

# Bridge inspection standards - A review of international practice to benchmark bridge inspection standards for KiwiRail Network's bridges

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## Summary

This paper describes how a review of international practice for bridge inspection has been applied to benchmark KiwiRail Network's (KRN) bridge inspection standards. The review was undertaken by KRN and Beca to update current practice for bridge inspection with respect to risk management and bridge safety.

The review included KRN's bridge inspection standards and operating environment for bridges, site inspection of a sample of KRN bridges at various locations around New Zealand, a literature search of international bridge inspection standards for similar organisations and assessment of appropriate bridge inspection standards for use by KRN. The review covered bridges only and excluded culverts, tunnels and retaining walls.

Benchmarking of KRN's bridge inspection standards with other similar organisations indicated that the frequency of detailed inspections should be increased and a number of measures introduced to improve the inspection procedures and reduce risks associated with KRN's bridges.

## Introduction

KiwiRail Network (KRN) owns and manages approximately 1,700 bridges, over 12,000 culverts and 150 tunnels on a rail network that extends the length and width of New Zealand. In addition there are about 500 bridges on the network that are owned by other organisations. The effective management of these assets and their ongoing maintenance is a major part of KRN's business as asset owner to provide safe and reliable infrastructure for Kiwi Rail's passenger and freight operations.

This paper outlines how a review of international practice for bridge inspection has been applied to benchmark KRN's bridge inspection standards. The review formed a critical part of a wider review of bridge inspection standards undertaken by KRN in relation to current practice with respect to risk management and bridge safety.

The review included current standards for bridge inspection, site inspection of a sample of bridges across New Zealand, a literature search of international bridge inspection standards for similar organisations and assessment of appropriate bridge inspection standards for use by KRN.

The review considered bridges only and excluded culverts, tunnels, retaining walls and other railway structures.

It should be noted that this study was completed in November 2008 and that international standards referenced in this paper may have been subject to subsequent amendment.

## Background

### KRN's bridge assets

KRN's 1,675 bridges are mostly rail bridges that carry the railway over rivers, roads and other features, although it includes about 120 road bridges, footbridges, stock underpasses and pedestrian subways.

Photo 1 – Typical KRN steel truss bridge



KRN's bridge stock is mature with 52% older than 70 years, 33% older than 80 and 23% older than 90 years. Many of the bridges were constructed in the period between 1910 and 1940 and to a lesser extent between 1950 and 1980, with relatively few constructed in the last 20 years.

Photo 2 – Typical KRN steel bridge with timber piers



The majority of bridge superstructures are constructed of steel or iron (59%), concrete/masonry (21%) and timber or combined timber, steel or concrete (20%). About 31% of substructures are constructed of timber, 60% of concrete or masonry and the remainder of steel, iron or a mixture of material.

The relatively high proportion of bridges with timber superstructures or sub-structures, which are often trestle piers, is a key factor in the management of KRN's bridges assets, especially as timber elements feature strongly among the older bridge assets. The timber is typically Ironbark, an Australian hardwood.

Photo 3 – Typical KRN concrete bridge



### KRN's operating environment for bridges

KRN essentially operates a freight network with only limited use by passenger trains in the metropolitan areas of Auckland and Wellington and limited cross-country passenger services between main cities and on tourist lines. Most of the lines carry predominantly freight traffic and this has implications for the levels of service to be met for KRN's bridge stock.

Freight traffic subjects the bridges to very heavy loading on a regular basis, with some lines carrying over 50 trains per day with approved axle loads up to 18 tonnes, although in contrast some remote branch lines may only carry one or two trains per day. The freight traffic usually operates at lower speeds than passenger trains. The actual loads on bridges are often close to the bridge rating capacity.

Much of the freight traffic using the rail network is energy or farm produce related such as coal, dairy or meat products, which are time critical. The economic effects of a bridge being restricted in either speed or load capacity can therefore be significant as many businesses are entirely reliant on the rail link for getting goods to markets or ports.

