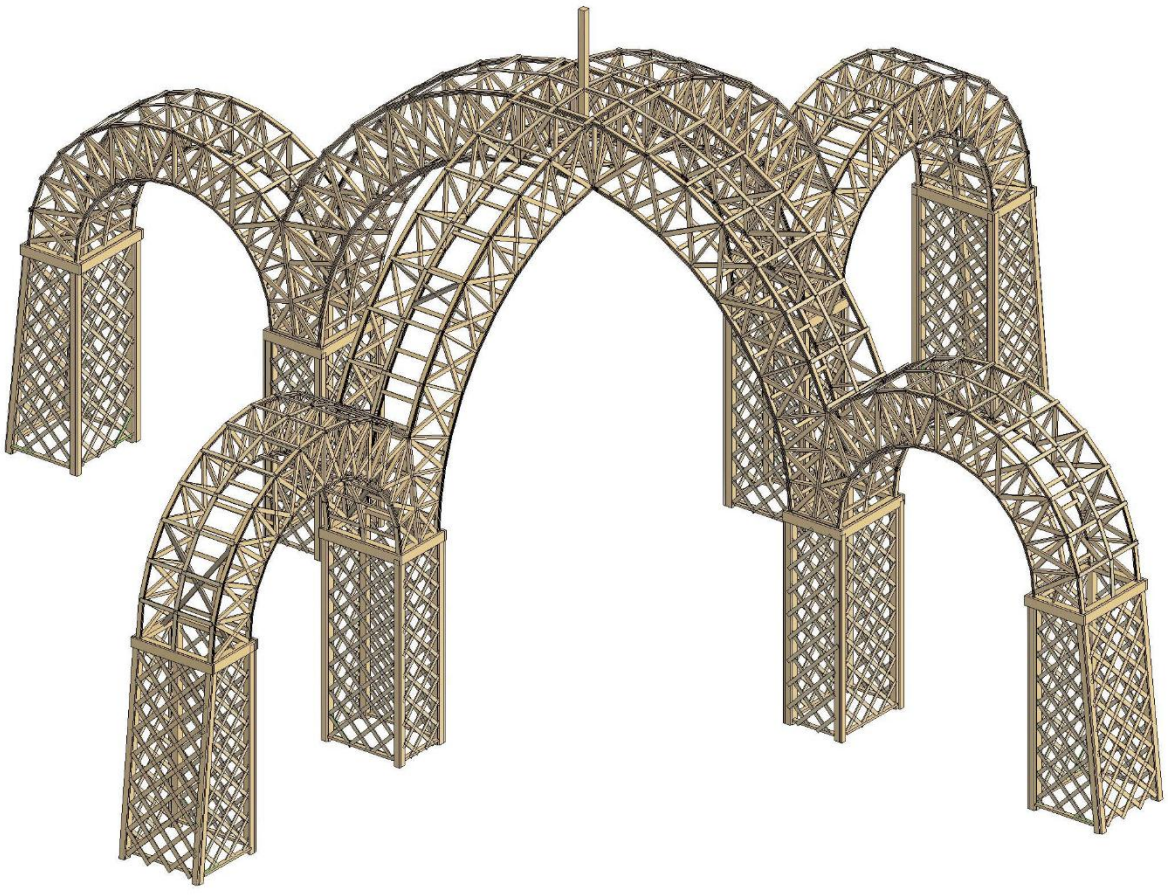
Remediation Options Assessment

Prince's Gate Arch and Gateway, 9 Queens Drive, Central Rotorua, Rotorua.

Rotorua Lakes Council



21 July 2026
Revision 3.0
Blueline Project: 10141

Disclaimer

This report has been prepared solely for the purposes agreed with Rotorua Lakes Council as our Client and should not be relied upon for any other purpose.

The statements and opinions expressed in this report have been made on good faith, and on the basis that all information provided to us is true and accurate in all material aspects, and not misleading by reason of omission or otherwise. Blueline Consulting will not be held liable for any loss, damage, cost or expense incurred or arising by reason of any person using or relying on the information in this report.

We reserve the right, but will be under no obligation, to review or amend this report, should any additional information, which was in existence on the date of this report, was not brought to our attention, or subsequently comes to light.

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Revision	Date	Status	Comment
1.0	04/11/2024	Working Draft	For internal coordination
2.0	9/12/2024	Final	For Issue
3.0	21/07/2026	Final	Revised Date

1.0 INTRODUCTION

The Prince's Gate Arches, a historic structure located at 9 Queens Drive in Rotorua Central, has long been a landmark of cultural and architectural significance (constructed in 1901). However, structural assessments have identified critical issues stemming from deterioration, aging materials, and environmental factors. These issues compromise the safety, durability, and integrity of the structure.

This report presents a comprehensive review of remediation options for the arches, outlining methodologies for both partial and full replacement approaches. Each option is evaluated based on engineering feasibility, material requirements, estimated costs, and anticipated long-term performance. Special consideration is given to the selection of materials, including the use of Totara timber, in alignment with Heritage NZ preservation goals.

The findings and recommendations in this report aim to provide the Rotorua Lakes Council with a clear framework to proceed with a restoration strategy that balances heritage conservation with practical construction and economic considerations.

The illustration below shows the highlighted members that are identified as requiring full replacement or likely requiring replacement (denoted as provisional, pending further onsite assessment) i.e. column footings below ground level not yet explored in detail but likely requiring replacement. A summary of each member is displayed in Table 1, where the naming convention for each element is taken from the plans in Appendix D.

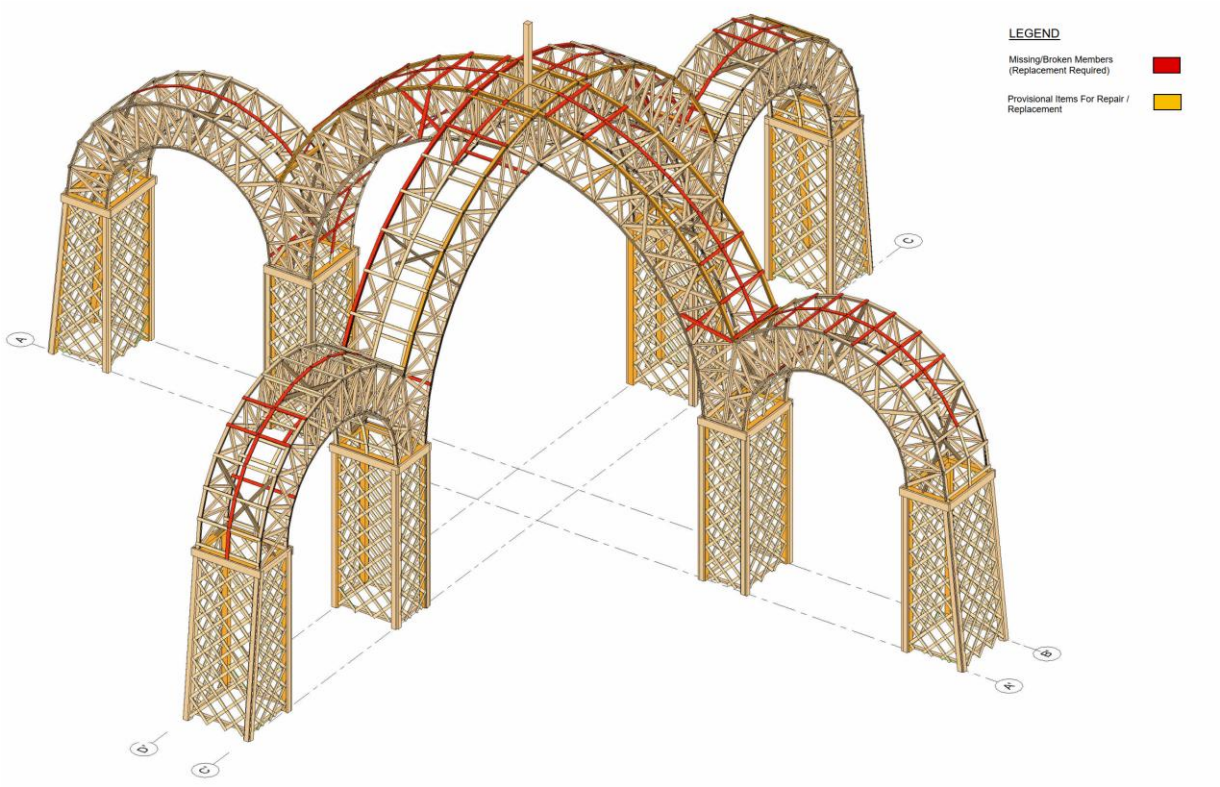

Figure.1 Illustration Showing Current Members that require Full Replacement or Provisional Replacement.

Table.1: Current Members that require Full Replacement or Provisional Replacement.

Member ID#	Work Required	Member ID#	Work Required	Member ID#	Work Required
CB4-CB9	Replacement	CB93	Replacement	MC41-53	Replacement
CB10-11	Provisional	CB94	Provisional	MC56-MC57	Replacement
CB12-14	Replacement	CB96	Provisional	MC63-72	Replacement
CB18-25	Replacement	CB98	Provisional	MC98	Replacement
CB27-28	Provisional	CB102	Replacement	MC105-107	Replacement
CB41-CB43	Provisional	CB103-104	Provisional	MC144-145	Replacement
CB44-45	Replacement	CB105-106	Replacement	MC161-162	Replacement
CB49	Provisional	CB108	Replacement	P1-32	Provisional
CB50-51	Replacement	CB110	Replacement	S36 (A)	Replacement
CB54-55	Provisional	CB143	Replacement	S55-56 (A)	Replacement
CB57	Replacement	CB148	Replacement	TC12 -30 (A)	Provisional
CB58	Provisional	CB155	Replacement	TC12-30 (B)	Provisional
CB59	Replacement	CB169	Replacement	TC12-30 (C)	Provisional
CB72-73	Replacement	MC1-17	Replacement	TC12-30 (D)	Replacement
CB87	Replacement	MC20-33	Replacement		

2.0 STRUCTURAL ASSESSMENT

2.1 Existing Structure

The condition assessment conducted by Prendos Property Group on 09/07/21, along with a visual assessment of the foundation system by Blueline Consulting, identified several damaged or defective members that pose a risk to the structural integrity of the structure. In particular, damage to one of the top chords due to the flag mast pole falling on it, which has subsequently caused stress to be redistributed throughout the structure. Additionally, rot at the base of the columns has created a disconnect in the foundation system, further overstressing the superstructure during uplift and lateral actions.

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Figure 2,3,4: Decay of post in contact with in-situ soils; exposed 600⌀ x 220mm concrete footing; & damaged top chord.

The existing structure was modelled in SAP2000 with the posts assumed to be pinned due to the lack of fixity between the post and the footing. The load combinations are as per NZS1170.0. The seismic and wind loading are based on a return period of 1 in 250 years (refer to calculations Appendix C).

The results of the analysis are tabulated below (Tables. 2, 3 & 4) – based on the existing structure with the members identified in Table 1 as requiring **full replacement** . The probable capacities of the main structural members were calculated to NZS3603:1993, assuming a characteristic bending, compression and axial capacity of 7.5MPa, 11.0MPa and 3.0MPa respectively.

Note the tower lattice was modelled as a 90x45 timber 'X' brace reducing the applied moment on the foundations and tower post. During the detailed design phase, it is recommended to perform supplementary calculations to determine whether lateral loads can be effectively transferred from the top to the bottom of the post via the lattice structure.

