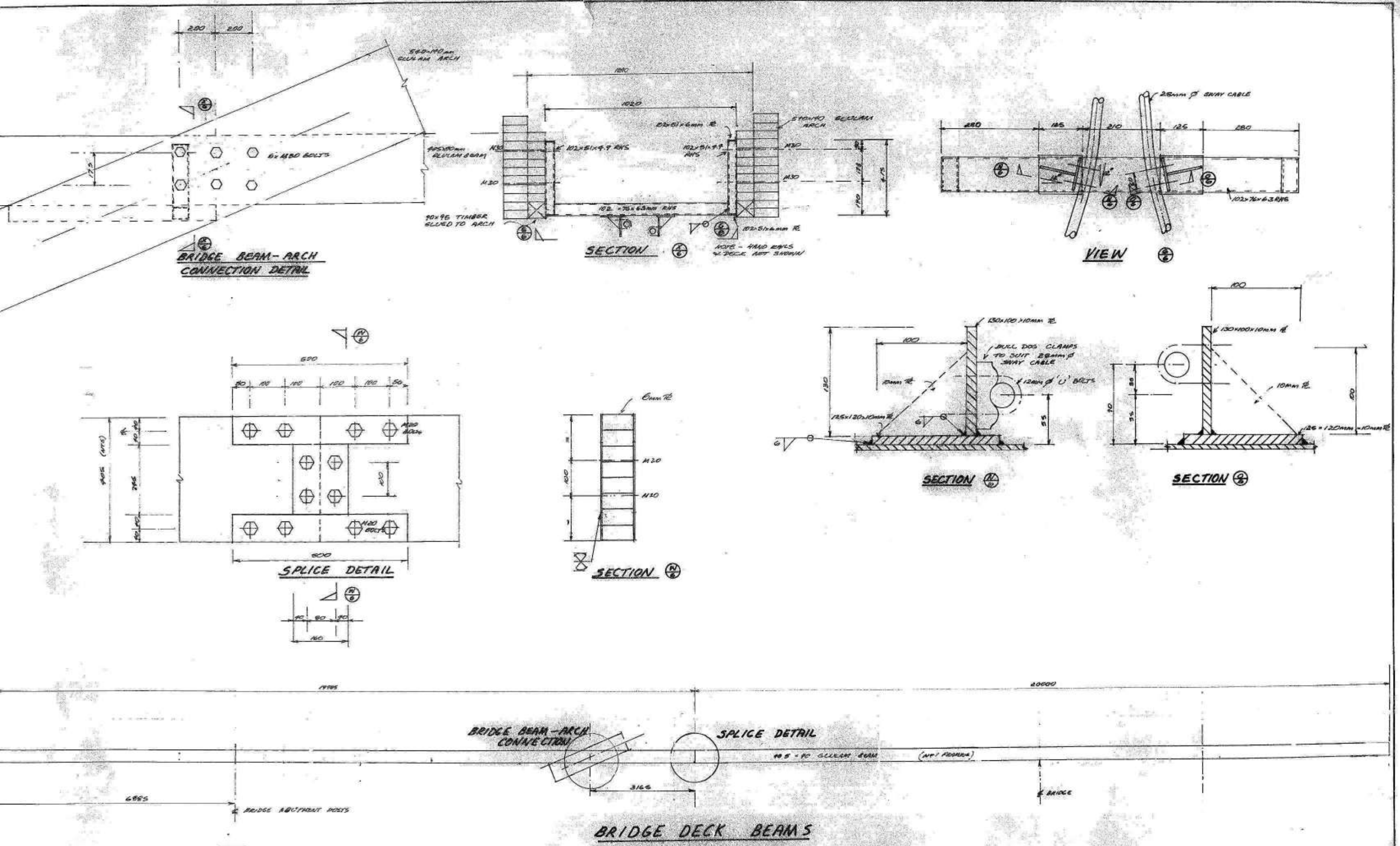
DRAWING No. 3226
SHEET 4 OF 6 SHEETS

© Auckland Council Archives
Auckland Council
This image is not to be reproduced in any form without acknowledgement of Auckland Council Archives and where necessary permission from copyright holder.



DRAWING No 3226
SHEET 5 OF 6 SHEETS

Project Engineer	Amendments			MOUNT WELLINGTON BOROUGH COUNCIL ARCH FOOTBRIDGE	kevin d. kelly & assoc.	Drawn	Job No. 363
	Splice Detail	25/1/84				Date 2/6/83	Sheet 5 of
						Scale 1:50 1:10	



© Auckland Council Archives

Auckland Council

This image is not to be reproduced in any form without acknowledgement of Auckland Council Archives and where necessary permission from copyright holder.

Project Engineer	Amendments	
	SPLICE PLATES 25/1/84	

MOUNT WELLINGTON BOROUGH COUNCIL ARCH FOOTBRIDGE

kevin d. kelly & assoc.

DRAWING NO. 3226

SHEET 6 OF 6 SHEETS

Job No. 363

Date 8/6/83

Scale 1:50 1:10 1:5

14.3 Appendix C – NZTA Bridge Inspection Report –S6

Rodney - Bridges / Culverts	Bridge Name: Jubilee Pedestrian Bridge	Bridge ID:	RP: -
Bridge Type: Glulam timber arch bridge		Report Type: Special Inspection	

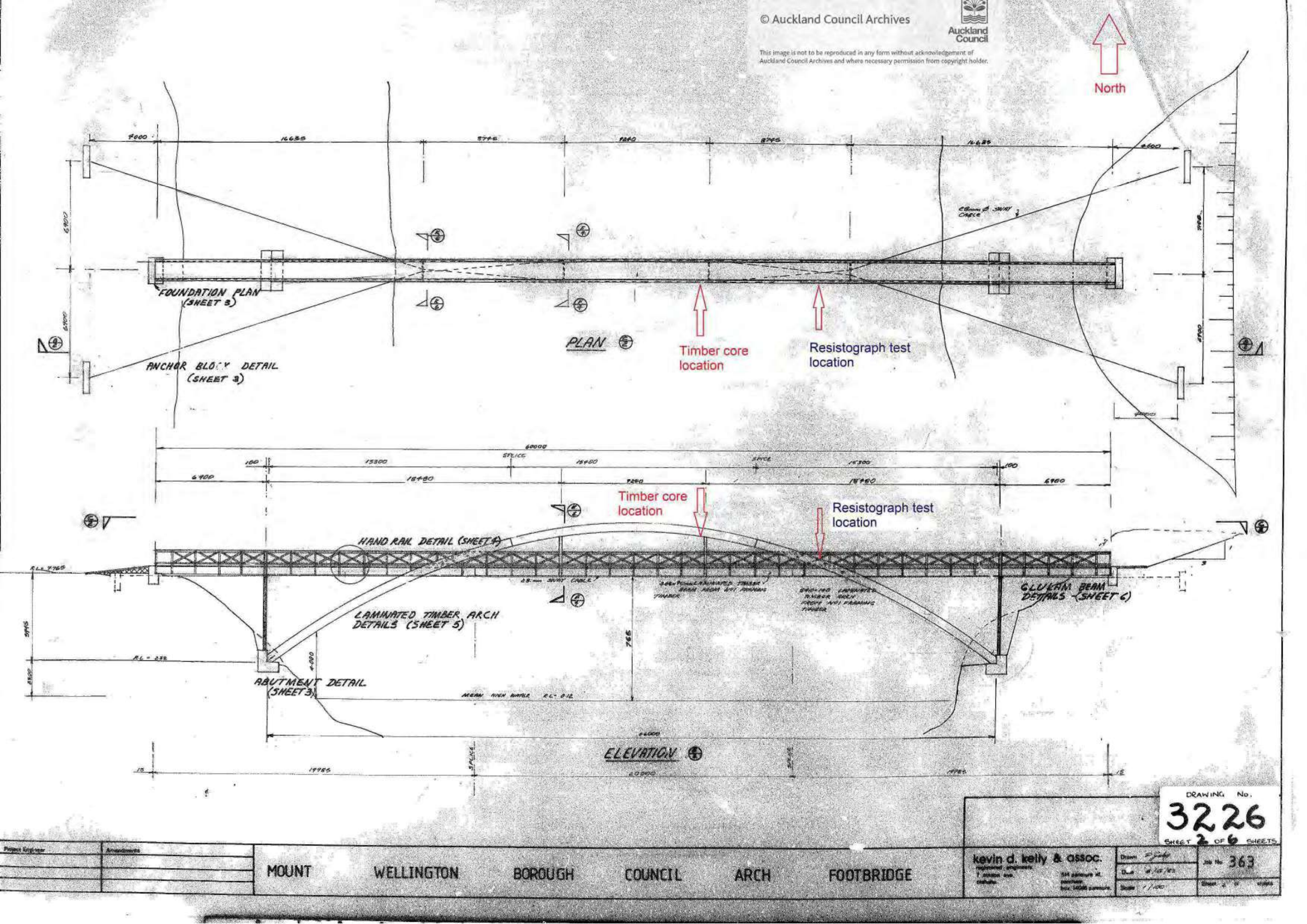
Extent marking code	Severity Code		
A = No defect B = Not > 5% C = Moderate 5 - 20% D = Wide 20 - 50% E = > 50%	1 = as new 2 = early signs of defect 3 = moderate defect 4 = severe defect 5 = element failed	Deck Width (m) 1.2 Bridge Length (m) 60 Span No. 1/6.9, 2 of Span Length (m) 46.2	Map Ref. (easting): 1765342.10 Map Ref. (northing): 5913892.70 Owner: Local Authority

