Port Craig Viaducts Engineering Assessment and Conservation Plan

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SUMMARY: *The Port Craig viaducts in Southland, New Zealand are located over deep gullies on the bush tramway that operated from 1917 to 1930 as part of the Port Craig timber harvesting and milling operation. This was the first introduction of high production heavy hauler harvesting in New Zealand and forms a notable chapter in indigenous logging history. The largest of the four timber viaducts, the Percy Burn, is 125m long and 36m high and was built to carry an 80 tonne hauler and also the passage of loaded log trams. These viaducts are the four largest remaining timber bush tramway viaducts in New Zealand and they remain fairly intact. These viaducts are now important visitor attractions and heritage items, but time and the elements have contributed to their deterioration since the mill closure in 1930 to the point where, without remedial work and preservation, they will begin to collapse. The history and significance of the Port Craig sawmilling story is covered in a paper in these proceedings titled* ***"Heritage Management at the Port Craig Sawmill Complex: Successes and Challenges"*** *by Rachael E Egerton, Department of Conservation.*

In 2007 The Port Craig Viaducts Charitable Trust commissioned a conservation plan for the purpose of documenting the history and significance of the viaducts as well as carrying out a detailed engineering assessment and developing a plan for their future restoration. This paper describes viaducts, as well as the methodology used to inspect and assess the viaducts and to develop the conservation plan and recommended restoration work. The conservation plan completed in August 2008 was prepared jointly by Chris Cochran, Conservation Architect; Michael Kelly, Heritage Consultant; Russell Murray, Conservation Architect and Trevor Butler, Consultant Engineer.

1. BACKGROUND

The Port Craig Viaducts were built as part of a bold initiative in 1917 by the Marlborough Timber Company to introduce large scale North American hauler logging techniques to New Zealand. The Southland coastal forest to the west of Port Craig offered the extensive harvestable terrain and was believed to contain the high volumes of timber to justify this scale of operation, previously unseen in New Zealand.

The several haulers for this operation were heavy pieces of equipment, the largest being the Lidgerwood hauler with a weight of 80 tonnes. The movement of such equipment required a substantial tramline with gentle grades so that it could be shifted to each setting location and set up for log hauling. Because the haulers were capable of high production rates, a reliable and efficient bush tramline was necessary to transport the logs from each hauler site to the mill at Port Craig. The tramline was built to 3' 6'' gauge (the New Zealand Railways' standard) rather than the narrow gauge typical of bush tramways. Hence, the curves had to be constructed with a much larger radius and the cuttings excavated wider than had been previously typical on bush tramways.

The tramway route traversed a wide relatively easy sloping terrace between the coastal escarpment and the steeply rising Hump Ridge to the north. The biggest impediments to the tramway were the incisions of four rivers, which have cut deeply into the terrace. To bench-cut the tramline into these deep ravines to cross the streams at a low level would have required significant additional length of tramline and the grades and curves required would have inhibited the efficiency of the logging operation. The solution was to construct large elevated timber trestle viaducts across these ravines. The first of these, near Sand Hill Point is only seven kilometers from the Port Craig Mill site, and the largest viaduct of the four, the Percy Burn is located only 800 metres beyond the first. These are believed to have been constructed in 1925.

Figure 1. *Lidgerwood chassis on the interpretative walk at Port Craig. (Crown Copyright: Department of Conservation, Te Papa Atawhai, 2005, Photographer: Rachael Egerton.)*

2. VIADUCT DESCRIPTION

Each of the viaducts is a large structure. The dimensions are shown in Table 1

Table 1 : Port Craig Viaduct Dimensions	
Sand Hill Viaduct	
Length	59m
Height	17m
Percy Burn Viaduct	
Length	125.2m
Height	36m
Edwin Burn Viaduct	
Length	50m
Height	22m
Francis Burn Viaduct	
Length	51.5m
Height	14.6m

Relatively little is known of the exact sequence the viaducts were constructed and the actual method of construction. Original drawings have not been found, however much of the detailing is typical of the type of construction found on many similar railway viaducts in New Zealand, Australia, USA and Canada. At one stage it was believed that the Percy Burn viaduct was one of the largest remaining timber trestle viaducts, however research by Michael Kelly has revealed several in existence that are higher and longer. Possibly the largest is the Goat Canyon Trestle in California, built in 1933 and standing a staggering 56m high and having a length of 197m.

Consistent with the high load capacity requirement and the expectation by MTC that the viaducts would provide access to the district after logging ceased, Australian hardwood timber was imported for their construction due to its greater strength and durability in comparison with New Zealand native timbers. Bolts for the bolted connections were made at Port Craig.