Table.2: SAP2000 Output Load Case: 1.35 x Gravity (1.35G)

Unique Member	Moment (kN-m)	Compressive Axial Load (kN)	Tensile Axial Load (kN)	Axial (C) Capacity (kN)	Axial (T) Capacity (kN)	Moment Capacity (kN-m)	Member Stress %
4/90x20 Chord	0.2	6	2	24	7	0.25	108%
3/90x20 Chord	0	3	0	18	6	0.14	17%
145x145 Post	0	8.5	0	69	19	1.1	12.3%

Table.3: SAP2000 Output Load Case: Gravity + Earthquake (G+E)

Unique Member	Moment (kN-m)	Compressive Axial Load (kN)	Tensile Axial Load (kN)	Axial (C) Capacity (kN)	Axial (T) Capacity (kN)	Moment Capacity (kN-m)	Member Stress %
4/90x20 Chord	0.3	7	3	40	12	0.4	100%
3/90x20 Chord	0	7.5	5	30	9	0.23	55%
145x145 Post	0.6	18	9	116	32	1.9	60%

Table.4: SAP2000 Output Load Case: Gravity + Wind (G+W)

Unique Member	Moment (kN-m)	Compressive Axial Load (kN)	Tensile Axial Load (kN)	Axial (C) Capacity (kN)	Axial (T) Capacity (kN)	Moment Capacity (kN-m)	Member Stress %
4/90x20 Chord	0.35	8	5	40	12	0.4	130%
3/90x20 Chord	0	8.2	6	30	9	0.23	68%
145x145 Post	1	23	17	116	32	1.9	105%

Summary of Structural Analysis of Existing Structure

The SAP model for the existing structure shows several members have become overstressed primarily due to the compromised foundations, broken top chord & several missing members.

Due to the rot at the base of the columns it's likely the uplift on the foundation during the ULS wind event will also exceed the capacity of the foundation. Based on prelim assessment, a minimum footing size of 600⌀ x 1.8m would be required to resist uplift forces. The moment on the top chord is due to the broken chord being unsupported for some length.

2.2 Post Initial Repairs

The SAP2000 model was subsequently updated assuming a repaired structure (fully replaced members, refer Table 1) with the posts pinned with some partial fixity due to the deeper foundations specified. A simplified hand calculation was undertaken in Appendix C to confirm the reaction forces generated by the model are within an acceptable range.

The load combinations are as per NZS1170.0. The seismic and wind loading are based on a return period of 1 in 250 years (refer to calculations in Appendix C).

The results of the analysis are tabulated in Tables 5, 6, & 7 – reflecting the structures performance with members replaced as identified in Table 1.

Table.5: SAP2000 Output Load Case: Gravity x 1.35 (1.35G)

Unique Member	Moment (kN-m)	Compressive Axial Load (kN)	Tensile Axial Load (kN)	Axial (C) Capacity (kN)	Axial (T) Capacity (kN)	Moment Capacity (kN-m)	Member Stress %
4/90x20 Chord	0	5	2	24	7	0.25	30%
3/90x20 Chord	0	3	1	18	6	0.14	17%
145x145 Post	0	8	0	69	19	1.1	11.5%

Table.6: SAP2000 Output Load Case: Gravity + Earthquake (G +E)

Unique Member	Moment (kN-m)	Compressive Axial Load (kN)	Tensile Axial Load (kN)	Axial (C) Capacity (kN)	Axial (T) Capacity (kN)	Moment Capacity (kN-m)	Member Stress %
4/90x20 Chord	0	6	4.5	40	12	0.4	37.5%
3/90x20 Chord	0	6.5	5	30	9	0.23	55%
145x145 Post	0.52	16.5	9	116	32	1.9	50%

Table.7: SAP2000 Output Load Case: Gravity + Wind (G + W)

Unique Member	Moment (kN-m)	Compressive Axial Load (kN)	Tensile Axial Load (kN)	Axial (C) Capacity (kN)	Axial (T) Capacity (kN)	Moment Capacity (kN-m)	Member Stress %
4/90x20 Chord	0	7	5	40	12	0.4	42%
3/90x20 Chord	0	8.2	6.2	30	9	0.23	70%
145x145 Post	0.9	25	16	116	32	1.9	98%

Summary of Structural Analysis of Existing Structure

By retrofitting the foundations and replacing the top chord (TC12-TC30) the stresses on the structure are reduced as not to overstress the structure.

Note, this does not account for degradation or section loss of the original Totara timbers. If partial replacement is desired as an option for remediation by the client, this will mean future replacement of the 3/90x20 chord is likely required, with regular inspections by council to identify damaged timber members, refer to Section 7.0 of this report.

3.0 ENGINEERING OPTIONS

Based on the structural analysis, two remediation options are proposed for the structure. Either partial replacement (Option A) or full replacement (Option B) of the superstructure. Table 8 below includes some comments comparing either option. Sections 4 & 5 of this report include a breakdown of the methodology for each option and Sections 6 to 8 of this report includes a breakdown of the cost for each option.

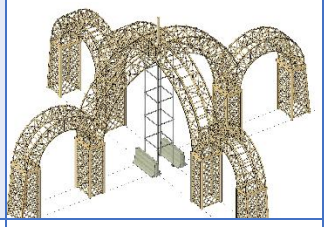
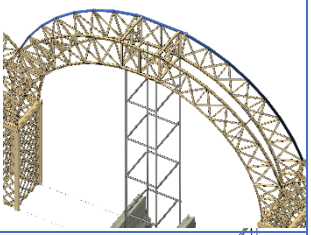
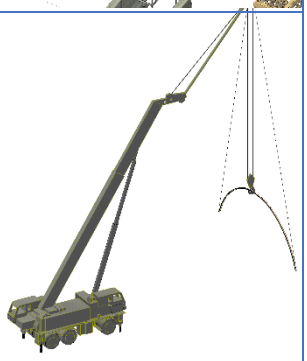
(A) Onsite Partial Replacement / Retrofit of Structure – Replacement of missing members and partial replacement / repair of provisional items in Table 1 (includes undermining and repair of existing foundations, replacement of damaged top chord TC12-TC30),with chords reinforced with exposed steel ties & rods, additional future works covered in Section 7.0 of this report.

(B) Off-Site Manufacturing and Full Replacement of Superstructure – Cut and removal of superstructure, to be craned off site and rebuilt using modern construction techniques and materials. Foundation repaired onsite in preparation for manufactured arch truss segments to be reassembled on site with overhead crane. Fixings are to be hidden and arch segments bolted together using steel dowels and plates.

Table.8: Comparison Between Engineering Options

Items	Option A Onsite – Partial Replacement	Option B Onsite / Offsite – Full Replacement
Traffic Management	High - Will require a complete road closure over the whole period of construction. (≈12 working days).	Medium - Will require a complete road closure over the period of disassembly & assembly of the structure (≈6 working days), the road could likely be opened during the interim period between disassembly and assembly.
Structural Life Span	Low confidence in the life span of the structure, unless future works are undertaken with bi-annual inspections to check decay of existing timbers.	High confidence in the life span of the structure. Since we are completely replacing the structure, the designer can guarantee a 50-year design life.
Recommendations by Pendos	Yes, covers all remedial works recommended.	Yes, covers all remedial works recommended.
Aesthetics	Exposed steel brackets, differing timber used. (Mixture of aged and new timbers)	Hidden fixings, matching timbers.
Durations of works	Estimated total duration of works is 12-15 working days.	Estimated total duration of works is 36-40 working days.
Cost	Less initial cost than Option B however, more expensive in the long term.	Higher initial cost than Option A however, cheaper in the long term.
Complexity	Moderate complexity, re-using existing connection details.	High complexity, replacing the entire structure. Requires a full set of engineering drawings with modular construction for ease of site assembly.

4.0 CONSTRUCTION METHODOLOGY – PARTIAL REPLACEMENT

Step (1)	Propping of structure at its mid-point, with a road & footpath closure in place (all four corners propped, where the chords intercept). Add concrete or waterfilled plastic barriers in place to anchor and protect the scaffolding.	
Step (2)	Remove and cut out one section of the top chord at a time, carefully unscrewing steel plates connecting laminated arch to other chords. Once removed, replace any diagonal bracing or struts missing as identified in Table.1.	
Step (3)	Crane into position 1/90x20 laminate arch at a time, lap over intercepting arches as per engineering plan, clamping them together using a steel plate and U bolt shackle. Once all four timbers comprising one complete arch segment are in place fix to steel brackets as per engineering plan. Fix to strut & diagonal bracing. Reinstall cross bracing and inner chord as required. Repeat steps (1-4) until all four 4/90x20 top chords are replaced.	
Step (4)	Remove scaffolding at centre of arches & reinstate roadway. Keep footpath closure in place.	
Step (5)	Remove pavers & expose footing (one footing at a time / tower). If the footing and post need replacing as determined by the engineer, remove cross bracing and trim as needed and proceed with step (8).	
Step (6)	Remove existing circular concrete footing and cut off post 2.2m above ground level. Auger footing to a depth of 1.8m below ground level with a 600⌀ auger. Splice 145x145 timber post (4m in length) to cut end of existing Totara pile as per splice detail. Then pour new concrete footing. Once concrete has allowed 4 days to cure remove propping and reinstate timber lattice and tower trims, replacing any decayed timbers identified with new timbers.	
Step (7)	Repeat steps 5-6 until all footings have been exposed and rectified as needed.	

5.0 CONSTRUCTION METHODOLOGY – FULL REPLACEMENT

Step (1)	Propping of structure at its mid-point, with a road & footpath closure in place (all four corners propped, where the chords intercept). Add concrete or waterfilled plastic barriers in place to anchor the scaffolding in place and protect the scaffolding.
Step (2)	Cut the larger inner arch into two sperate segments, the smaller arches can be cut off as one segment. Truck all arch segments off site for partial reassembly by the manufacturer on site to aid in construction of new arch trusses. Leaving tower posts & tower ring beam intact on site.
Step (3)	Remove scaffolding at centre of arches & reinstate roadway. Keep footpath closure in place.
Step (4)	Remove trims and timber lattice from the towers. Replace the ring beam, posts & footings as per engineering plans. Re-attach timber lattice and trims, replacing decayed or missing timbers.
Step (5)	Put a road and footpath closure in place, truck in completed arch segments, crane and assemble on site as per engineering plans. Segments to bolt together to form completed arch structure. Post assembly reinstate roadway and footpath.

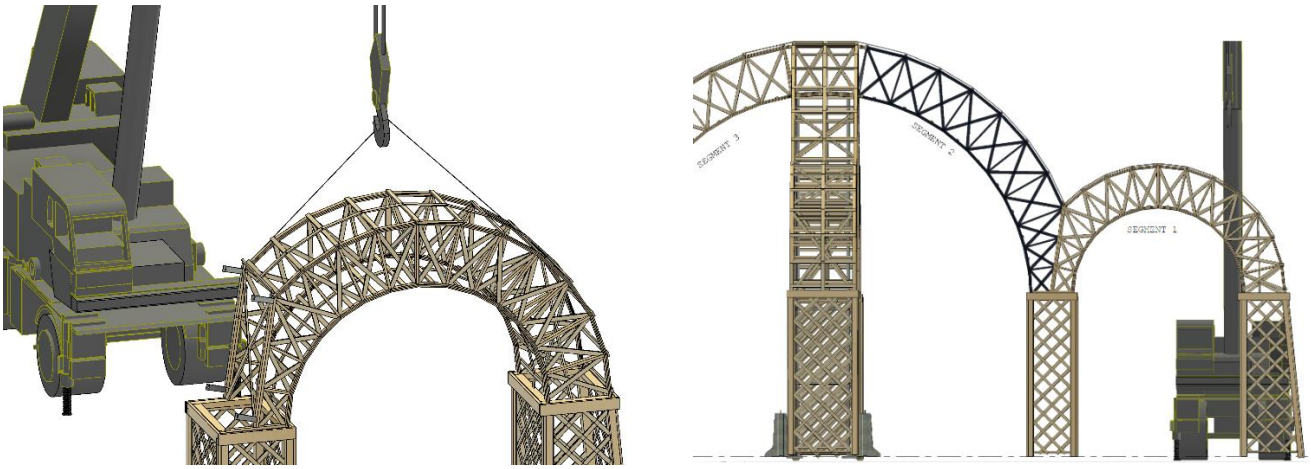


Figure 5,6: Illustration of craning in modular arch sections for onsite assembly, arch superstructure broken into four segments for quick assembly on site.