Ext = Extent; Sev = Severity	Inspector: N Broad	Next Inspection Type: General Inspection
S = Structural Mtce. ; R = Routine Mtce.	Date: 15-Aug-13	Next Inspection Date: 15-Aug-15

Element Set	No	Description		Ext	Sev	S/R	Brief description of fault and comments
Superstructure Elements	1	Primary load carrying elements		B	3	S	Localised areas of moderate to advanced fungal attack to main arch beams
	2	Secondary element(s)	Transverse Beams	D	3	S	Ply box beams de-laminated, fixing heavily corroded, ply sheeting to diaphragms heavily decayed & nail slip seen
	3		Other (incl. deck)	C	4	S	Advanced decay to deck planks, some boards appeared to have fractured - replace.
	4	Half Joints		NA	NA		
	5	Seismic linkages / H.Down Bolts		C	3	S	Holding down bolts heavily corroded, washers appear to have completed failed - re-fasten
	6	Parapet beam or cantilever		NA	NA		
	7	Cross bracing		B	2	R	Minor corrosion to wire stays & brackets seen - apply protective coating
Load Bearing Substructure	8	Foundations		A	1		Concrete shelf appears to be in reasonable condition
	9	Abutments		C	3	R	Soil and plant growth needs to be removed - allow timber to air
	10	Headwall		A	1		
	11	Pier / column		D	3	S	Advanced decay, urgent attention required to protect timber at bolted connection to prevent failure
	12	Cross-head / capping beam		A	1		
	13	Bearings		D	2	R	Early signs of decay to, treat timber to preserve
	14	Bearing plinth / shelf		A	1		
Durability Elements	15	Superstructure drainage		A	1		
	16	Substructure drainage		C	3	R	Install positive drainage system to eastern abutment
	17	Movement / expansion joints		NA	NA		
	18	Painting : Superstructure element		C	3	R	Lichen growth, paint chipping & fracturing to timber arch beams - apply new coating system
	19	Painting : Substructure elements		C	3	R	Weathering of paint, flaking/splitting of paint in area
	20	Painting : barriers / guardrails		D	3	R	Re-paint handrail

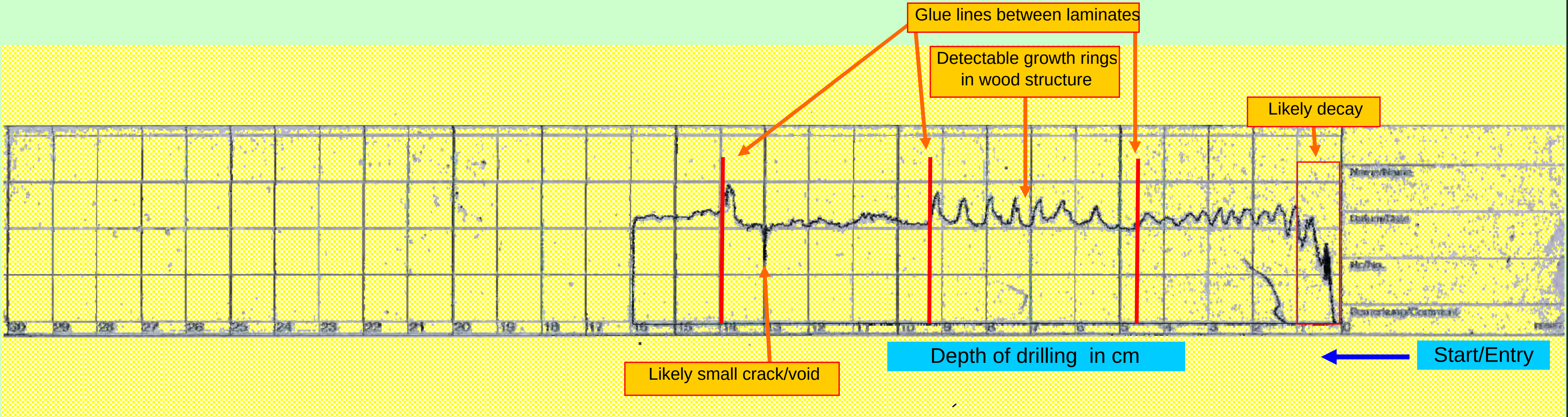
Rodney - Bridges / Culverts			Bridge Name: Jubilee Pedestrian Bridge			Bridge ID:	RP: -
Element							
Set	No	Description	Ext	Sev	S/R	Brief description of fault and comments	
Safety Elements	21	Access / walkways / gantries	NA	NA			
	22	Guardrail/handrail/safety fences	B	2	S	Damage to chain-link fence - replace affected areas with compliant mesh	
	23	Carriageway surfacing	NA	NA			
	24	Footway/verge/footbridge surface	B	2	R	Non- slip layer lifting in places - secure	
Waterway Elements	25	Invert / river bed	A	1			
	26	Aprons	NA	NA			
	27	River bed upstream	A	1			
	28	River bed downstream	A	1			
	29	Scour	A	1			
	30	River banks	A	1			
Retaining Elements	31	Revetment / batter slope paving	NA	NA			
	32	Wing walls	A	1			
	33	Retaining walls	A	1			
	34	Embankments	A	1			
Other Elements	35	Approach rails / barrier walls	A	1			
	36	Approach adequacy	A	1			
	37	Signs	A	1			
	38	Lighting	NA	NA			
	39	Services	B	2	R	Animal life nesting on service ducts	
	40	Appearance	C	3	R	R	

14.4 Appendix D – Inspection Test Results



© Auckland Council Archives
Auckland Council
This image is not to be reproduced in any form without acknowledgement of Auckland Council Archives and where necessary permission from copyright holder.
North
FOUNDATION PLAN (SHEET 3)
ANCHOR BLOCK DETAIL (SHEET 3)
PLAN
Timber core location
Resistograph test location
HAND RAIL DETAIL (SHEET 4)
LAMINATED TIMBER ARCH DETAILS (SHEET 5)
ABUTMENT DETAIL (SHEET 3)
GLULAM BEAM DETAILS (SHEET 6)
ELEVATION
60000
DRAWING No.
3226
SHEET 2 OF 6 SHEETS
MOUNT WELLINGTON BOROUGH COUNCIL ARCH FOOTBRIDGE
kevin d. kelly & assoc.
363

Probe # 10(drilled on an angle appr. 10 Degrees from vertical above the original #5 drill hole)



Drilling was undertaken using an FS400 Resistograph, a device used to determine decay and other defects in trees and structural timbers.

The sample indicates surface decay at the entry point to a depth of approximately 10mm with sound timber after that.

The small dip in timber strength at 130mm depth likely indicates a small crack in the timber.