All four viaducts exhibit similar design features, but each has its own peculiarities, suggesting that there was some refinement of the design, and also adaptation to meet the specific challenges that each site presented. The towers of the Sand Hill viaduct are constructed from round hardwood poles with the low durability sapwood left in place. The latter viaducts are all constructed from squared timbers with the sapwood removed.

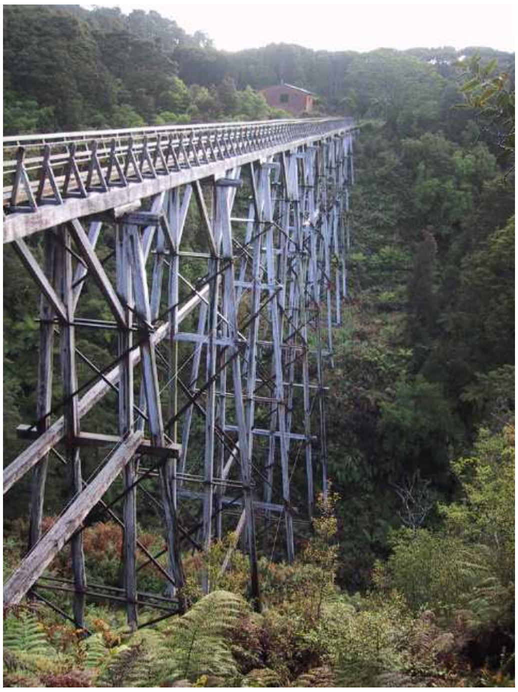

Figure 2. *Current appearance of Percy Burn Viaduct*

The towers of the Percy Burn and Edwin Burn viaducts have splices in the main columns because it was not possible to source and transport a single length of hardwood to match the full height of these viaducts. The highest columns of the Percy Burn viaduct required three separate timber columns spliced end to end to achieve the necessary 36m height. The Edwin Burn viaduct has a longer central span with steel tie bars so that the wider main stream channel could be crossed without the need for a pier within the waterway.

Figure 3. *The longer central span of the Edwin Burn Viaduct*

The footings of the piers near the base of the ravines consist of concrete pads founded on the mudstone rock. The piers nearer the ends of the viaducts consist of the hardwood columns being simply embedded into the clay gravel soil.

The rail deck of each viaduct was typically supported by large cross section timber beams spanning an average of 10m between corbels at the piers and propped with pairs of diagonal props from each pier. This structural form is very efficient on materials. Diagonal bracing to the piers is provided by railway irons and longitudinal stability to the piers is provided by horizontal timber members running the full length of the viaducts and anchored to the ground at each end. It is these horizontal braces that exhibit possibly the only serious deficiency in original design. The half splices at the ends of these bracing members have suffered from severe decay and many of these braces have fallen from the viaducts.

3. HISTORY

The viaducts were in use for little more than five years. The Port Craig sawmilling operation was closed in 1928 as a result of forest yields being well below that expected, and the high capital cost of the logging operation being well beyond that which could be economically sustained. It re-opened briefly in 1930 before closing permanently.

The tramway and viaducts deteriorated and in 1937, the successor of MTC, Holdings Ltd salvaged the rails and other items of value, but left the viaducts in place. For the following decades the viaducts provided access for hunters and trampers however by the 1970’s the decks, made from locally sourced timber of low durability, had deteriorated such that any crossing of the viaducts on foot was somewhat precarious. The NZ Forest Service undertook basic repairs and in 1979 the Deerstalkers Association re-decked the viaducts.

By the 1990’s there was growing recognition that the Port Craig Viaducts had heritage value and that there was merit in undertaking work to prolong their existence. Detailed drawings were prepared in 1987 and public meetings held to engage community support for remedial work on the viaducts.

In 1993, Southland’s Port Craig Viaducts Charitable Trust was formed with the aim to stabilise the viaducts. With extensive voluntary community support, and the input of a rigging contractor, extensive work was carried out on the Percy Burn Viaduct in 1994 which involved replacement of rotted timbers with bolted splices, and the application of preservative treatment.

The other three viaducts received remedial work in 1999 consisting of replacement of critical bolts, rails and timbers. Further work on the Percy Burn Viaduct was carried out at this time as well.

Three of the viaducts lie on legal road reserve and are owned by the Southland District Council. The Edwin Burn viaduct is on freehold Maori land. Management of the viaducts is vested with the Port Craig Viaducts Charitable Trust, with the support of the Southland District Council (SDC), Venture Southland, DOC, and NZHPT.