6.0 MATERIAL SELECTION

The original structure is primarily made of Totara timber, a native softwood with a high strength-to-weight ratio. At the time of construction of the Prince's Arches (1901), Totara timber was readily available in large sizes and cut lengths. Today, Totara is in limited supply and the cut lengths, sizes and processing time are subject to the limited quantity provided by local suppliers.

The cost of Greenheart Totara timber is approximately $7,000/m³, excluding drying, milling, and cartage. In comparison, the cost of green pine is $800/m³, excluding drying, milling, and cartage.

Blueline has contacted three local suppliers to quote full or partial member replacement using Totara timbers. Mike Prior Sawmilling LTD (Tokoroa) , NZ Totara (Kerikeri) and NZ Native Timber Supplies (Reikorangi). Due to the quantity of timber required it would be recommended that timbers be sourced for a variety of native timber suppliers. Perhaps having all of the green rough sawn Totara cut to size at its place of origin and carted to Rotorua for drying and finishing at a specialist timber supplier such as Red Stag Timber or other such manufacturer which has facilities to dry & store the timber as well as steaming and bending of the laminated arches.

Finished Totara timber is approximately 8.0–9.0 times more expensive than pine. If the client opts for a hybrid approach using both timber types, it is advisable to prioritise Totara for the most critical components. For example, elements like laminated arches or tower posts, which demand substantial effort to reinstall or replace, should be made of Totara. Meanwhile, less critical components, such as cross braces or the tower lattice, could initially be constructed from pine and replaced with Totara later, as their replacement involves less complexity.

7.0 FUTURE COSTS

(Option A) Future Costs (2025-2050)

Given the low confidence in the condition of the aged Totara timbers, selecting the partial replacement option will incur higher future costs. It is anticipated that the bottom main chord (spanning approximately 13m) and the smaller top and bottom chords (spanning approximately 6m) will need to be replaced in the next 1-2 decades, dependent on bi-annual council inspections to determine the appropriate timing for replacement.

Later in the lifetime of the structure,possibly within the next 2-3 decades, the secondary elements such as the truss web, bracing and timber lattice may need to be replaced as major section loss is likely to occur with timbers of this age.

The total cost estimate (including future costs) for the partial replacement option is summarised in the Engineer's Estimate in Section 8.1 of this report.

(Option B) Future Costs

The future costs over the next 50 years for option B are considered negligible as the replacement structure will be designed for a 50-year design life, although council may ask for additional inspections in the later period of the design life, however we have not assumed this is our total cost estimate for Option B.

The total cost estimate (including future costs) for the full replacement option is summarised in the Engineer's Estimate in Section 8.2 of this report.

8.0 ENGINEER'S ESTIMATE

8.1 Engineer's Estimate (Option A – Partial Replacement)

For Option A (Partial Replacement) the initial material cost (excluding future costs) has been estimated using Totara timber (Table.9) as well as pine (Table.10) to allow the cost comparison between the two materials.

Table.9 Material Cost Estimate – Option A (Partial Replacement, Totara Timber, excluding Future Costs)

Dressed Member Sizes	90x20 (mm)	75x20 (mm)	145x145 (mm)	145x100 (mm)	200x75 (mm)	90x45 (mm)	75x30 (mm)	90x20 (mm)
Member Description	Arch Chords	Tower Lattice	Tower Post	Ring Beam	Ring Trims	Truss Member	Cross Brace	Inner chord
Material	Totara	Totara	Totara	Totara	Totara	Totara	Totara	Totara
Cut Length (m)	6m	1.5m	4.0m	1.8 & 1.0m	2.0 & 1.2m	2m	1.8	6
Estimated Quantity	44	72	32	16/16	16/16	18	43	11
Total Length (m)	264m	108m	128	45	52	36	78	66
Estimated Cost	$7750	$7250	$30,750	$7750	$15,750	$5250	$11,250	$13,250
Est Time to Source	6-8 Months	2-6 Months	6-8 Months	6-8 Months	2-6 Months	2-6 Months	2-6 Months	2-6 Months

**Includes cost of drying, planning, cartage & steaming laminated chords.*

Total Estimated Material Cost (Partial Replacement (Totara): $99,000.00

Table.10 Material Cost Estimate – Option A (Partial Replacement, Pine Timber, excluding Future Costs)

Dressed Member Sizes	90x20 (mm)	75x20 (mm)	145x145 (mm)	145x100 (mm)	200x75 (mm)	90x45 (mm)	75x30 (mm)	90x20 (mm)
Member Description	Arch Chords	Tower Lattice	Tower Post	Ring Beam	Ring Trims	Truss Member	Cross Brace	Inner chord
Material	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)
Cut Length (m)	6m	1.5m	4.0m	1.8 & 1.0m	2.0 & 1.2m	2m	1.8	6
Estimated Quantity	44	72	32	16/16	16/16	18	43	11
Total Length (m)	264m	108m	128	45	52	36	78	66
Estimated Cost	$1500	$1300	$3500	$900	$1700	$600	$1250	$1500
Est Time to Source	1-2 Months	1-2 Weeks	1-2 Weeks	2-4 Weeks	2-4 Weeks	1-2 Days	2-4 Weeks	1-2 Weeks

**Includes cost of drying, planning, cartage & steaming laminated chords*

Total Estimated Material Cost (Partial Replacement Pine): $12,250.00

Above material cost estimates are exclusive of labour, temporary works, connection & build costs etc, which are detailed in the cost estimates within Appendix A. i.e. the initial investment cost for Option A is $239,800 excluding GST if Totara timber is to be used. Or $135,700 excluding GST if pine is used in lieu of Totara.

A brief summary of the initial & future costs for partial replacement (option A) is tabulated in (Table.11).

Table.11: A summary of estimated costs for partial replacement Option A.

Stage	Initial Replacement /Repairs	Future upgrade /maintenance #1	Future upgrade /maintenance #2	Future upgrade /maintenance #3
Year	2025	2035	2040	2050
Comment	Replace top chord (4/90x/20), missing braced members & foundation remediation	Replace bottom chord (4/90x20)	Replace smaller top & & bottom chord (3/90x20)	Replace secondary elements truss members / bracing elements, timber lattice.
Assumptions	Refer to Section 3.0	Similar to cost to replace top chord in 2025 however excluding foundation repair & missing truss members.	Liner cost / m of chord to replaced applied excluding traffic management cost as chords are not above roadway.	Cost of replacing the secondary elements + road closure / traffic management.
Estimated Cost (excluding GST & Inflation) (Totara Timbers Only)	$239,800 (i.e. $99k materials + build cost)	$149,875	$132,700	$325,120
Estimated Cost (excluding GST & Inflation) (Pine Timbers Only)	$135,700 (i.e. $12.25k materials + build cost)	$67,325	$53,650	$135,670

The estimated total cost of partial replacements including future costs (with pine) is considered to be **$392,350** excluding GST or accounting for inflation.

The estimated total of partial replacements including future costs (with Totara) is considered to be **$847,500** excluding GST or accounting for inflation.

8.2 Engineer's Estimate (Option B – Full Replacement)

For Option B (Full Replacement) the cost has been estimated using Totara timber (Table.12) as well as pine (Table.13) to allow the cost comparison between the two materials.

Table.12 Material Cost Estimate – Option B (Full Replacement – Totara)

Dressed Member Sizes	90x20 (mm)	75x20 (mm)	145x145 (mm)	145x100 (mm)	200x75 (mm)	140x45 (mm)	90x45 (mm)	90x45 (mm)	75x30 (mm)
Member Description	Arch Chords	Tower Lattice	Tower Post	Ring Beam	Ring Trims	Tower Post Trims	Truss Member	X Brace	Cross Brace
Material	Totara	Totara	Totara	Totara	Totara	Totara	Totara	Totara	Totara
Cut Length (m)	6	1.5	6.3	1.8 & 1.0m	2.0 & 1.2m	5	1.4	2	1.8
Estimated Quantity	181	640	32	16/16	16/16	64	600	32	175
Total Length (m)	1086	960	202	45	52	320	840	64	315
Estimated Cost	$31,500	$64,320	$48,480	$7750	$15,570	$70,400	$121,800	$9280	$44,100
Est Time to Source	1-2 Months	1-2 Weeks	1-2 Weeks	2-4 Weeks	1-2 Weeks	1-2 Weeks	1-2 Weeks	1-2 Days	1-2 Weeks

**Includes cost of drying, planning, cartage & steaming laminated chords.*

Total Estimated Material Cost (Full Replacement Totara): $413,200

Table.13 Material Cost Estimate – Option B (Full Replacement - Pine)

Dressed Member Sizes	90x20 (mm)	75x20 (mm)	145x145 (mm)	145x100 (mm)	200x75 (mm)	140x45 (mm)	90x45 (mm)	90x45 (mm)	75x30 (mm)
Member Description	Arch Chords	Tower Lattice	Tower Post	Ring Beam	Ring Trims	Tower Post Trims	Truss Member	X Brace	Cross Brace
Material	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)	Pine (H4)
Cut Length (m)	6	1.5	6.3	1.8 & 1.0m	2.0 & 1.2m	5	1.4	2	1.8
Estimated Quantity	181	640	32	16/16	16/16	64	600	32	175
Total Length (m)	1086	960	202	45	52	320	840	64	315
Estimated Cost	$10,000	$7500	$6000	$850	$1700	$950	$13,000	$1000	$7250
Est Time to Source	1-2 Months	1-2 Weeks	1-2 Weeks	2-4 Weeks	1-2 Weeks	1-2 Weeks	1-2 Weeks	1-2 Days	1-2 Weeks

**Includes cost of drying, planning, cartage & steaming laminated chords.*

Total Estimated Material Cost: (Full Replacement Pine) $50,000

Above material cost estimates are exclusive of labour, temporary works, connection & build costs etc, which are detailed in the cost estimates within Appendix B. A brief summary of the initial & future costs for full replacement (Option B) is tabulated in (Table.14).

Table.14: A summary of estimated total costs for full replacement Option B.

Year	2025
Comment	Full replacement of structure,
Estimated Cost (excluding GST & Inflation) (Pine Timbers Only)	$303,650 (i.e. $50k materials + build cost)
Estimated Cost (excluding GST & Inflation) (Totara Timbers Only)	$739,400 (i.e. $413.2k materials + build cost)

The estimated total cost of full replacement including future costs (with pine) is considered to be **is $303,650** excluding GST or accounting for inflation.

The estimated total cost of full replacement including future costs (with Totara) is considered to be **is $739,400** excluding GST or accounting for inflation.

9.0 CONCLUSION

Based on the findings of this report, both partial and full replacement of the Prince's Gate Arches are viable options, with distinct benefits and limitations. Partial replacement presents a lower initial cost and preserves some aspects of the original structure. However, this approach requires ongoing remediation and future replacement of key structural elements, which could lead to higher cumulative costs over time. Additionally, the long-term reliability of the structure under this approach remains uncertain, given the age and condition of the original materials.