Auckland Council- Jubilee Bridge Resistograph Assessment.(1 Drill hole only, taken 15 August 2013)

Date: 19 August 2013	**Approved by: Willy Coenradi**
Drawn by: Willy Coenradi	**Scale: N/A**

Wilcon Sylvan Parks and Landscape Management Ltd.
341 Rimmer Road, RD2
HELENSVILLE 0875
Ph: 09-420 6455 Mobile: 021-223 8723
E-Mail: coenradi@ihug.co.nz www.wilconsylvan.com

14.5 Appendix E – Original Schedule of Quantities

Dowener & Co Ltd constrcution Schedule of Qauntities				
	Original rates in 1980's schedule of quanities			
Description	Material	Labour	Plant	**Sub-Total**

Cost rates considereing Increased rates				
	Increased rates for 2013			
Revised rates	Material	Labour	Plant	Total

s7(2)(b)(ii) Prejudice to commercial position s7(2)(b)(ii) Prejudice to commercial position

s7(2)(b)(ii) Prejudice to commercial position

Opus International Consultants Ltd
Level 1, 12 - 14 Northcroft St, Takapuna
PO Box 33 1527, Takapuna, North Shore
City 0740
New Zealand

t: +64 9 488 4570
f: +64 9 488 4571
w: www.opus.co.nz

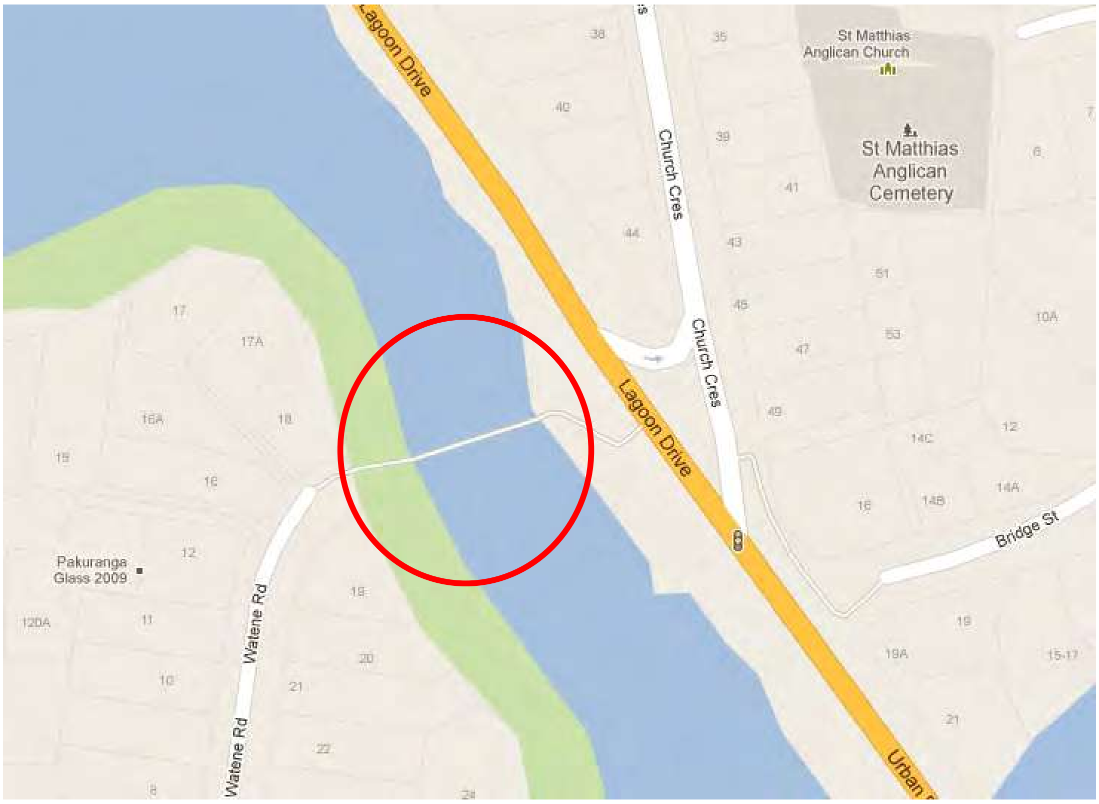
Appendix B – Resistograph Timber Decay Assessment (January 2013)

Wilcon Sylvan Parks and Landscape Management
341 Rimmer Road, RD2
Helensville 0875
Ph: 09-420 6455 Mobile: 021-223 8723
E-Mail: coenradi@ihug.co.nz Web: www.wilconsylvan.com

17 January 2013

Auckland Council- Panmure Basin Pedestrian Bridge- Resistograph timber decay assessment.

Introduction:
Visual inspection of the timber laminate structure pedestrian bridge crossing the entrance channel to the Panmure Basin, Mount Wellington indicate possible decay of some of the structural members.



Site Location

Wilcon Sylvan Parks and Landscape management Ltd. – Willy Coenradi- has been engaged to undertake a preliminary assessment of the condition of some of the structural timber laminate components using a Resistograph IML Resi F400-S measuring tool.

This equipment is used extensively throughout the world to detect decay in living trees, power poles, retaining walls and other structural timbers.

Experience in NZ has mainly been limited to living trees rather then “dead” structural timber and interpretation of the results therefore is strongly influenced by the experience of the operator.

Project Brief:
To undertake Resistograph testing of timber bridge components as directed by Project Engineer on site and to provide a report with interpretation of the test results.

Site description and observations:
The pedestrian bridge at the Panmure Basin connects the bottom of Watene Road across the Panmure Basin channel to Lagoon Drive and is well used by pedestrians.

The bridge was constructed in 1984 by the then Mt Wellington Borough Council and is of a timber construction.

The main beams supporting the deck surface are constructed of laminated Pinus radiata as are the overhead curved support beams.

There is concern regarding the structural integrity of the structure with apparent possible de-lamination and timber decay.

Methodology:
The usual methodology applied is in order of sequence as follows. Each method is more “intrusive” and will increasingly adversely affect the structural integrity of the item assessed/tested:

1. Initial Visual Assessment: The item to be tested is assessed for visual clues as to signs of decay or defects. May also include sound testing (using a hammer) and manual probing with a sharp item. Does not adversely affect the structural integrity.
2. If decay or defects are suspected, Resistograph samples are taken and analysed. (The Resistograph drills and pushes a thin 3mm wide steel specialised drill bit into the wood measures the resistance as it penetrates and records the data on a graph for further analysis). Minor adverse effects will result due to the removal of material and increased likelihood of decay (In the case of untreated timbers).
3. If the Resistograph assessment indicates severe decay or other significant defects, a core sample may be taken using an Increment Drill (This equipment drills a 10mm diameter hole and removes an approximately 6mm core of material which can then be further analysed). Increased levels of possible adverse effects due to large holes drilled.

Our brief at this stage was limited to Step 1 and Step 2 only.

Test locations were selected by Kyle Kaliniak from Blue Barn Consulting Ltd., the engineer responsible for this project.

10 probes were taken of which one failed due to the drill diverging sideways off course and emerging prematurely from the beam tested. The results of this probe have therefore been discarded.

Probes were taken at the following locations:

Probe #	Location description
1	Lagoon Drive side, Northern curved beam. (Beam “A”) Top of beam, centre, 445 mm from end of beam
2	Lagoon Drive side, Northern curved beam. Side of beam, 150mm from top of beam. (Beam “A”), 175mm from end of beam
3	Lagoon Drive side, Southern curved beam. (Beam ”B”)Side of beam, 130mm from top of beam, 140mm from end of beam
4	Lagoon Drive side, Southern curved beam. Top of beam, centre (Beam ”B”), 450 mm from end of beam
5	Bridge span, Southern curved beam close to the middle of the span.
6	Watene Road, Southern curved beam. Side of beam (Beam “C”), 130mm from top of beam, 100mm from end of beam
7	Watene Roadside, Southern curved beam. (Beam “C”) Top of beam, centre, 445 mm from end of beam
8	Watene Roadside, Northern curved beam. Top of beam, centre (Beam “D”), 510 mm from end of beam
9	Watene Road, Northern curved beam. Side of beam, 310 from top of beam (Beam “D”), 100mm from end of beam

Photos of Probe Locations and other issues noted.

Probe #1 & #2, Beam “A”

Probe #3 & #4 (#4A is the location of the “failed” probe) (Beam “B”)

Photo showing the end of Beam “B” showing end decay and lateral de-lamination.

Photo showing Beam "B" with manual probe pushed into decayed wood.

As above

Photo showing the location of Probe #5

Severely decayed wood below handrail support (Beam "B". 150mm manual probe completely inserted

Photo showing beam “C”, probe #6 and decay at beam end.