In 2007 the Trust commissioned a detailed conservation plan for the four viaducts and engaged Chris Cochran (Conservation Architect), Trevor Butler (Engineer), Michael Kelly (Heritage Consultant) and Russell Murray (Conservation Architect) to prepare the plan.

4. ENGINEERING INVESTIGATIONS

The methodology for assessment of the viaducts consisted of:

- Review of previous inspection and upgrade reports
- Detailed visual assessment from ground and deck level
- Assessment of condition of each component member based on visual appearance, close inspection and sounding with a hammer.
- Abseil inspection of selected locations.
- Review of deck lateral load deflection data.
- Detailed photographic record.

Figure 4. *Close inspection of Percy Burn Viaduct piers*

Whilst there was a significant body of knowledge about the condition of the viaducts from several previous inspections and reports, it was clear that for the purpose of the Conservation Plan it was necessary to establish a schedule of the condition of each component for each viaduct.

This schedule was prepared over a period of 8 days on site with the assistance of Trust personnel and rope access experts from Adventure Southland. It involved establishment of a clear component identification system and then for each component, recording its physical dimensions, materials and condition. For timber members this included recording the percentage of length that was affected by rot and also the extent of replacement by splicing in new timber that had taken place in the past.

This detailed investigation was carried out by visual assessment from deck level and ground level using binoculars, and was followed up by representative test boring and close inspection by descending on ropes. The end result of this work is a detailed schedule of current condition of every member of all four viaducts. This work was checked against previous inspections to identify any advance of deterioration. This inspection and scheduling work was facilitated by the thorough and detailed drawings of all four viaducts that were prepared by A Suchanski and S L Dsouza for the NZ Historic Places Trust in 1989.

In addition to the above, the Conservation Plan work included detailed photography of the viaducts, a geotechnical assessment and extensive research into the history and relevance of the viaducts.

5. CONDITION

The viaducts are in surprisingly good condition given their age. The remedial work and vegetation clearance carried out by the Trust since 1990 has clearly slowed the deterioration process and restored stability to the viaducts. There are however several common deterioration processes underway on all four viaducts. These are:

- Site instability: Continued down cutting of the streams will begin to undermine foundations near the stream edge.

- Pile rot and settlement: Several hardwood piles embedded in the alluvial gravels have deteriorated to the point where some are non existent below ground level.

- Weathering: This inorganic process of deterioration of the wood under solar radiation is evident on the viaducts but is not yet a threat.

- Sapwood Loss: The decay and almost complete loss of sapwood is most evident on the Sand Hill viaduct where round timbers were used for vertical pier members. This loss has resulted in joint loosening.

- Butt-end centre rot: Fungal attack of the less resistant pith wood is a characteristic of eucalypt logs. Several of the longer timbers are suffering from this type of rot and the remedial work carried out in 1993 on the Percy Burn viaduct was predominantly for the purpose of addressing this issue.

- End Rot: Fungal rot enters hardwood timbers along the more permeable longitudinal grain from exposed ends. Several pier caps suffer from this, however good construction detailing in most places (except the horizontal pier bracing) has minimised the structural impact of this effect.

- General Rot: Where soil and vegetation has accumulated against the structural timbers, the damp conditions have been more conducive to rot. This is most prevalent in the lower shaded sections and in the timber sills that are in direct contact with concrete foundations.

- Gutter Rot: This describes the rot that occurs along the tops of beams along the line of sleeper spikes. Iron promotes fungal decay and when the spikes rust away, they provide a path for moisture and fungal attack to the more prone pith wood inside the beam members. Gutter rot is the predominant threat to the main beams of the viaducts.

- Missing members: The viaducts are generally intact apart from the original decking, barriers and horizontal bracing timbers. Pilfering of items from the structures has not been a problem. The loss of the longitudinal bracing from the Percy Burn viaduct makes it prone to damage or collapse under severe earthquake.

- Rusting of Rail bracing: The original tramline bracing has survived well, probably due to the cooler temperatures of the site, but there is evidence of rusting arising from exposure to salt laden winds on the more exposed parts of the viaducts.

- Rusting bolts and fixings: The forged bolts and fittings have become rusted, and in many cases the square nuts are almost completely deteriorated.

Figure 5. *End rot at the ends of pier columns*

Figure 6. *Previously repaired pier columns with laminated spliced timber*

6. REMEDIAL OPTIONS

Any remedial work carried out on heritage structures needs to be undertaken in accordance with the general principles and conservation processes outlined in the ICOMOS New Zealand Charter for the Conservation of Places of Cultural and Heritage Value. Where the existing structural fabric is severely deteriorated, a major dilemma exists as to whether to provide introduced structural support for the original fabric, or to replace the original fabric with similar materials and structural form. The ICOMOS principles drove the decision process surrounding the establishment of recommendations for remedial work.