Passenger traffic is generally much lighter than freight and has higher operating speeds. Again, safety and reliability are critical with on-time running a key aspect of reliability.

KRN therefore operates in an environment in which their bridge assets are vital components in providing a safe and reliable rail network. Their bridges are subject to heavy loading from relatively high volumes of freight traffic and at the same time they are expected to carry infrequent passenger services that demand higher speeds and on-time running. When the age of the bridge assets and the high proportion of timber bridges are also taken into account, the importance of effective bridge asset management practices can be seen to be critical for KRN's business.

### Literature search of international standards

#### Scope of literature search

The literature search was undertaken to review standards for bridge inspection in similar organisations to KRN on an international basis. Organisations selected for review were railway organisations in Australia and the UK and roading authorities in New Zealand which operate in a similar environment to KRN. The findings of this search are summarised below, starting with an overview of KRN's current bridge inspection requirements.

## KRN bridge inspection standards

KRN's bridge inspection standards are set out in the following documents:

- W200: Structures Inspection Manual
- Structures Code Section W004: Structures

The Structures Inspection Manual (W200) provides detailed advice on the inspection and reporting requirements for KRN's structures, covering a range of structure types and materials. This document was published by Tranz Rail (predecessor of KRN) in October 2000 and includes details of the types of inspection to be undertaken and specific guidance on issues to be considered with particular types of structure and materials. It does not include requirements relating to the frequency of inspections.

KRN bridge inspection types are set out in Chapter 6 of the manual and comprise:

- General inspections
- Detailed inspections
- Supplementary inspections
- Other inspections

General inspections comprise an overall examination of the site and the structure noting any obvious defects or unusual features and looking for evidence of how the structure is performing. Individual components are not required to be examined in detail, but significant and obvious changes since the previous inspection are to be identified. Any outstanding work tasks are also to be considered. When there is no detailed inspection scheduled, the general inspection is required to be sufficiently detailed to determine structural condition and how the structure is performing. This could involve a detailed examination as per the requirements of a detailed inspection.

Detailed inspections are described in the standards as the most thorough inspections that most structures will receive. Every component and feature of the site must be carefully examined (as far as practically possible) and its condition reported. Non-destructive testing may be required. The internal condition of hardwood timber is required to be ascertained by inspection boring. It is noted that the manual allows detailed inspections to be undertaken to every component 'as far as practically possible', and so some components may not receive close up examination, if for example access is difficult or operating conditions do not permit.

Supplementary Inspections involve the detailed re-examination of specific components or features, and are usually intended to address deteriorated or defective components for which more frequent examination is required than would be necessary under normal inspections.

Other inspections used include Special Inspections that are undertaken in addition to the normal inspections described above and which are required for a specific purpose.

The inspection manual has specific requirements for reporting of results in terms of identification of bridge components and description of the condition of each item. The reports have sections for estimated life expectancy of components and description of remedial work that is required.

The Structures Code Section W004: Structures, is a Tranz Rail document published in November 2000 which sets out responsibilities for bridge inspections and specifies the types and frequencies of the inspections. Table W20 of the code specifies the frequency of general and detailed structures inspection for a range of structure types, including bridges. The inspection frequency required for general inspection of bridges is 1 year and for detailed inspections it is 8 years for KRN owned bridges. For non-KRN bridges, general inspections are carried out at 1 year intervals, and detailed inspections are not required, for such as overbridges and footbridges owned by roading authorities.

KRN's bridge inspections are carried out by regionally based bridge inspectors who are generally highly experienced tradesmen who have been trained into these roles, often from a carpentry background which reflects the prevalence of timber in the bridge stock. The bridge inspectors belong to the KNR regional infrastructure units and are supported by 'buddy' engineers from KRN's head office who provide technical support and peer review.

## RailCorp bridge inspection standards

RailCorp (Rail Corporation of New South Wales), which operates the metropolitan rail system in Sydney, extending from Newcastle to Wollongong and east to Lithgow in the Blue Mountains, owns around 1,200 bridges including underbridges, overbridges and footbridges.