Photo showing Beam “C” and probe #7

Photo showing Beam “D” and Probe #8

Photo showing beam “D” and probe #9

Conclusions:

General:

Indications are that decay is well advanced at the tested locations with the structural integrity of critical parts likely compromised to some degree.

It is likely that further decay will be found in areas that were inaccessible during this testing. The exact extent of decay can only be determined as part of more detailed investigations.

Although the timber was likely treated when installed, it is noted that decay fungi species are present and active in some locations.

Specifically tested components:

Beam “A”

Severe decay at beam ends and bottom where in contact with the soil/concrete, progressing inwards but decreasing within 100mm from end.

Beam “B”

As per Beam “A” but slightly more severe. Top of beam also showing signs of decay as per photo.

Beam “B” where crossing/meeting handrail.

Severe decay where meeting the handrail supports. Decay here is if particular concern as it projects down from the nail hole by at least 80mm, likely severely adversely affecting structural integrity to some degree.

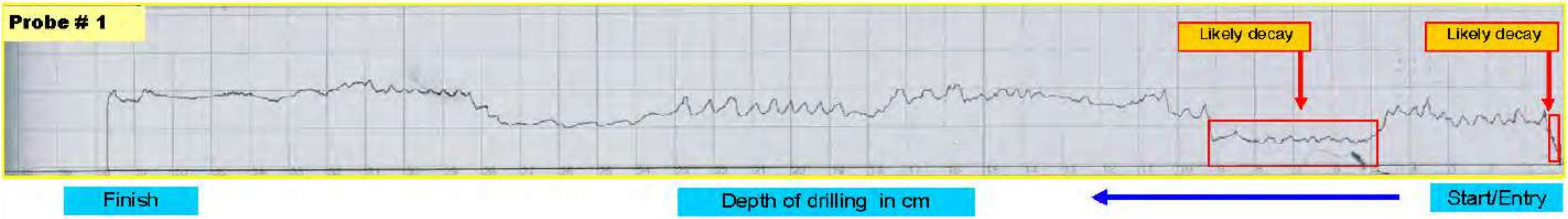
Beam “C”

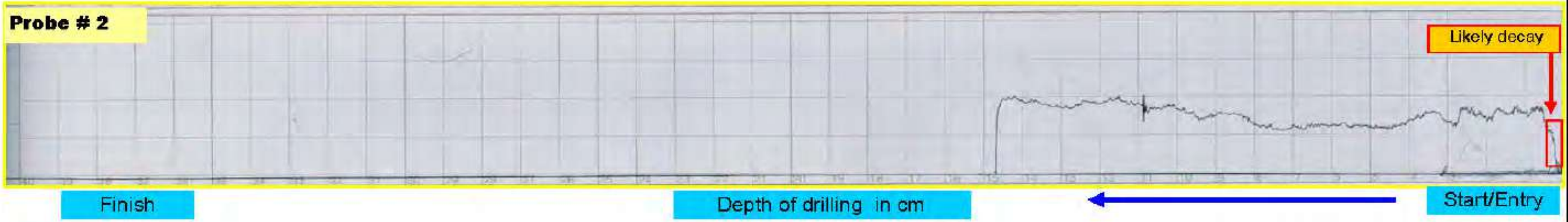
Severe decay at beam ends and bottom where in contact with the soil/concrete, progressing inwards but decreasing within 100mm from end

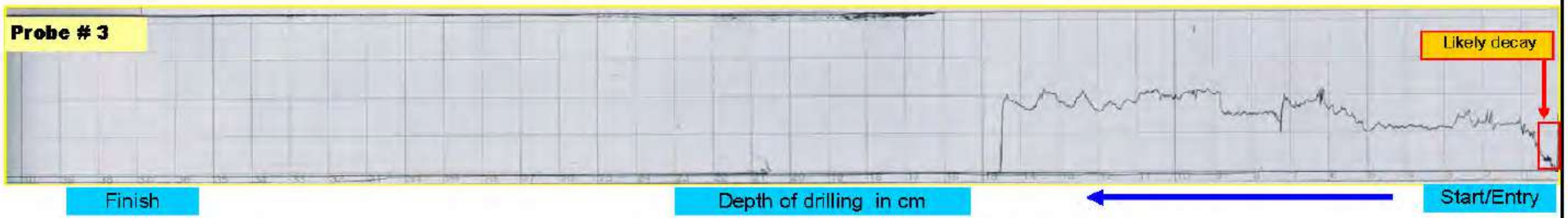
Beam “D”

Severe decay at beam ends and bottom where in contact with the soil/concrete, progressing inwards but decreasing within 100mm from end.

Resistograph probe results by Probe reference number:



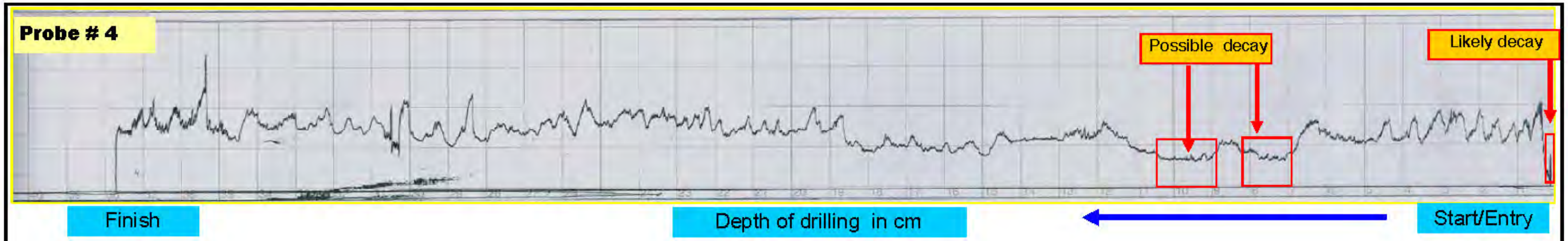


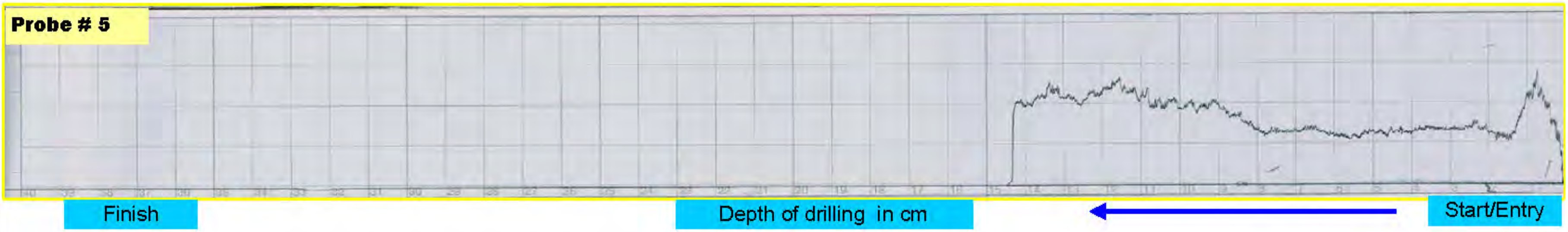


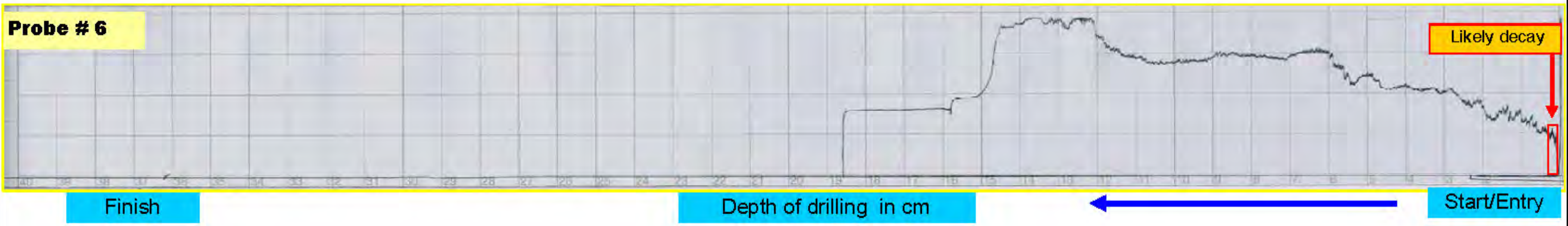
Auckland Council- Panmure Basin Pedestrian Bridge Resistograph Assessment.