The remedial work options considered for the Port Craig Viaducts included:

- External Support: Provision of external support for the self weight of component members. This option was discounted in most instances because of the extensive introduced support structure that would be necessary and the desire to avoid cluttering the slenderness and simplicity of the original structural form of the viaducts.

- Lamination: Removal of rotted portions of original hardwood timbers and replacement of these with spliced laminates. The 1994 and 1999 work included this type of work and it has been highly effective in maintaining structural integrity and was achieved at reasonable cost. Whilst this approach has provided a structurally successful solution which assimilates the original structural form of the viaducts, the appearance of large numbers of bolted and spliced timbers detracts from the clean simple original appearance. There is a concern that if this approach is continued, the viaducts would take on the appearance of “giant lego”. For this reason, continuation of pinus radiata splicing is regarded as an option that should be pursued only if more visually acceptable options cannot be adopted.

- Replacement: Removal of rotted sections of members and/or whole timber members that have significant rot and replacement of these with durable eucalypt hardwood timber of the same dimensions as the original. This option is only possible if there is an available supply of suitable large cross section hardwood timber. With the replacement of several hardwood timber railway and road bridges underway in NZ, there is potential to reserve suitable timber from the structures that are being removed. These structures often contain sound durable hardwood that with suitable treatment, can be expected to remain serviceable for a significant time.

- Void Filling: Where pipe rot and gutter rot is present in members but there is still sufficient structural capacity in the remaining timber to carry the self weight and pedestrian loads on the structures, there is potential to treat the remaining timber with preservative foam. There is also an option to then fill the cavities with polyurethane foam filler. This foam filler provides added strength and stability to the member as well as reduces the tendency for any preservative to come out of the wood into the cavity.

- Surface Preservative Treatment: Surface rot is best controlled by keeping the timber surfaces dry and by applying a preservative that inhibits fungal attack. Spray application of copper naphthenate emulsion to all exposed timber surfaces is the recommended primary means treatment for fungal attack for the viaducts.

- Internal rot treatment: Where internal cavities are accessible, treatment with preservative foam is recommended, however access to most internal cavities in the viaduct timber is extremely difficult. Insertion of boron paste into bored holes at the ends of timber members is recommended. This is more suitable for dry timber and diffuses more readily through timber than copper naphthenate.

- Bolts and Fixings: Leaving existing deteriorated bolts in place and adding new bolts is preferred from the perspective of retaining original structure fabric, however this option is not favoured because, given the nature of the structural joints on the viaducts, there are limited locations for new bolt positions. Hence the recommended approach is to remove all badly deteriorated bolts and replace these with new hexagon head galvanized bolts.

- Steel fittings: Where the original steel fittings are badly deteriorated, replacement of these with new, similarly detailed fittings is proposed. Galvanized finishing will differentiate the new fittings from the original.

- Rusted steel rail bracing: Where rails are badly rusted, replacement of these with similar section rail is recommended. This bracing is critical to the lateral integrity of the structure.

- Steelwork protection: All remaining steel fittings and rails and any new rails are recommended for treatment with Shell Ensis V or Fishoilene. This will retain the original rusted rail appearance, but slow the rate of deterioration.

7. WORK REQUIRED

Urgent remedial work to the worst rotted piles of the Percy Burn Viaduct has been carried out since the investigation work for the Conservation Plan was completed. This work has been successful in stabilizing the structure and rectifying the sideways deformation of the viaduct.

A detailed schedule of remedial work and treatment for each viaduct is included in the Conservation Plan. This includes various combinations of the options outlined above. This work is essential if the deterioration of the viaducts is to be arrested and their survival for more than the next few years is to be assured.

With the replacement of the worst of the deteriorated items and treatment of the remaining original fabric, the Port Craig Viaducts can be expected to remain intact for a further 80 years, provided a programme of inspection, re-treatment and remedial work is maintained.

The estimated cost of the currently recommended remedial work for all four viaducts is $2.02M. This significant sum needs to be raised in the near future if these structures are to be saved. Given the Port Craig Viaducts provide a spectacular attraction and are an important component of the whole Port Craig sawmilling story that entices visitors to the area, it is expected that expenditure on restoration will be returned in the form of profit from tourism revenue for the region.

8. ACKNOWLEDGEMENTS

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- Helen Hall who managed the food and cooking for the team on site.

9. REFERENCES

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