The majority of bridges are constructed of steel or concrete, with only a few timber bridges remaining in service. There are also a number of wrought iron and broad flange beam bridges, as well as masonry arch bridges. Many of the older bridges have masonry substructures. The bridge stock is relatively old with an average age based on oldest component of 60 years, although many older bridges have had their superstructures replaced in recent years. Bridges in the rural areas of New South Wales were transferred to the Australian Rail Track Corporation (ARTC) in 2004.

RailCorp's standards for bridge inspection are specified in the following documents:

- ESC 100 – Civil Technical Maintenance Plan
- TMC 110 – Structures Services Schedules
- TMC 301 – Structures Examination Manual

RailCorp's standards require detailed inspections and visual (mid-cycle) inspections at specified time intervals depending on the type of bridge and with specific requirements for old bridges and higher risk materials. The basic requirements for bridges are:

- Underbridges – Detailed inspection at two year intervals with visual inspection at mid-cycle between detailed inspections
- Overbridges and footbridges – Detailed inspection at four year intervals with visual inspection between
- Timber bridges and timber transoms on underbridges – Detailed inspection at two year intervals with visual inspection between. Frequency of drilling of timber members is not specified in the standards
- Wrought iron and steel underbridges older than 100 years – Detailed inspection at one year intervals with visual inspection between
- Broad-flange bridge beams over roadways – Inspection at one month intervals (Broad flange beams are a particular structural type found in Australia that are prone to brittle failure due to the materials used. It is believed that this type of structure has never been used in New Zealand)
- Underwater examinations for underbridges with piers permanently underwater - Inspection of underwater elements at six yearly intervals.

Detailed and visual inspections are defined in the RailCorp standards as:

- Detailed inspection – Close up inspection of all structural members within 1 m of the surface of the component. Where close up inspection is difficult, expensive or requires major track possessions or road closures, it may be undertaken every second cycle, with visual inspection undertaken utilising binoculars etc. on the alternate inspection
- Visual inspection – Visual inspection of all components undertaken at least once mid-cycle between detailed inspections.

RailCorp's bridge inspections are undertaken by bridge inspectors in each region with steel bridges being inspected by the steel bridge inspectors. Mid-cycle inspections are undertaken by the regional structures manager. The engineering department at head office also undertakes audits of bridges on a sampling basis to confirm that standards are being complied with.

### ARTC bridge inspection standards

The Australian Rail Track Corporation (ARTC) owns the railway infrastructure throughout Australia except for the metropolitan areas of Sydney, Melbourne, Adelaide and Perth, and the state of Queensland. The ARTC network is essentially rural and carries predominantly freight traffic, but with some passenger services between main centres.

ARTC owns a large number of older bridges with a high proportion of timber, steel and wrought iron bridges within the network. There are a significant number of large river crossings utilising steel or wrought iron trusses or girders.

ARTC's bridge inspection standards are based on the RIC standards which were the predecessors to RailCorp's current standards. ARTC's bridge inspection standards are:

- *BES 01 – Bridge and Structure Examination: General Requirements*
- *BEP 03 – Examination of Bridges and Structures Handbook*

ARTC's bridge inspection standards require detailed cyclic inspections of all bridges with spans greater than 300 mm (small culverts), to be undertaken by the bridge inspector. The steel bridges inspector also undertakes inspections of all steel bridges. Visual detailed cyclic inspections are also undertaken by a nominated structures representative at least once in the period between detailed inspections.

The frequency of detailed inspections is:

- Timber bridges and timber components of other bridges are inspected in detail once every two years
- Steel underbridges on specific railway lines are inspected in detail once every two years
- Steel underbridges on other lines are inspected in detail once every four years
- Steel overbridges and steel footbridges are inspected in detail once every four years
- Underbridges with broad-flange beams over roadways are inspected monthly
- Concrete, brick and masonry underbridges, overbridges and footbridges are inspected in detail at the same frequencies as steel bridges
- Other bridge materials are inspected at the same frequencies as concrete bridges.