Date: 17 January 2013	**Approved by: Willy Coenradi**
Drawn by: Willy Coenradi	**Scale: As shown**

Wilcon Sylvan Parks and Landscape Management Ltd.
341 Rimmer Road, RD2
HELENSVILLE 0875
Ph. 09-420 6455 Mobile: 021-223 8723
E-Mail: coenradi@ihug.co.nz



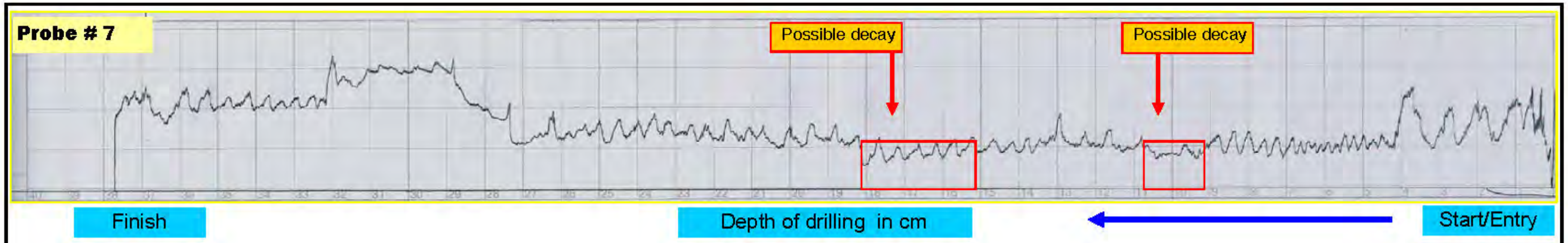


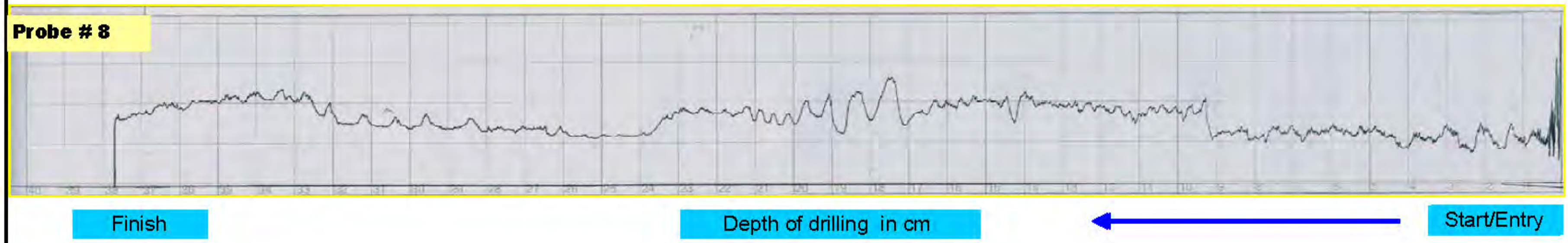


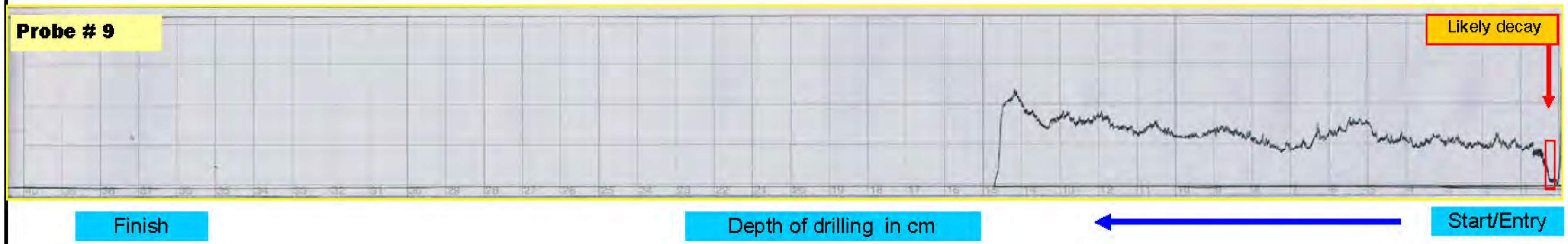
Auckland Council- Panmure Basin Pedestrian Bridge Resistograph Assessment.

Date: 17 January 2013	Approved by: Willy Coenradi
Drawn by: Willy Coenradi	Scale: As shown

Wilcon Sylvan Parks and Landscape Management Ltd.
341 Rimmer Road, RD2
HELENSVILLE 0875
Ph: 09-420 6455 Mobile: 021-223 8723
E-Mail: coenradi@ihug.co.nz







Auckland Council- Panmure Basin Pedestrian Bridge Resistograph Assessment.

Date: 17 January 2013	**Approved by: Willy Coenradi**
Drawn by: Willy Coenradi	**Scale: As shown**

Wilcon Sylvan Parks and Landscape Management Ltd.
341 Rimmer Road, RD2
HELENSVILLE 0875
Ph: 09-420 6455 Mobile: 021-223 8723
E-Mail: coenradi@ihug.co.nz

Recommendations:
Further monitoring, investigations, and analysis of the information gained is recommended.

Investigations should include disassembly of critical parts for closer inspection and assessment by suitably qualified and experienced personnel and possible (laboratory) testing to determine the structural strength of componentry, severity of decay and identification of the fungal species that are active.

Yours sincerely

Willy Coenradi.
Wilcon Sylvan Parks and Landscape Management

Date: 17 January 2013

Limitations/Disclaimers:

This report and information contained herein has been completed by Wilcon Sylvan Parks and Landscape Management Ltd.("Wilcon Sylvan") with the usual care and thoroughness of the consulting profession for use by Auckland Council and only those third parties which have been authorized in writing by Wilcon Sylvan to rely on the information contained in this report..
This report is based on generally accepted practices and standards for Arboricultural Risk and Condition Assessment at the time it was prepared and no other warranty, expressed or implied is made as to the additional professional advice included in this report.
This report was completed on the date noted on the front page of this document. Wilcon Sylvan Parks and Landscape Management Ltd. disclaims any responsibility for changes that may have ensued after the time of this audit.

Appendix C – Resistograph Timber Decay Assessment (July 2023)

Wilcon Sylvan Parks and Landscape Management
341 Rimmer Road, RD2
Helensville 0875
Ph: 09-420 6455 Mobile: 021-223 8723
E-Mail:wilconsylvan@gmail.com; www.wilconsylvan.com

3 July 2023

Auckland Council- Panmure Basin Pedestrian Bridge- Resistograph timber decay assessment June 2023.

Background:
The Jubilee pedestrian bridge was constructed in 1984 by the then Mt Wellington Borough Council and is of a timber construction.

The main beams supporting the deck surface are constructed of laminated Pinus radiata as are the overhead curved support beams.

It forms part of the McCullough Walkway that circles the Panmure Basin.

Introduction:
Wilcon Sylvan Parks and Landscape Management (WSPLM) was involved in the initial structural assessment of the pedestrian bridge back in 2013 when concerns were raised about the structural integrity of the bridge.