Conversely, full replacement involves a higher upfront investment but offers a more robust solution. By replacing all structural components with modern materials, this option ensures greater confidence in the structure's durability, performance, and compliance with current design standards. Furthermore, a full replacement extends the life expectancy of the arches, reducing the likelihood of significant maintenance or retrofitting within the next 50 years.

If partial replacement (Option A) is pursued, it is imperative that the top chord (TC12–TC30) and missing members are replaced promptly to address immediate safety concerns. This work should include propping the main chords at their midspan during construction to prevent overloading adjacent members. Any timber salvaged from the remediation process should undergo destructive testing to assess the residual strength and suitability for reuse or archival purposes.

Ultimately, the choice between partial and full replacement hinges on balancing heritage conservation priorities with financial constraints and long-term performance goals.

APPENDIX A
Option A - Partial Replacement Engineer's Estimate

Princess Arch's - Engineers Estimate - Option A (Partial Replacement) - Material: Pine

Item	Description	Quantity	Unit	Rate	Amount
2025 - Cost of Partial Replacment - Option A					
1.01	**Traffic Management**				
a)	TMP drafted & submitted	1	LS	$1,500.00	$ 1,500.00
b)	Road & footpath closure in place	12	Days	$2,000.00	$ 24,000.00
				Sum(Excluding GST)	$ 25,500.00
1.02	**Material Cost**				
a)	Timber (Pine)	1	LS	$12,250.00	$12,250.00
				Sum(Excluding GST)	$ 12,250.00
1.03	**Scaffolding & Temporary Works**				
a)	Scaffolding setup/dismantle cost	40.80	sq.m	$50.00	$ 2,040.00
b)	Scaffolding hire cost	7	Days	$61.20	$ 428.40
c)	Water filled barrier hire & setup cost	1	LS	$410.00	$ 410.00
d)	Sand bags	20	LS	$11.00	$ 220.00
e)	Safety netting	90	sq.m	$40.75	$ 3,667.50
				Sum(Excluding GST)	$ 6,765.90
1.04	**Installation of New Top Chord & Missing Member Replacement**				
a)	Crane hire (labour & fuel included)	7	Days	$450.00	$ 3,150.00
b)	Scissor lift hire (labour & fuel included)	7	Days	$211.50	$ 1,480.50
c)	Haulage / skip hire	7	Days	$104.00	$ 728.00
d)	Labour - dismantle / assembly (assume 5 person crew, 7 days)	280	hrs	$70.00	$ 19,600.00
				Sum(Excluding GST)	$ 24,958.50
1.05	**Foundation / Tower Remediation**				
a)	Labour - removal and reinstallation of pavers surrounding the posts to facilitate foundation inspection / work	48	hrs	$110.00	$ 5,280.00
b)	Haulage / skip hire	5	Days	$104.00	$ 520.00
c)	Propping & removal excavation of existing footing.	32	LS	$190.00	$ 6,080.00
d)	Labour -Splicing new post to tower post. (2 person, 1 hour / post)	32	LS	$140.00	$ 4,480.00
e)	Labour & Material -Pouring foundation	20	cu.m	$357.00	$ 7,082.88
f)	Labour - replacement of timber lattice	32	LS	$70.00	$ 2,240.00
g)	Labour - replacement of ring beam & tower trims	32	LS	$560.00	$ 17,920.00
				Sum(Excluding GST)	$ 43,602.88

20% Contingency	**$**	**22,615**
Sub Total Estimated Cost (Excluding GST)	**$**	**135,700**

Item	Description	Quantity	Unit	Rate	Amount
2035 - Cost of Partial Replacment - Option A					
2.01	**Traffic Management**				
a)	TMP drafted & submitted	1	LS	$1,500.00	$ 1,500.00
b)	Road & footpath closure in place	7	Days	$2,000.00	$ 14,000.00
				Sum(Excluding GST)	$ 15,500.00
2.02	**Material Cost**				
a)	Timber (Pine)	1	LS	$8,875.00	$8,875.00
				Sum(Excluding GST)	$ 8,875.00
2.03	**Scaffolding & Temporary Works (Required)**				
a)	Scaffolding setup/dismantle cost	40.80	sq.m	$50.00	$ 2,040.00
b)	Scaffolding hire cost	7	Days	$61.20	$ 428.40
c)	Water filled barrier hire & setup cost	1	LS	$410.00	$ 410.00
d)	Sand bags	20	LS	$11.00	$ 220.00
e)	Safety netting	90	sq.m	$40.75	$ 3,667.50
				Sum(Excluding GST)	$ 6,765.90
2.04	**Inspection Costs**				
a)	Years untill last maintenance work	10	Yrs	$4,000.00	$ 40,000.00
2.05	**Installation of New Bottom Chord (4/90x20)**				
a)	Crane hire (labour & fuel included)	7	Days	$450.00	$ 3,150.00
b)	Scissor lift hire (labour & fuel included)	7	Days	$211.50	$ 1,480.50
c)	Haulage / skip hire	7	Days	$104.00	$ 728.00
d)	Labour - dismantle / assembly (assume 5 person crew, 7 days)	280	hrs	$70.00	$ 19,600.00
				Sum(Excluding GST)	$ 24,958.50
20% Contingency					**$ 11,220**
Sub Total Estimated Cost (Excluding GST)					**$ 67,325**

Item	Description	Quantity	Unit	Rate	Amount
2040 - Cost of Partial Replacment - Option A					
3.01	**Material Cost**				
a)	Timber (Pine)	1	LS	$8,500.00	$8,500.00
				Sum(Excluding GST)	$ 8,500.00
3.02	**Inspection Costs**				
a)	Years untill last maintenance work	5	Yrs	$4,000.00	$ 20,000.00
				Sum(Excluding GST)	$ 20,000.00
3.03	**Installation of New bottom & top chord for smaller arches (3/90x20)**				
b)	Scissor lift hire (labour & fuel included)	7	Days	$211.50	$ 1,480.50
c)	Haulage / skip hire	7	Days	$104.00	$ 728.00
d)	Labour - dismantle / assembly (assume 5 person crew, 5 days)	200	hrs	$70.00	$ 14,000.00
				Sum(Excluding GST)	$ 16,208.50
20% Contingency					**$ 8,942**
Sub Total Estimated Cost (2025) (Excluding GST)					**$ 53,650**

Item	Description	Quantity	Unit	Rate	Amount
2050 - Cost of Partial Replacment - Option A					
4.01	**Traffic Management**				
a)	TMP drafted & submitted	1	LS	$1,500.00	$ 1,500.00
	Road & footpath closure in place	10	Days	$2,000.00	$ 20,000.00
				Sum(Excluding GST)	$ 21,500.00
4.02	**Material Cost**				
a)	Timber (Pine)	1	LS	$20,375.00	$20,375.00
				Sum(Excluding GST)	$ 20,375.00
4.03	**Inspection Costs**				
a)	Years untill last maintenance work	10	Yrs	$4,000.00	$ 40,000.00
				Sum(Excluding GST)	$ 40,000.00
4.04	**Installation of New Bracing & Truss Members**				
b)	Scissor lift hire (labour & fuel included)	10	Days	$211.50	$ 2,115.00
c)	Haulage / skip hire	10	Days	$104.00	$ 1,040.00
d)	Labour - dismantle / assembly (assume 5 person crew, 10 days)	400	hrs	$70.00	$ 28,000.00
				Sum(Excluding GST)	$ 31,155.00
20% Contingency					**$ 22,606**
Sub Total Estimated Cost (2025) (Excluding GST)					**$ 135,670**

Total Cost (Excluding GST) + 20% Contingency	**$**	**392,350**

Princess Arch's - Engineers Estimate - Option A (Partial Replacement) - Material: Totara

Item	Description	Quantity	Unit	Rate	Amount
2025 - Cost of Partial Replacment - Option A					
1.01	**Traffic Management**				
a)	TMP drafted & submitted	1	LS	$1,500.00	$ 1,500.00
b)	Road & footpath closure in place	12	Days	$2,000.00	$ 24,000.00
				Sum(Excluding GST)	$ 25,500.00
1.02	**Material Cost**				
a)	Timber (Totara)	1	LS	$99,000.00	$99,000.00
				Sum(Excluding GST)	$ 99,000.00
1.03	**Scaffolding & Temporary Works**				
a)	Scaffolding setup/dismantle cost	40.80	sq.m	$50.00	$ 2,040.00
b)	Scaffolding hire cost	7	Days	$61.20	$ 428.40
c)	Water filled barrier hire & setup cost	1	LS	$410.00	$ 410.00
d)	Sand bags	20	LS	$11.00	$ 220.00
e)	Safety netting	90	sq.m	$40.75	$ 3,667.50
				Sum(Excluding GST)	$ 6,765.90
1.04	**Installation of New Top Chord & Missing Member Replacement**				
a)	Crane hire (labour & fuel included)	7	Days	$450.00	$ 3,150.00
b)	Scissor lift hire (labour & fuel included)	7	Days	$211.50	$ 1,480.50
c)	Haulage / skip hire	7	Days	$104.00	$ 728.00
d)	Labour - dismantle / assembly (assume 5 person crew, 7 days)	280	hrs	$70.00	$ 19,600.00
				Sum(Excluding GST)	$ 24,958.50
1.05	**Foundation / Tower Remediation**				
a)	Labour - removal and reinstallation of pavers surrounding the posts to facilitate foundation inspection / work	48	hrs	$110.00	$ 5,280.00
b)	Haulage / skip hire	5	Days	$104.00	$ 520.00
c)	Propping & removal excavation of existing footing.	32	LS	$190.00	$ 6,080.00
d)	Labour -Splicing new post to tower post. (2 person, 1 hour / post)	32	LS	$140.00	$ 4,480.00
e)	Labour & Material -Pouring foundation	20	cu.m	$357.00	$ 7,082.88
f)	Labour - replacement of timber lattice	32	LS	$70.00	$ 2,240.00
g)	Labour - replacement of ring beam & tower trims	32	LS	$560.00	$ 17,920.00
				Sum(Excluding GST)	$ 43,602.88

20% Contingency	**$**	**39,965**
Sub Total Estimated Cost (Excluding GST)	**$**	**239,800**

Item	Description	Quantity	Unit	Rate	Amount
2035 - Cost of Partial Replacment - Option A					
2.01	**Traffic Management**				
a)	TMP drafted & submitted	1	LS	$1,500.00	$ 1,500.00
b)	Road & footpath closure in place	7	Days	$2,000.00	$ 14,000.00
				Sum(Excluding GST)	$ 15,500.00
2.02	**Material Cost**				
a)	Timber (Totara)	1	LS	$77,650.00	$77,650.00
				Sum(Excluding GST)	$ 77,650.00
2.03	**Scaffolding & Temporary Works (Required)**				
a)	Scaffolding setup/dismantle cost	40.80	sq.m	$50.00	$ 2,040.00
b)	Scaffolding hire cost	7	Days	$61.20	$ 428.40
c)	Water filled barrier hire & setup cost	1	LS	$410.00	$ 410.00
d)	Sand bags	20	LS	$11.00	$ 220.00
e)	Safety netting	90	sq.m	$40.75	$ 3,667.50
				Sum(Excluding GST)	$ 6,765.90
2.04	**Inspection Costs**				
a)	Years untill last maintenance work	10	Yrs	$4,000.00	$ 40,000.00
2.05	**Installation of New Bottom Chord (4/90x20)**				
a)	Crane hire (labour & fuel included)	7	Days	$450.00	$ 3,150.00
b)	Scissor lift hire (labour & fuel included)	7	Days	$211.50	$ 1,480.50
c)	Haulage / skip hire	7	Days	$104.00	$ 728.00
d)	Labour - dismantle / assembly (assume 5 person crew, 7 days)	280	hrs	$70.00	$ 19,600.00
				Sum(Excluding GST)	$ 24,958.50
20% Contingency					**$ 24,975**
Sub Total Estimated Cost (Excluding GST)					**$ 149,875**