## New Zealand Transport Agency

New Zealand Transport Agency (NZTA) owns about 2,300 bridges throughout New Zealand with the majority of these bridges constructed of concrete. There are a small proportion of steel bridges which are mostly steel trusses or girders onto concrete sub-structures; and there are a significant number of timber bridges, particularly in the South Island and in rural areas. The average age of NZTA's bridges is around 40 years, although there are a significant number of older bridges and some exceed 100 years.

Standards for bridge inspection within NZTA are specified in TNZ S6:2000 – Bridge Inspection Policy. This document specifies four categories of bridge inspection as follows:

- Superficial inspection
- General inspection
- Detailed inspection
- Special inspection

The standard requires that bridge inspections are undertaken to the standard defined in UK Department of Transport publication Bridge Inspection Guide published by DOT in 1983. In addition NZTA also publish a Bridge Inspection and Maintenance Manual which supplements the DOT guide. In general, NZTA bridge inspection follows UK Department of Transport standards in many respects.

Superficial inspections are undertaken for obvious defects covering such items as impact damage, build-up of flood debris, deck drainage problems etc as required.

General inspections are undertaken of all bridges every two years. The inspections are carried out by the bridge inspector if there is no history of maintenance problems and with a design engineer or other specialist staff if there have been maintenance problems in the past. The inspection verifies the bridge inventory data.

Detailed inspections are undertaken at intervals not exceeding six years. Inspections are carried out at close quarters for all external surfaces and where appropriate all internal surfaces. Underwater inspections are also required where recommended by the regional bridge engineer for structures in waterways. Inspections are undertaken by the bridge inspector and by specialist staff where required.

Special inspections involve particular types of structure or circumstances such as posted bridges, Bailey bridges, large or complex bridges, post-earthquakes, post-flood inspections and prior to carrying overloads.

There are no specific requirements in the standard to undertake more frequent inspections for old bridges or timber bridges unless they fall into the category that would require special inspections to be undertaken.

NZTA's bridge inspections are the responsibility of regional bridge engineers who are usually professional engineers. Inspections are undertaken by bridge inspectors who report to the regional bridge engineers. The NZTA bridge inspectors are generally degree qualified engineers with experience in this type of work and who have been trained in bridge inspection practice. Formerly, NZTA bridge inspectors were trades people who had progressed into bridge inspection, but these personnel have now mostly retired.

## Network Rail

Network Rail in the UK owns a large number of bridges with a variety of bridge types and materials used for construction. Many bridges are constructed of wrought iron, steel and masonry. There are few if any timber railway bridges in the UK, but there are a high proportion of older bridges that date from when the railway network was first constructed.

Network Rail appears to have withdrawn standards for safe management of structures as instructed by Briefing Note PP204 dated May 2005 and has not yet provided replacement standards. Previous requirements for bridge inspection are set out in Railway Group Standard GC/RT 5100 – Safe management of Structures, published in 2004. The requirements of this standard are summarised below:

- Detailed inspections at six year intervals
- Detailed inspections of parts of structures below water and where depth prevents visual examination at three year intervals
- Visual inspections at not greater than one year intervals
- Special examinations are required after flooding, scour, wave action, tidal action, gales, earthquakes or following accidental or deliberate damage.

The interval between detailed inspections can be increased on the basis of risk assessment by up to twice the normal period, and are to be reduced where structures are subject to a rapid change in condition or circumstances.

The standards require detailed inspections to be generally carried out from a position where the inspector is within touching distance of the part being inspected, unless otherwise justified.

The various standards for bridge inspection reviewed in the literature search are summarised in Table 1 below.