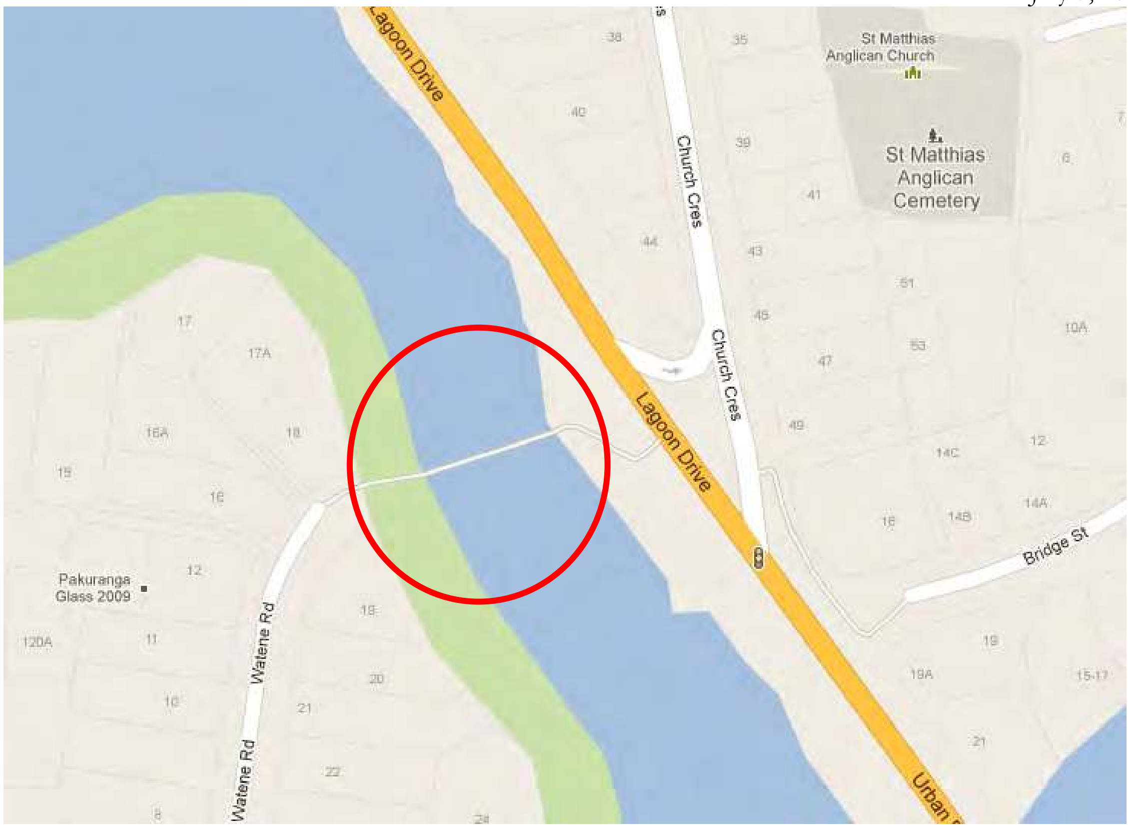
This was limited to undertaking sampling investigation at specific locations using a Resistograph IML Resi F400-S measuring tool.

WSPLM has been engaged again, this time by CLC Consulting Ltd. to provide the same service using the same equipment.

An initial site visit was undertaken during May 2023 with Jonah Tahir from CLC Ltd. To obtain an initial visual impression of the bridge and structure, and to decide on the locations for further sampling investigations using the Resistograph.

Sampling investigations were then undertaken on 7 June 2023 with the results discussed in this report.

Site description:
The pedestrian bridge known as the Jubilee Bridge is part of the Mc Cullough Walkway and provides a link across the Panmure Basin Channel from Watene Road to Lagoon Drive.



Site Location

Project Brief:
Our brief was to undertake probe drill testing using a Resistograph testing of timber bridge components as directed by Project Engineer on site and to provide a report with interpretation of the test results.

The Resistograph IML Resi F400-S measuring tool:
The Resistograph measuring tool was developed in Germany and is used to detect the presence of decay and/or other possible issues in living trees and also in "dead" structural timbers such as powerpoles, timber piles and the like.

The Resistograph drills and pushes a thin 3mm wide steel specialised drill bit into the wood measuring the resistance as it penetrates and records the data as a graph for further analysis.

The Resistograph model used is capable of testing timber to a depth of up to 400mm.

Methodology:
The usual methodology applied is in order of sequence as follows. Each method is more "intrusive" and will increasingly adversely affect the structural integrity of the item assessed/tested:

1. Initial Visual Assessment: The item to be tested is assessed for visual clues as to signs of decay or defects. May also include sound testing (using a hammer) and manual probing with a sharp item. Does not adversely affect the structural integrity.

2. If decay or defects are suspected, Resistograph samples are taken and analysed. Some adverse effects will result due to the removal of material and increased likelihood of decay (In the case of untreated timbers).
3. If the Resistograph assessment indicates severe decay or other significant defects, a core sample may be taken using an Increment Drill (This equipment drills a 10mm diameter hole and removes an approximately 6mm core of material which can then be further analysed). Increased levels of possible adverse effects due to large holes drilled.

Our brief at this stage was limited to Step 1 and Step 2 only.

Important note:
It is important to note that the drilling test results and interpretations in this report apply specifically and only to the actual sampling locations.

This means that the results and interpretations are highly localised and limited to the size of the 3mm diameter drilling needle hole at each sample testing location.

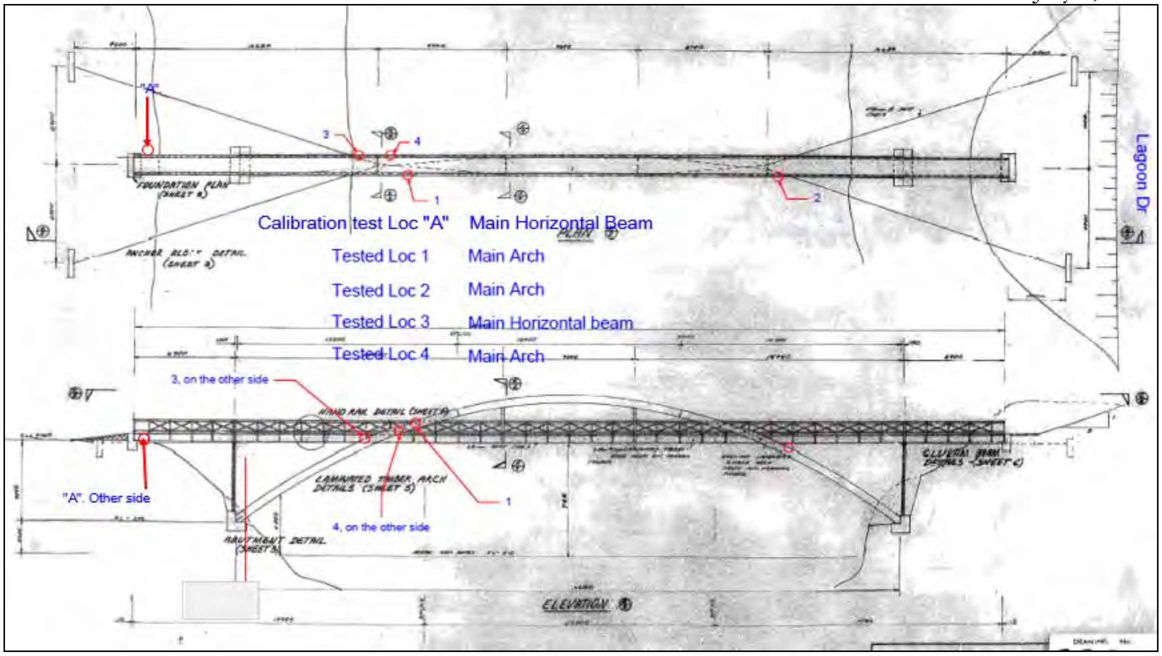
The testing using the Resistograph must be regarded as an aid and part of a wider investigation undertaken to Engineering standards and procedures.

Test locations were selected by Jonah Tahir from CLC Consulting, the engineer responsible for this project.

Five drillings were taken of which one was undertaken for calibration purposes in order to provide a baseline for the investigations.

Probes were taken at the following location and are shown in Appendixthe s:

Probe #	Location description
Test location “A”	Watene Road side, end of Northern main horizontal beam
Test location 1	Watene Road side, Southern arch, where handrail connects to arch
Test location 2	Lagoon Drive side, Southern arch, where vertical strut connects to arch. (Note: due to the tight location the drilltesting was undertaken on an approximately 10 percent angle resulting in the drill needle exiting the arch beam prematurely).
Test location 3	Watene Road side, Northern horizontal beam, through the deck and the beam.
Test location 4	Watene Road side, Northern arch, adjacent hand rail post.



Plan showing the test locations

Photos of Probe Locations and other issues noted.