Item	Description	Quantity	Unit	Rate	Amount
2040 - Cost of Partial Replacment - Option A					
3.01	**Material Cost**				
a)	Timber (Totara)	1	LS	$74,375.00	$74,375.00
				Sum(Excluding GST)	$ 74,375.00
3.02	**Inspection Costs**				
a)	Years untill last maintenance work	5	Yrs	$4,000.00	$ 20,000.00
				Sum(Excluding GST)	$ 20,000.00
3.03	**Installation of New bottom & top chord for smaller arches (3/90x20)**				
b)	Scissor lift hire (labour & fuel included)	7	Days	$211.50	$ 1,480.50
c)	Haulage / skip hire	7	Days	$104.00	$ 728.00
d)	Labour - dismantle / assembly (assume 5 person crew, 5 days)	200	hrs	$70.00	$ 14,000.00
				Sum(Excluding GST)	$ 16,208.50
20% Contingency					**$ 22,117**
Sub Total Estimated Cost (2025) (Excluding GST)					**$ 132,700**

Item	Description	Quantity	Unit	Rate	Amount
2050 - Cost of Partial Replacment - Option A					
4.01	**Traffic Management**				
a)	TMP drafted & submitted	1	LS	$1,500.00	$ 1,500.00
	Road & footpath closure in place	10	Days	$2,000.00	$ 20,000.00
				Sum(Excluding GST)	$ 21,500.00
4.02	**Material Cost**				
a)	Timber (Totara)	1	LS	$178,280.00	$178,280.00
				Sum(Excluding GST)	$ 178,280.00
4.03	**Inspection Costs**				
a)	Years untill last maintenance work	10	Yrs	$4,000.00	$ 40,000.00
				Sum(Excluding GST)	$ 40,000.00
4.04	**Installation of New Bracing & Truss Members**				
b)	Scissor lift hire (labour & fuel included)	10	Days	$211.50	$ 2,115.00
c)	Haulage / skip hire	10	Days	$104.00	$ 1,040.00
d)	Labour - dismantle / assembly (assume 5 person crew, 10 days)	400	hrs	$70.00	$ 28,000.00
				Sum(Excluding GST)	$ 31,155.00
20% Contingency					**$ 54,187**
Sub Total Estimated Cost (2025) (Excluding GST)					**$ 325,120**

Total Cost (Excluding GST) + 20% Contingency	**$**	**847,500**

APPENDIX B
Option B -Full Replacement Engineer's Estimate

Princess Arch's - Engineers Estimate - Option B (Full Replacement) - Material: Pine

Item	Description	Quantity	Unit	Rate	Amount
1.01	**Traffic Management**				
a)	TMP drafted & submitted	1	LS	$1,500.00	$ 1,500.00
b)	Road & footpath closure in place	6	Days	$2,000.00	$ 12,000.00
				.	$ 13,500.00
1.02	**Scaffolding & Temporary Works**				
a)	Scaffolding setup/dismantle cost	40.80	sq.m	$50.00	$ 2,040.00
b)	Scaffolding hire cost	5	Days	$61.20	$ 306.00
c)	Water filled barrier hire & setup cost	1	LS	$410.00	$ 410.00
d)	Sand bags	20	LS	$11.00	$ 220.00
e)	Safety netting	90	sq.m	$40.75	$ 3,667.50
				Sum(Excluding GST)	$ 6,643.50
1.03	**Removal of Superstructure & Haulage off Site**				
a)	Crane hire (labour & fuel incl)	3	Days	$450.00	$ 1,350.00
b)	Scissor lift hire (labour & fuel incl)	3	Days	$211.50	$ 634.50
c)	Labour (8 person crew , 3-5 days)	200	Hrs	$70.00	$ 14,000.00
d)	Flat bed hire & haulage	5	Days	$945.00	$ 4,725.00
e)	Dumping fee	25	Tonnes	$60.00	$ 1,500.00
				Sum(Excluding GST)	$ 22,209.50
1.04	**Material Costs**				
a)	Timber (pine)	1	LS	$50,000.00	$ 50,000.00
				Sum(Excluding GST)	$ 73,709.50
1.05	**Factory / Manufacturers Costs**				
a)	Factory space hire (including utilities)	30	Days	$450.00	$ 13,500.00
b)	Labour (3 person team, 30 days)	720	Hrs	$70.00	$ 50,400.00
				Sum(Excluding GST)	$ 63,900.00
1.06	**On site Assembly of Superstructure**				
a)	Crane hire (labour & fuel incl)	3	Days	$450.00	$ 1,350.00
b)	Scissor lift hire (labour & fuel incl)	3	Days	$211.50	$ 634.50
c)	Flat bed hire & haulage	3	Days	$945.00	$ 2,835.00
d)	Labour (5 person team, 3 days)	120	Hrs	$70.00	$ 8,400.00
				Sum(Excluding GST)	$ 13,219.50
1.07	**Foundation Remediation**				
a)	Labour - removal and reinstallation of pavers surrounding the posts to facilitate foundation inspection / work	48	hrs	$110.00	$ 5,280.00
b)	Haulage / skip hire	5	Days	$104.00	$ 520.00
c)	Propping & removal of excavation of existing footing.	32	LS	$190.00	$ 6,080.00
d)	Replacing posts on towers	32	LS	$365.00	$ 11,680.00
e)	Pouring new foundation	20	cu.m	$357.00	$ 7,082.88

f)	Full replacement of timber lattice & trim	32	LS	$350.00	$ 11,200.00
g)	Labour - replacement of ring beam & tower trims	32	LS	$560.00	$ 17,920.00
				Sum(Excluding GST)	$ 59,762.88
Total Estimated Cost + 20% contingency (Excluding GST)					**$ 303,650**

Princess Arch's - Engineers Estimate - Option B (Full Replacement) - Material: Totara

Item	Description	Quantity	Unit	Rate	Amount
1.01	**Traffic Management**				
a)	TMP drafted & submitted	1	LS	$1,500.00	$ 1,500.00
b)	Road & footpath closure in place	6	Days	$2,000.00	$ 12,000.00
				Sum(Excluding GST)	$ 13,500.00
1.02	**Scaffolding & Temporary Works**				
a)	Scaffolding setup/dismantle cost	40.80	sq.m	$50.00	$ 2,040.00
b)	Scaffolding hire cost	5	Days	$61.20	$ 306.00
c)	Water filled barrier hire & setup cost	1	LS	$410.00	$ 410.00
d)	Sand bags	20	LS	$11.00	$ 220.00
e)	Safety netting	90	sq.m	$40.75	$ 3,667.50
				Sum(Excluding GST)	$ 6,643.50
1.03	**Removal of Superstructure & Haulage off Site**				
a)	Crane hire (labour & fuel incl)	3	Days	$450.00	$ 1,350.00
b)	Scissor lift hire (labour & fuel incl)	3	Days	$211.50	$ 634.50
c)	Labour (5 person crew , 5 days)	200	Hrs	$70.00	$ 14,000.00
d)	Flat bed hire & haulage	5	Days	$945.00	$ 4,725.00
e)	Dumping fee	25	Tonnes	$60.00	$ 1,500.00
				Sum(Excluding GST)	$ 22,209.50
1.04	**Material Costs**				
a)	Timber (Totara)	1	LS	$413,200.00	$ 413,200.00
				Sum(Excluding GST)	$ 436,909.50
1.05	**Factory / Manufacturers Costs**				
a)	Factory space hire (including utilities)	30	Days	$450.00	$ 13,500.00
b)	Labour (3 person team, 30 days)	720	Hrs	$70.00	$ 50,400.00
				Sum(Excluding GST)	$ 63,900.00
1.06	**On site Assembly of Superstructure**				
a)	Crane hire (labour & fuel incl)	3	Days	$450.00	$ 1,350.00
b)	Scissor lift hire (labour & fuel incl)	3	Days	$211.50	$ 634.50
c)	Flat bed hire & haulage	3	Days	$945.00	$ 2,835.00
d)	Labour (5 person team, 3 days)	120	Hrs	$70.00	$ 8,400.00
				Sum(Excluding GST)	$ 13,219.50
1.07	**Foundation Remediation**				
a)	Labour - removal and reinstallation of pavers surrounding the posts to facilitate foundation inspection / work	48	hrs	$110.00	$ 5,280.00
b)	Haulage / skip hire	5	Days	$104.00	$ 520.00
c)	Propping & removal of excavation of existing footing.	32	LS	$190.00	$ 6,080.00
d)	Replacing posts on towers	32	LS	$365.00	$ 11,680.00
e)	Pouring new foundation	20	cu.m	$357.00	$ 7,082.88

f)	Full replacement of timber lattice & trim	32	LS	$350.00	$ 11,200.00
g)	Labour - replacement of ring beam & tower trims	32	LS	$560.00	$ 17,920.00
				Sum(Excluding GST)	$ 59,762.88
Total Estimated Cost + 20% contingency (Excluding GST)					**$ 739,400**

APPENDIX C
Preliminary Structural Calculations

Introduction

This is a set of Preliminary calculations to estimate the structural capacity of the existing totara members. Since there is no characteristic bending , shear & axial capacity values for native timbers to NZS3603 , the properties forcharacteristic bending, compression & axial capacity as assumed to be 7.5MPa, 11.0MPa & 3.0MPa. These values align with the properties of green No.1 framing timber adopted from table 2.2 in the appendix of NZS3603.

Design Assumptions

Design Life	50 *yrs*
Importance Level	*IL1*

General Dead Area Loads

Assumed timber unit weight (Totara) > 12% m/c $10\ \frac{kN}{m^3}$

Wind Loading to NZS1170.2:2021

Site Wind Speed	$V_{site\beta} = V_R \cdot M_c \cdot M_d \cdot (M_{zcat} \cdot M_s \cdot M_t)$	
Return Period	$\frac{1}{250}$	- IL1 , 50year design life
Site elevation	289 *m*	
Reference height (building)	$z \approx 11\ m$	
Regional wind gust	$V_R := 44\ \frac{m}{s}$	- Refer Zone 2, Table 3.1 (ANZS 1170.2.2021)
Climate change multiplier	$M_c := 1$	- Refer table 3.3 (ANZS 1170.2.2021)
wind directional multipliers	$M_d := 1$	- Refer table 3.2(B) (ANZS 1170.2.2021)
Height multipliers	$M_{zcat} := \frac{0.97 + 1.05}{2} = 1.01$	- 1/2 TC2.5 1/2 TC2, h > 10m
Shielding multipliers	$M_s := 1$	- Conservative to ignore
Topographic multipliers	$M_t := 1$	- Flat site , not in a lee zone
Site Wind Speed	$V_{site\beta} := V_R \cdot M_c \cdot M_d \cdot (M_{zcat} \cdot M_s \cdot M_t) = 44.44\ \frac{m}{s}$	
Site design wind speed	$V_{des\theta} := V_{site\beta}$	- any direction
Site design wind speed	$V_{des\theta} = 44.44\ \frac{m}{s}$	
Density of air	$\rho_{air} := 1.2\ \frac{kg}{m^3}$	
Design Wind Pressure	$q_{des\theta} := 0.5 \cdot \rho_{air} \cdot (V_{des\theta})^2 = 1.185\ kPa$	