Photo showing the location of the calibration drilling "A"

As per above

Photo showing the location of test drilling #1 The red arrow(s) depict the approximate drilling angle(s)

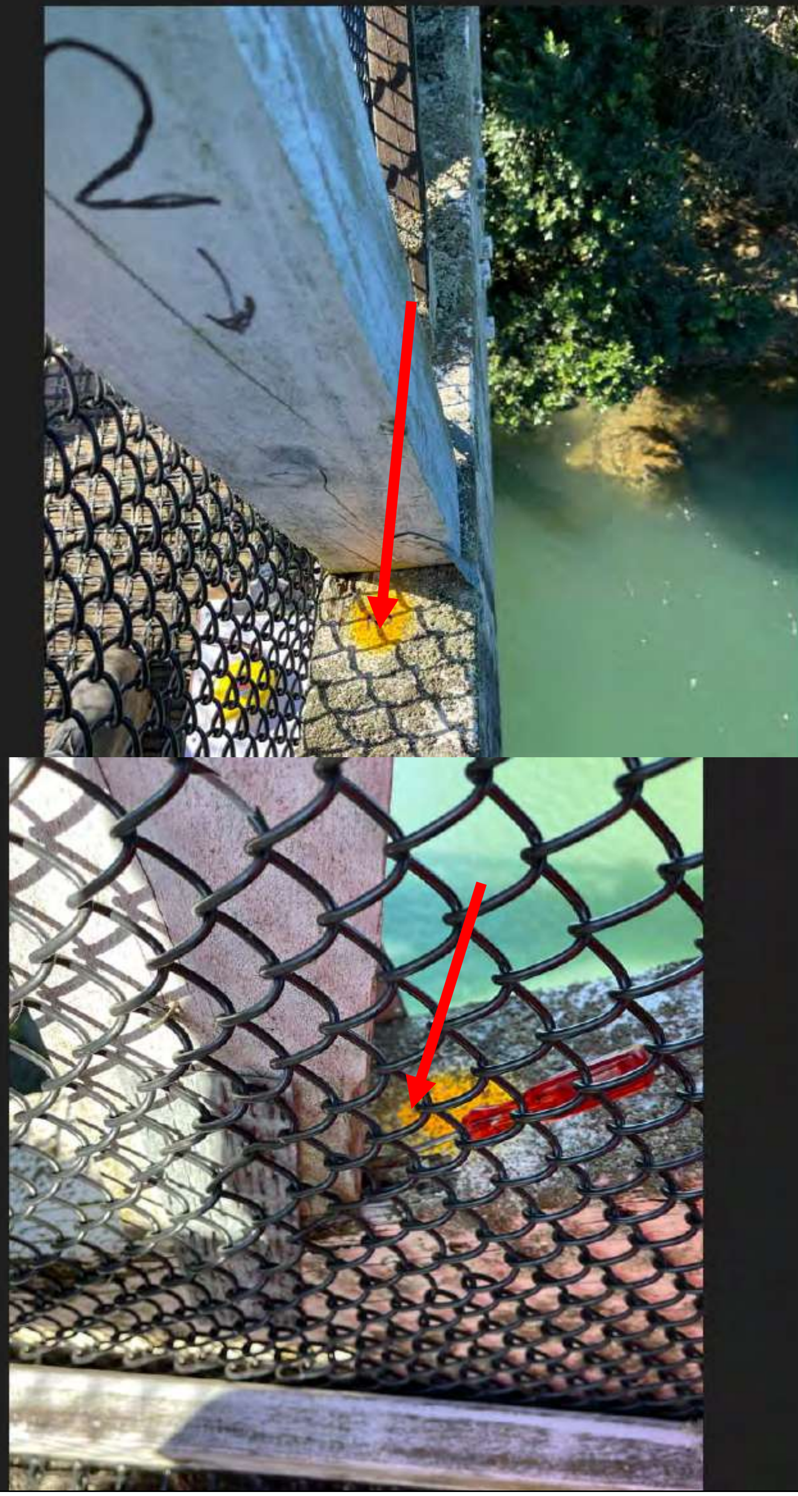


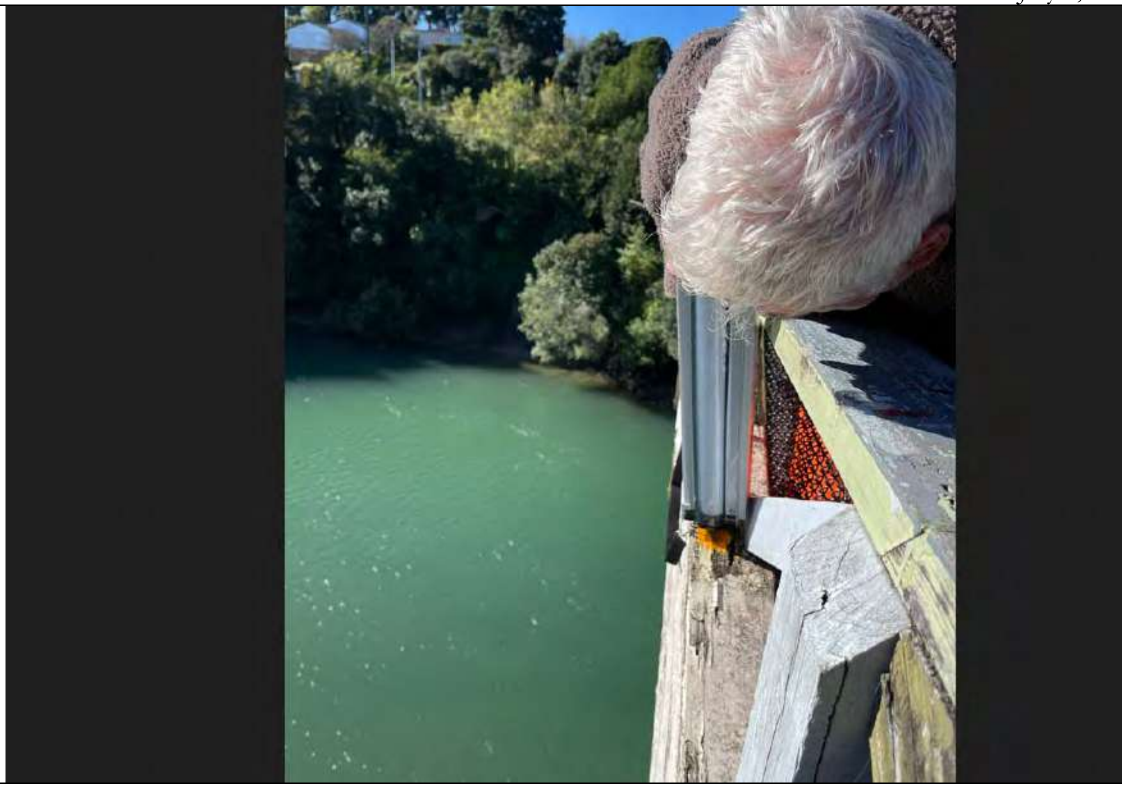
Photo showing the location of test drilling #2. The red arrow(s) depict the approximate drilling angle(s)

#2 severe decay detected under handrail post

Photo showing the location of test drilling #3 The red arrow(s) depict the approximate drilling angle(s) Drilling was undertaken near vertical through the deck into horizontal beam

As per above

Photo showing the location of test drilling #4 Drilling was undertaken near vertical into the arch.



As per above.

Conclusions:

General:

The main differences between the 2013 condition of the bridge and the recent site investigations relate to the connecting structures between the two arches, i.e. the connection timbers between the arches and the associated plywood bracing which appears to have deteriorated considerably.

It must be noted (as explained above) that each of the test drillings undertaken is limited to a specific 3mm point and the angle the test drilling was made.

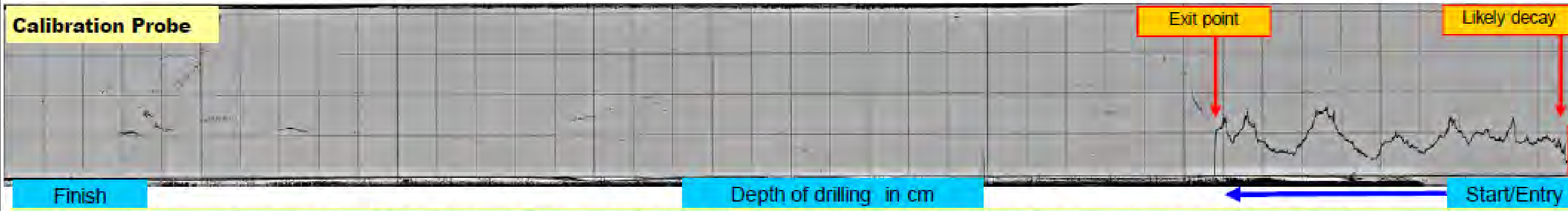
As such, results found from one point to the next may be entirely different, and point to point comparisons should not be made.