5.0 Seismic Loading to NZS1170.5:2004

JOB TITLE	RLC Princess Arches Restoration	JOB NO.	10141	
ADDRESS	Queens Drive, Rotorua	*DATE*	9/09/2024	

DETERMINATION OF EARTHQUAKE ACTIONS
In Accordance with NZS1170.5: 2004 (Soil Class E not included)

Elastic Site Hazard Spectrum : $C(T) = C_h(T)ZRN(T,D)$

Special Shape Factor $C_h(T)$ =	3.00	Soil Class D
Hazard Factor Z =	0.24	Rotorua
Return Period Factor R_{ULT} =	0.75	1/250 ULS Event - Table 3.5
Return Period Factor R_{SERV} =	0.25	
Near Fault Factor N(T,D) =	1.00	

$C(T)_{ULT}$ = 0.5400
$C(T)_{SERV}$ = 0.1800

Horizontal Design Action Coefficient = $C_d(T_1) = \frac{C(T_1)S_P}{k_\mu}$

Structural Ductility Factor μ_{ULT} = 2.00
Structural Ductility Factor μ_{SERV} = 1.00

Structural Performance Factors (Refer NZS 1170.5 Clause 4.4)

Structural Performance Factor $S_{p(ULT)}$ = 0.70
Structural Performance Factor $S_{p(SERV)}$ = 0.70

Period T_1 = 0.35

$k_{\mu(ULT)}$ = 1.5000
$k_{\mu(SERV)}$ = 1.0000

Ultimate $C_d(T_1)$ = 0.2520
Serviceability $C_d(T_1)$ = 0.1260

3/90x20 - Existing Totara Chord - Estimated Member Capacities

K factors

$k_8 := 1$ $k_4 := 1.14$ $k_5 := 1$ $\phi := 0.5$ $k_{1p} := 0.6$ $k_{1m} := 0.8$ $k_{1b} := 1.0$ $f_b := 7.5\ MPa$

Member Moment Capacity

Section Modulus $Z_x := \langle 90\ mm \cdot (60\ mm)^2 \rangle \div 6 = \langle 5.4 \cdot 10^4 \rangle\ mm^3$

Permanent Moment Capacity $\phi M_p := \phi \cdot k_{1p} \cdot k_4 \cdot k_5 \cdot k_8 \cdot f_b \cdot (Z_x) = 0.14\ kN \cdot m$

Brief Duration Moment Capacity $\phi M_b := \phi \cdot k_{1b} \cdot k_4 \cdot k_5 \cdot k_8 \cdot f_b \cdot (Z_x) = 0.231\ kN \cdot m$

Member Compressive Axial Capacity

$b := 90\ mm$ (width) $d := 60\ mm$ (depth) $k_{10} := 1$ (pinned) $f_c := 11\ MPa$ $L := 14.8\ m$

Compressive capacity $\phi N_c = k_1 \cdot k8 \cdot f_c \cdot A$

k factor $k_1 := 1.0$ (breif) - Table 2.4

reduction factor $\phi := 0.5$ - Aged timber

Distance in weak axis laterally restrained $L_{ay} := 810\ mm$ - Restrained by diagonal braces

Distance in strong axis laterally restrained $L_{ax} := 810\ mm$ - Restrained by cross braces

Slenderness factor $S_2 := min\left(\frac{k_{10} \cdot L}{d}, \frac{L_{ax}}{d}\right) = 13.5$ => $k_8 := 1$

Slenderness factor $S_3 := min\left(\frac{k_{10} \cdot L}{b}, \frac{L_{ay}}{b}\right) = 9$ => $k_8 := 1$

Permanent Compressive Capacity $\phi N_{cp} := \phi \cdot k_{1p} \cdot k_8 \cdot f_c \cdot (b \cdot d) = 18\ kN$

Brief Duration Compressive Capacity $\phi N_{cb} := \phi \cdot k_{1b} \cdot k_8 \cdot f_c \cdot (b \cdot d) = 30\ kN$

Member Tensile Axial Capacity

$b := 90\ mm$ (width) $d := 60\ mm$ (depth) $k_{10} := 1$ (pinned) $f_t := 3\ MPa$ $L := 14.8\ m$

Permanent Tensile Capacity $\phi N_{tp} := \phi \cdot k_{1p} \cdot k_4 \cdot f_t \cdot (b \cdot d) = 6\ kN$

Brief Duration Tensile Capacity $\phi N_{tb} := \phi \cdot k_{1b} \cdot k_4 \cdot f_t \cdot (b \cdot d) = 9\ kN$

4/90x20 - Existing Totara Chord - Estimated Member Capacities

K factors

$k_8 := 1$ $k_4 := 1.14$ $k_5 := 1$ $\phi := 0.5$ $k_{1p} := 0.6$ $k_{1m} := 0.8$ $k_{1b} := 1.0$ $f_b := 7.5\ MPa$

Member Moment Capacity

Section Modulus $Z_x := (90\ mm \cdot (80\ mm)^2) \div 6 = (9.6 \cdot 10^4)\ mm^3$

Permanent Moment Capacity $\phi M_p := \phi \cdot k_{1p} \cdot k_4 \cdot k_5 \cdot k_8 \cdot f_b \cdot (Z_x) = 0.25\ kN \cdot m$

Brief Duration Moment Capacity $\phi M_b := \phi \cdot k_{1b} \cdot k_4 \cdot k_5 \cdot k_8 \cdot f_b \cdot (Z_x) = 0.4\ kN \cdot m$

Member Compressive Axial Capacity

$b := 90\ mm$ (*width*) $d := 80\ mm$ (*depth*) $k_{10} := 1$ (*pinned*) $f_c := 11\ MPa$ $L := 14.8\ m$

Compressive capacity $\phi N_c = k_1 \cdot k8 \cdot f_c \cdot A$

k factor $k_1 := 1.0$ (*breif*) - Table 2.4

reduction factor $\phi := 0.5$ - Reduced due to condition of aged timber

Distance in weak axis laterally restrained $L_{ay} := 810\ mm$ - Restrained by diagonal braces

Distance in strong axis laterally restrained $L_{ax} := 810\ mm$ - Restrained by cross braces

Slenderness factor $S_2 := min\left(\frac{k_{10} \cdot L}{d}, \frac{L_{ax}}{d}\right) = 10.125$ => $k_8 := 1$

Slenderness factor $S_3 := min\left(\frac{k_{10} \cdot L}{b}, \frac{L_{ay}}{b}\right) = 9$ => $k_8 := 1$

Permanent Compressive Capacity $\phi N_{cp} := \phi \cdot k_{1p} \cdot k_8 \cdot f_c \cdot (b \cdot d) = 24\ kN$

Brief Duration Compressive Capacity $\phi N_{cb} := \phi \cdot k_{1b} \cdot k_8 \cdot f_c \cdot (b \cdot d) = 40\ kN$

Member Tensile Axial Capacity

$b := 90\ mm$ (*width*) $d := 80\ mm$ (*depth*) $f_t := 3\ MPa$

Permanent Tensile Capacity $\phi N_{tp} := \phi \cdot k_{1p} \cdot k_4 \cdot f_t \cdot (b \cdot d) = 7\ kN$

Brief Duration Tensile Capacity $\phi N_{tb} := \phi \cdot k_{1b} \cdot k_4 \cdot f_t \cdot (b \cdot d) = 12\ kN$

145x145- Existing Totara Post - Estimated Member Capacities

K factors

$k_8 := 1$ $k_4 := 1$ $k_5 := 1$ $\phi := 0.5$ $k_{1p} := 0.6$ $k_{1m} := 0.8$ $k_{1b} := 1.0$ $f_b := 7.5\ MPa$

Member Moment Capacity

Section Modulus $Z_x := (145\ mm \cdot (145\ mm)^2) \div 6 = (5.08 \cdot 10^5)\ mm^3$

Permanent Moment Capacity $\phi M_p := \phi \cdot k_{1p} \cdot k_4 \cdot k_5 \cdot k_8 \cdot f_b \cdot (Z_x) = 1.14\ kN \cdot m$

Brief Duration Moment Capacity $\phi M_b := \phi \cdot k_{1b} \cdot k_4 \cdot k_5 \cdot k_8 \cdot f_b \cdot (Z_x) = 1.9\ kN \cdot m$

Member Compressive Axial Capacity

$b := 145\ mm$ (width) $d := 145\ mm$ (depth) $k_{10} := 1$ (pinned) $f_c := 11\ MPa$ $L := 3\ m$

Compressive capacity $\phi N_c = k_1 \cdot k8 \cdot f_c \cdot A$

k factor $k_1 := 1.0$ (breif) - Table 2.4

reduction factor $\phi := 0.5$

Distance in weak axis laterally restrained $L_{ay} := 250\ mm$ - Assume Restrained by lattice structure

Distance in strong axis laterally restrained $L_{ax} := 250\ mm$ -Assume Restrained by lattice structure

Slenderness factor $S_2 := min\left(\frac{k_{10} \cdot L}{d}, \frac{L_{ax}}{d}\right) = 1.724$ => $k_8 := 1$

Slenderness factor $S_3 := min\left(\frac{k_{10} \cdot L}{b}, \frac{L_{ay}}{b}\right) = 1.724$ => $k_8 := 1$

Permanent Compressive Capacity $\phi N_{cp} := \phi \cdot k_{1p} \cdot k_8 \cdot f_c \cdot (b \cdot d) = 69\ kN$

Brief Duration Compressive Capacity $\phi N_{cb} := \phi \cdot k_{1b} \cdot k_8 \cdot f_c \cdot (b \cdot d) = 116\ kN$

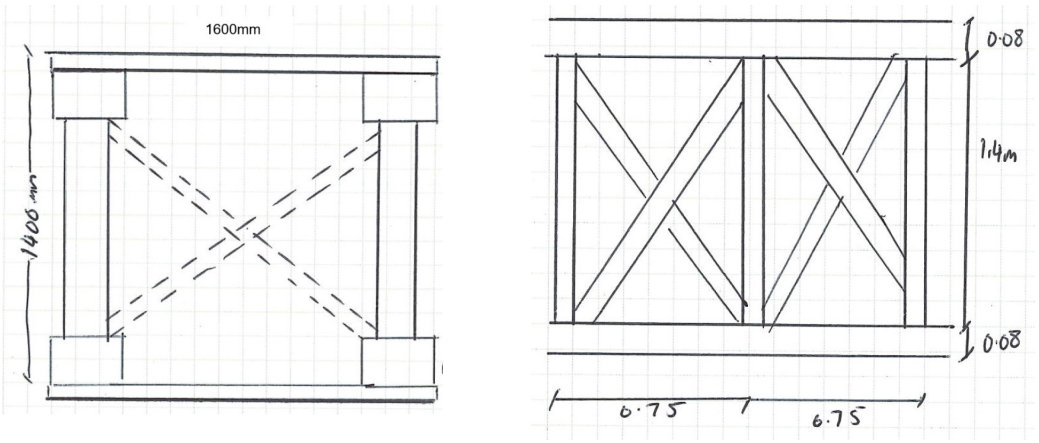
Member Tensile Axial Capacity

$b := 145\ mm$ (width) $d := 145\ mm$ (depth) $f_t := 3\ MPa$

Permanent Tensile Capacity $\phi N_{tp} := \phi \cdot k_{1p} \cdot k_4 \cdot f_t \cdot (b \cdot d) = 19\ kN$

Brief Duration Tensile Capacity $\phi N_{tb} := \phi \cdot k_{1b} \cdot k_4 \cdot f_t \cdot (b \cdot d) = 32\ kN$

Hand Calculation to Check SAP2000 Output



Figure(s) : General Arch dimensions , in & out of plane.