In our opinion it is highly likely that further decay will be found in other locations, including those that were inaccessible for testing or locations not selected for testing. The exact extent of decay can only be determined as part of more detailed investigations.

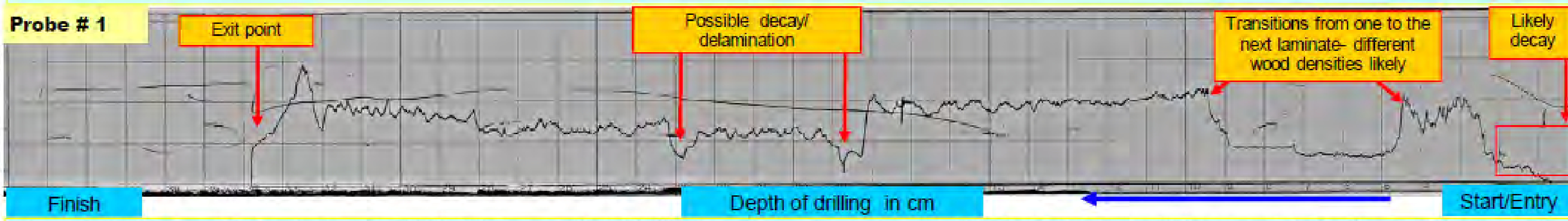
Recommendations:

The investigations undertaken should be part of a process of further monitoring, investigations, and analysis of the information provided in this report and therefore cannot be relied on as the sole source of information.

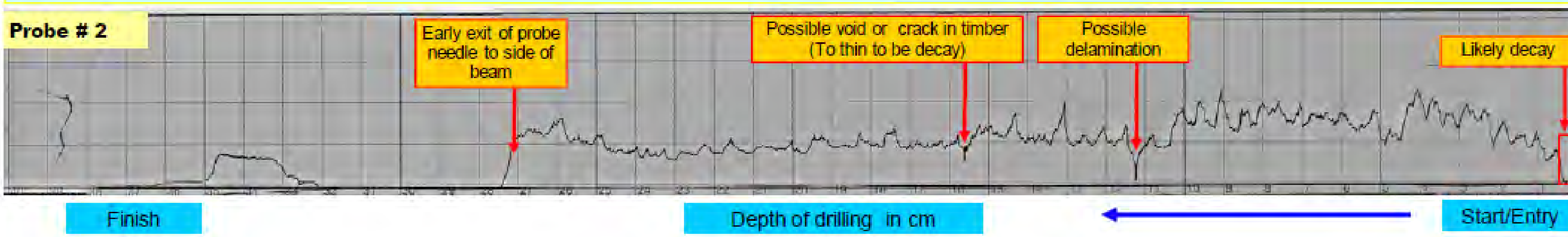
It is recommended that additional investigations are undertaken including the disassembly of critical parts for closer inspection and assessment by suitably qualified and experienced personnel and possible (laboratory) testing to determine the structural strength of any componentry, severity of decay and identification of the any fungal species that may be active and could affect the structural integrity of any of the componentry.



A calibration drilling was undertaken at point "A" of the bridge, drilling horizontally through the laminated beam. This would have drilled through a single laminate only. The beam is painted which may explain what appears the low resistance for the first 3mm or so. The quite steeply fluctuating peaks and troughs every 15mm or so could represent the annual growth rings of the timber, subject to the direction of the timber when it was processed being across the grain.

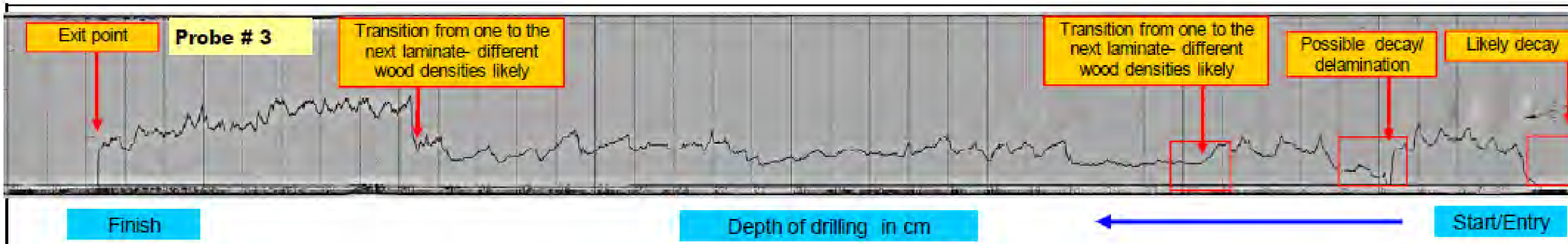


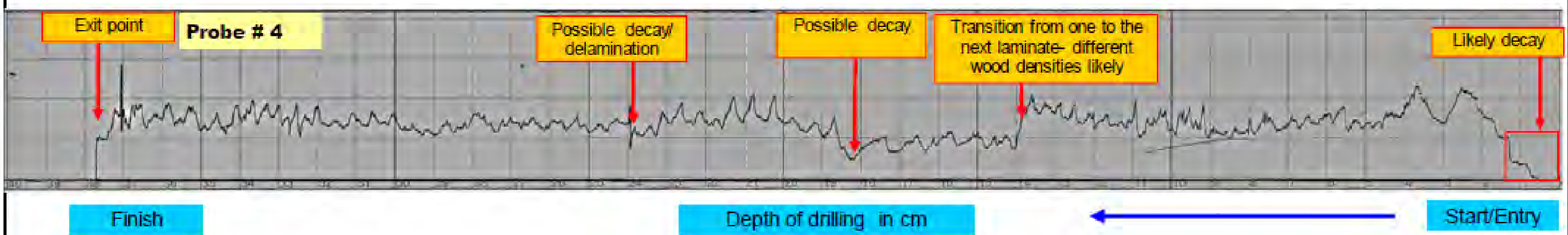
This sample drilling was undertaken at referencepoint #1 drilling near vertically into the beam. The transition between the timber laminate layers and differing wood desities of some visible at several locations. considerable decay is noted to a depth of at least 20mm into the first laminate, and low timber density is noted of the second laminate at this point



Auckland Council- Panmure Basin Pedestrian Bridge Resistograph Assessment.	
Date: 10 June 2023	Approved by: Willy Coenradi
Drawn by: Willy Coenradi	Scale: As shown

Wilcon Sylvan Parks and Landscape Management Ltd.
341 Rimmer Road, RD2
HELENSVILLE 0875
Ph: 09-420 6455 Mobile: 021-223 8723
E-Mail: coenradi@ihug.co.nz



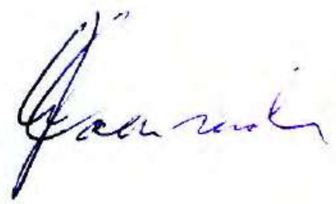


Auckland Council- Panmure Basin Jubilee Pedestrian Bridge Resistograph Assessment.

Date: 10 June 2023	Approved by: Willy Coenradi
Drawn by: Willy Coenradi	Scale: As shown

Wilcon Sylvan Parks and Landscape Management Ltd.
341 Rimmer Road, RD2
HELENSVILLE 0875
Ph: 09-420 6455 Mobile: 021-223 8723
E-Mail: coenradi@ihug.co.nz

Yours sincerely



Willy Coenradi.
Wilcon Sylvan Parks and Landscape Management

Date: 3 July 2023

Limitations/Disclaimers:

This report and information contained herein has been completed by Wilcon Sylvan Parks and Landscape Management Ltd. (WSPLM) with the usual care and thoroughness of the consulting profession for use by CLC Consulting Ltd. and only those third parties which have been authorized in writing by WSPLM to rely on any information contained in this report.

This report is based on generally accepted practices and standards for Arboricultural Risk and Condition Assessment at the time it was prepared and no other warranty, expressed or implied is made as to the additional professional advice included in this report.

This report was completed on the date noted on the front page of this document. Wilcon Sylvan Parks and Landscape Management Ltd. disclaims any responsibility for changes that may have ensued after the date of the site investigations having been undertaken.