If we determine the weight of the structure for one wall & general weight of cross bracing members we can estimate the total weight of the truss in kN /m of truss.

Looking at the side wall for a 1.4x1.4m section, its comprised of two chords (4/90x20), one top, one bottom, diagonal bracing (90x45) & 3 truss web (90x45).

Total volume of side wall section $V_T := 1.4\ m \cdot 1.4\ m \cdot 0.1\ m = 0.196\ m^3$

Volume of web (side section) $V_1 := (90\ mm \cdot 45\ mm \cdot 1.4\ m) \cdot 3 = 0.017\ m^3$

Volume of diagonal brace (side section) $V_2 := (90\ mm \cdot 45\ mm \cdot 1.65\ m) \cdot 4 = 0.027\ m^3$

Volume of top & bottom chord (side section) $V_3 := (4 \cdot 90\ mm \cdot 20\ mm \cdot 1.4\ m) \cdot 2 = 0.02\ m^3$

Estimated weight of side wall $G_{wall} := \dfrac{(V_1 + V_2 + V_3) \cdot 10\ \frac{kN}{m^3}}{1.4\ m} = 0.456\ \frac{kN}{m}$

Estimated unit weight of cross bracing $\dfrac{\left(75\ mm \cdot 30\ mm \cdot 10\ \frac{kN}{m^3} \cdot 1.6\ m\right) \cdot 6}{1.4\ m} = 0.154\ \frac{kN}{m}$ - 3 cross braces top and bottom

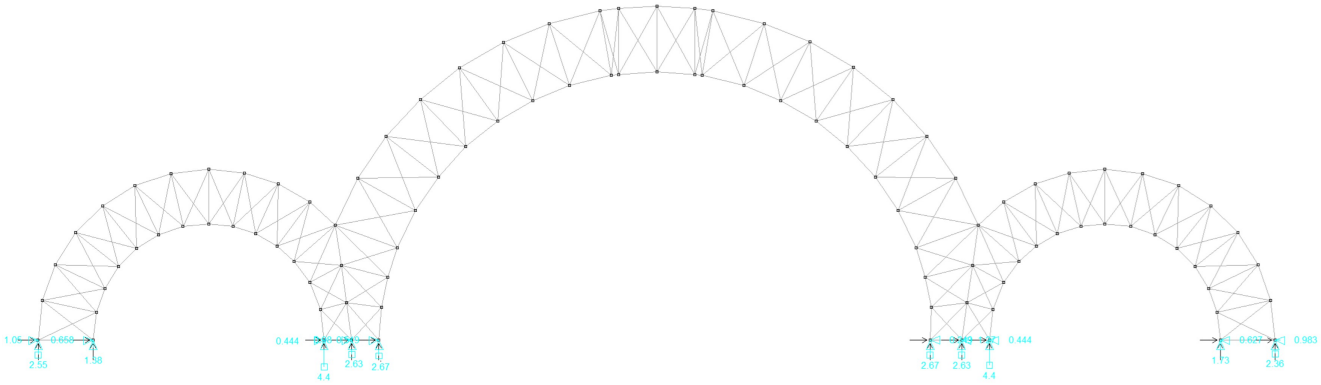
Estimated unit weight of X brace $\dfrac{\left(90\ mm \cdot 45\ mm \cdot 10\ \frac{kN}{m^3} \cdot 2.2\ m\right) \cdot 2}{3000\ mm} = 0.059\ \frac{kN}{m}$ - Assume 1/cross brace every 3m

Misc weight $0.1\ \frac{kN}{m}$ - Inner chord & ducting for lights

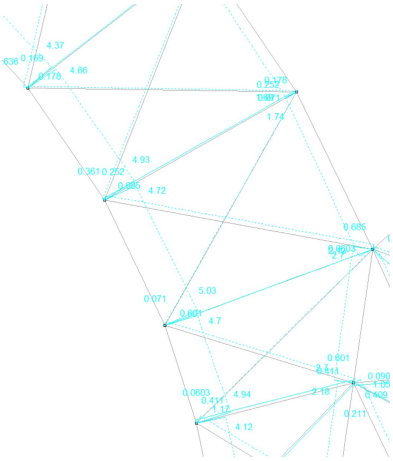
Unit weight of crossing bracing /m $G_{cross} := (0.16 + 0.06 + 0.1)\ \frac{kN}{m} = 0.32\ \frac{kN}{m}$

Total estimated weight of truss / m $G_{truss} := G_{wall} \cdot 2 + G_{cross} = 1.2\ \frac{kN}{m}$

We can assume this total weight is supported by 4/chords => 0.3kN/m load per chord



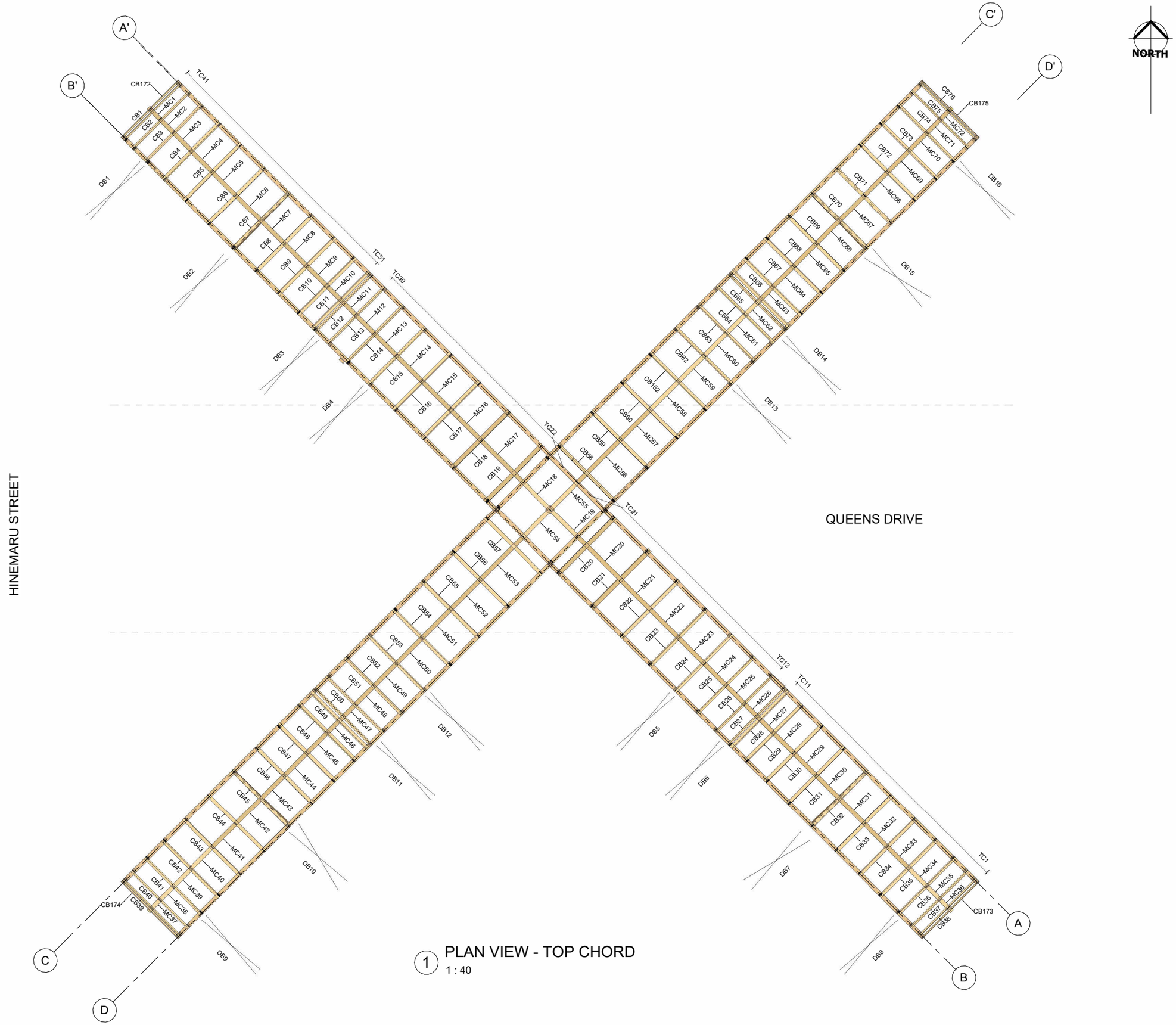
Modelling the arches as a 3d model in and applying 0.3 kN/m along the top & bottom chord , then multiplying the loads by 1.35G to emulate the 1.35G load case in microstran we get a maximum estimated compressive reaction for a single pole of 4.4 + 2.63/2 = 5.8kN , this is less than the base reaction in the SAP output of 8kN however, the sap calculation included the weight of the towers and poles. So this give us some confidence our sap output is inline with the expected result.



Looking the maximum compressive axial force, the microstran model shows this as 5.03kN which is the same as our SAP2000 output of 5kN

This check is intended as a sanity check to ensure the model outputs align with our values based of loads derived from hand calculations applied to a simplified 2D model.

APPENDIX D
Preliminary Structural Plans



1 PLAN VIEW - TOP CHORD
1 : 40

1.0	5/12/24	For Client Comment
ISSUE:	DATE:	DESCRIPTION:

Blueline
1/127 TONGARIRO STREET,
TAUPO, NEW ZEALAND
PHONE: (07) 809 5070
info@blueline consulting.co.nz
www.blueline consulting.co.nz

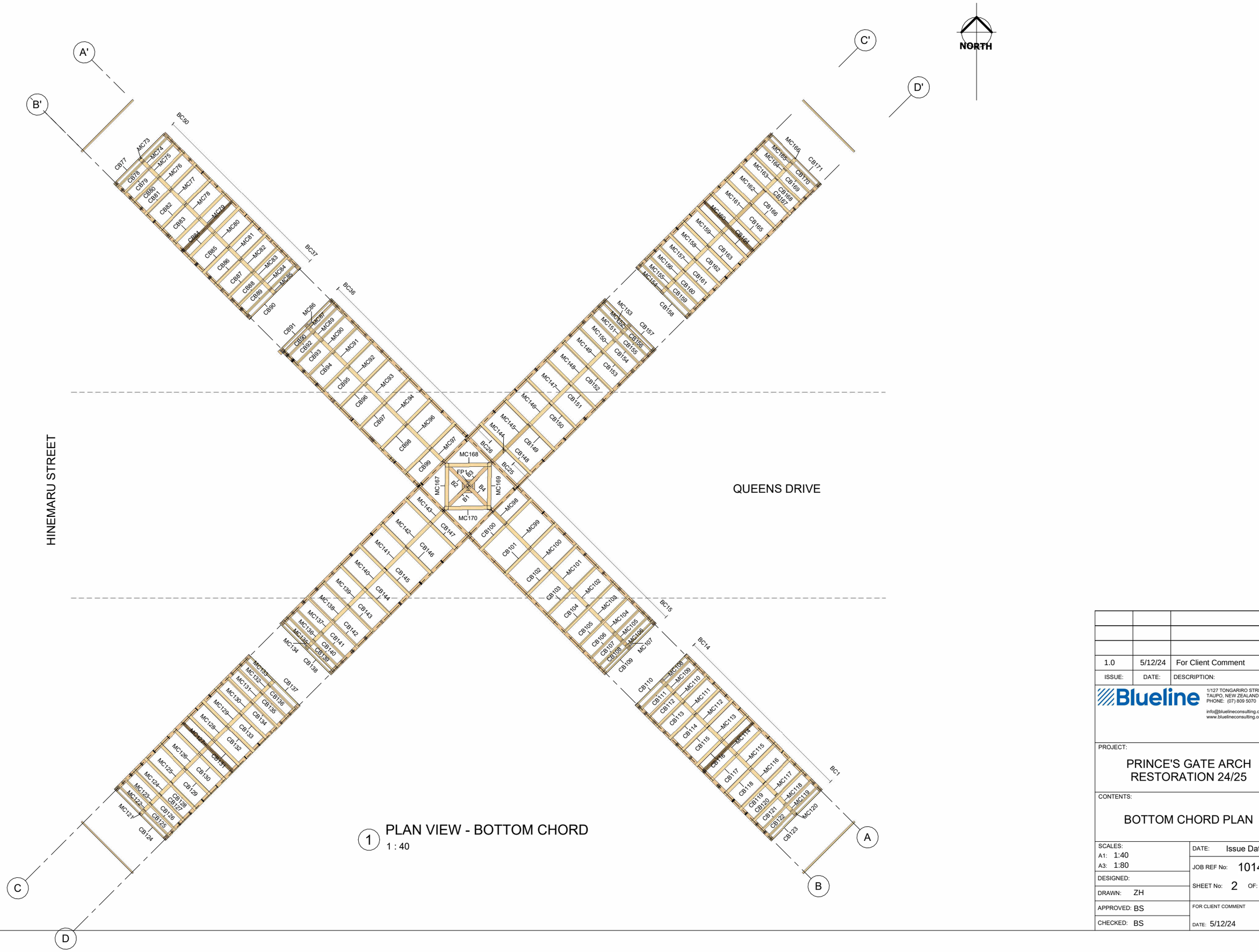
PROJECT:

PRINCE'S GATE ARCH
RESTORATION 24/25

CONTENTS:

TOP CHORD PLAN

SCALES: A1: 1:40 A3:	DATE: Issue Date
	JOB REF No: 10141
DESIGNED:	SHEET No: 1 OF: 4
DRAWN: ZH	
APPROVED: BS	FOR CLIENT COMMENT
CHECKED: BS	DATE: 5/12/24



1 PLAN VIEW - BOTTOM CHORD
1 : 40

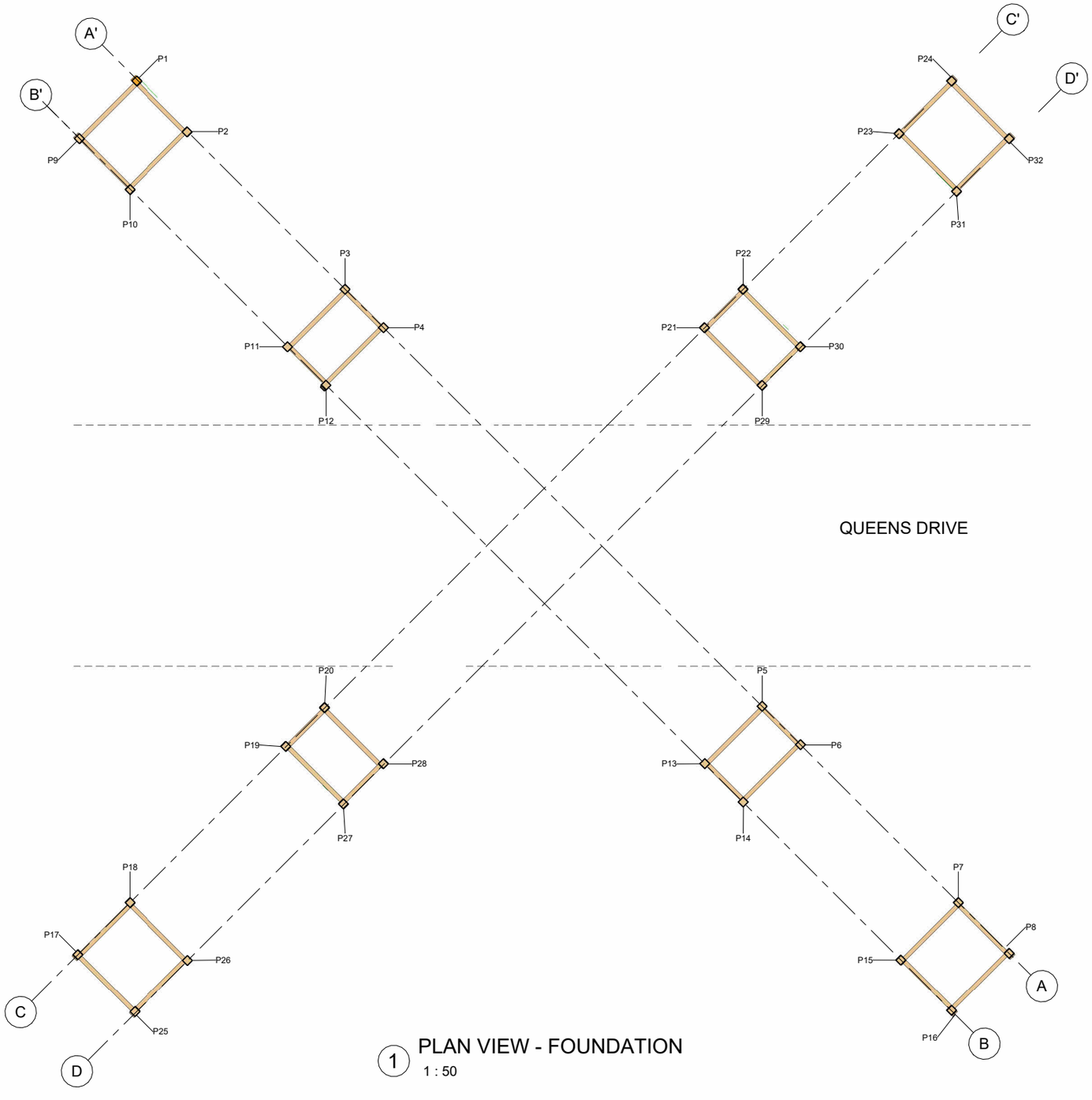
1.0	5/12/24	For Client Comment
ISSUE:	DATE:	DESCRIPTION:

Blueline
1/127 TONGARIRO STREET,
TAUPO, NEW ZEALAND
PHONE: (07) 809 5070
info@blulineconsulting.co.nz
www.blulineconsulting.co.nz

PROJECT:
PRINCE'S GATE ARCH RESTORATION 24/25

CONTENTS:
BOTTOM CHORD PLAN

SCALES: A1: 1:40 A3: 1:80	DATE: Issue Date
	JOB REF No: 10141
DESIGNED:	SHEET No: 2 OF: 4
DRAWN: ZH	
APPROVED: BS	FOR CLIENT COMMENT
CHECKED: BS	DATE: 5/12/24



1 PLAN VIEW - FOUNDATION
1 : 50

NORTH

1.0	5/12/24	For Client Comment
ISSUE:	DATE:	DESCRIPTION:

Blueline
1/127 TONGARIRO STREET,
TAUPO, NEW ZEALAND
PHONE: (07) 609 5070
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www.bluelineconsulting.co.nz

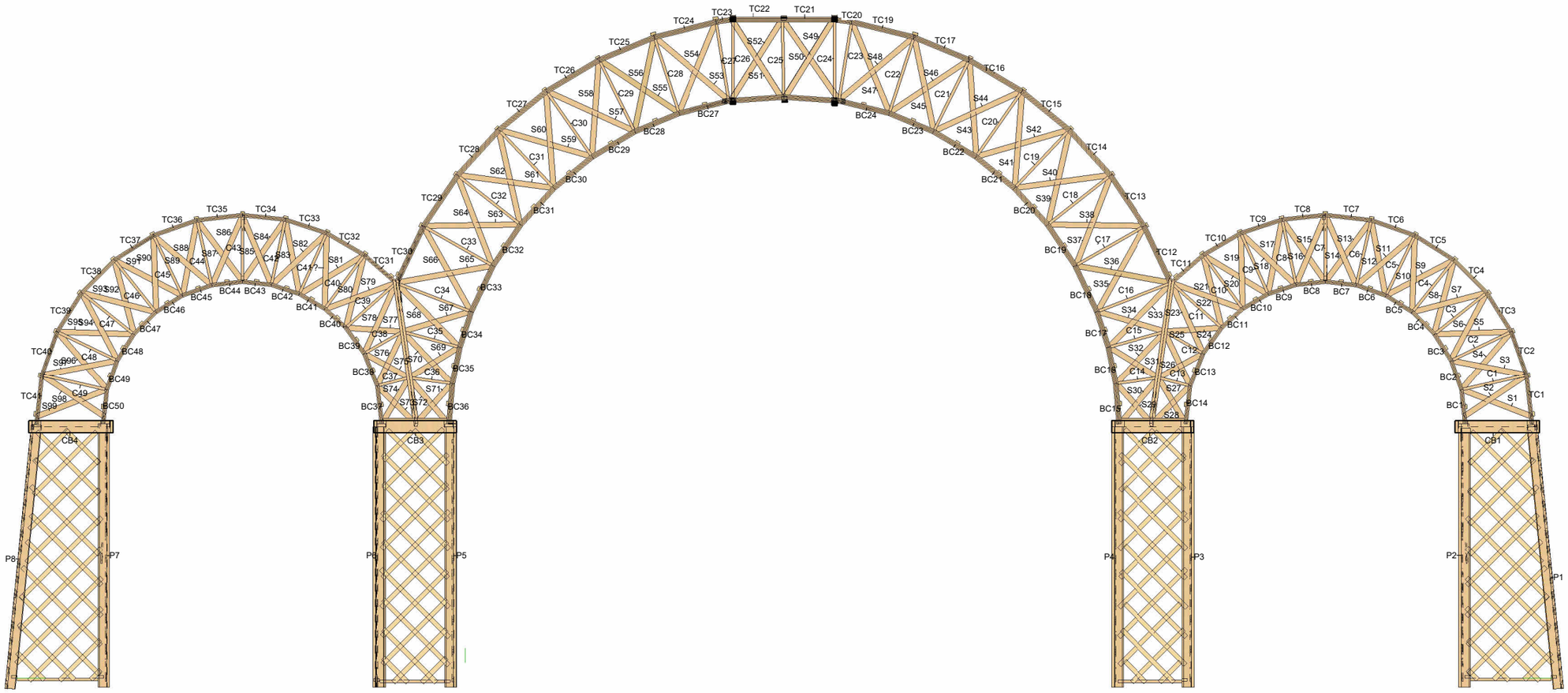
PROJECT:

PRINCE'S GATE ARCH
RESTORATION 24/25

CONTENTS:

FOUNDATION PLAN

SCALES: A1: 1:40 A3: 1:80	DATE: Issue Date
	JOB REF No: 10141
DESIGNED:	SHEET No: 3 OF: 4
DRAWN: ZH	
APPROVED: BS	FOR CLIENT COMMENT
CHECKED: BS	DATE: 5/12/24



1 CROSS SECTION - A-1A

1 : 40

1.0	5/12/24	For Client Comment
ISSUE:	DATE:	DESCRIPTION:

Blueline
1/127 TONGARIRO STREET,
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PROJECT:

PRINCE'S GATE ARCH
RESTORATION 24/25

CONTENTS:

CROSS SECTION

SCALES: A1: 1:40 A3: 1:80	DATE: Issue Date
DESIGNED:	JOB REF No: 10141
DRAWN: ZH	SHEET No: 4 OF: 4
APPROVED: BS	FOR CLIENT COMMENT
CHECKED: BS	DATE: 5/12/24