Table 1 - Comparison of bridge inspection standards

Bridge Authority	Underbridge Inspection Requirements	Overbridge and Footbridge Inspection Requirements	Timber Bridge Inspection Requirements	Special Inspection Requirements for Other Bridge Types
KRN	General – 1 year Detailed – 8 years	General – 1 year Detailed – 8 years	General – 1 year Detailed – 8 years	Supplementary – as required
RailCorp	Visual – 1 year Detailed – 2 years	Visual – 2 years Detailed – 4 years	Visual – 1 year Detailed – 2 years	Wrought iron and steel bridges >100 years – Visual 1 year, detailed 1 year. Broad flanged beams over roads – 1 month. Underwater – 6 years
ARTC	Visual – 1 or 2 years Detailed – 2 or 4 years	Visual – 2 years Detailed – 4 years	Visual – 2 years Detailed – 4 years	BFB over roads – 1 month
NZTA	General – 2 years Detailed – 6 years	General – 2 years Detailed – 6 years	General – 2 years Detailed – 6 years	Underwater – as required Special – as required
Network Rail	Visual – 1 year Detailed – 6 years	Visual – 1 year Detailed – 6 years	Visual – 1 year Detailed – 6 years	Underwater – 3 years Special for flood, scour etc

### Discussion of findings of literature search

The comparison of bridge inspection standards between the various organisations reviewed indicates that each organisation has a different approach to bridge inspection in terms of the types of inspection, the frequency of the inspections, the definition of the various inspection types and the type of personnel that undertake the inspections.

This is largely a reflection on the history of the various organisations and the type and age of assets that they own. There are, however, some common standards due to various organisations having adopted standards from other organisations, but often these have then been modified to suit the new organisation.

It can be seen that for the Australian rail organisations it is usual to adopt a more stringent inspection regime for underbridges that carry the railway compared with overbridges that carry road traffic or footbridges. This is a reflection of the risk profile for the various bridge types and their ownership, since road bridges are generally owned by roading authorities. Road authorities do not usually make this distinction as generally all highway bridges carry the same type of loads.

In comparing bridge inspection standards between road and railway authorities it is important to recognise the differences in the risk environment between road and rail transport. Rail can be considered to be higher risk than road in that passenger lines have a higher single incident exposure to people risk due to the high number of passengers on a train, compared to roads which can be lightly trafficked and for which each vehicle carries only a few passengers. However, rail has more control over the

use of their bridges in terms of loads, speed and braking, can often stop trains quickly in the event of a bridge failure using radio, its freight lines have lower exposure to people risk and the rail network has more 'eyes and ears' than the road network, providing early warning of problems through the frequent track inspection regime. In contrast, road bridges can be subject to considerable overloading due to illegal loads.

Special inspection requirements with higher frequency of inspection are adopted by some authorities for timber bridges, wrought iron and steel bridges older than 100 years and underbridges with broad flange beams. Again this reflects the higher risk associated with these bridges types.

Some authorities have requirements for underwater inspection of components that are permanently underwater, but this is not consistent across organisations.

KRN's bridge inspection standards differ from the other organisations primarily in respect of the interval for detailed bridge inspections which is greater than any of the other organisations reviewed, and the interval for general inspections which is shorter than for each of the other organisations reviewed except Network Rail.

However, supplementary inspections are a key mechanism used by KRN for the management of older bridges, timber bridges and wrought iron bridges. KRN does not specify the frequency of supplementary inspections as these are undertaken as required for a particular structure taking account of its condition. The frequency of supplementary inspections is a matter of judgement and is determined by the bridge inspector and reviewed by the Head Office 'Buddy Engineer' to suit the specific circumstances.

Inspection of underwater components is also not specified at present by KRN, although a code supplement for underwater inspections is currently being written. It is noted that underwater inspections are mandatory for bridges in tidal areas and are at the discretion of the bridge inspector when scour risk is assessed as being present for bridges in non-tidal areas.

KRN has a lower frequency of detailed bridge inspections compared to other similar organisations. The organisations reviewed either carry out detailed inspections at six year intervals with general inspections at one or two year intervals, or detailed inspections at two or four year intervals, depending on bridge type, with mid-cycle visual inspections. RailCorp and ARTC carry out detailed inspection of timber bridges at two year intervals.

The definition of the various inspection types varies between organisations and some organisations do not provide detailed definitions. KRN is like some other organisations in that while general and detailed inspections are defined, there is lack of specific requirements in terms of how close to the structure the inspector should be to carry out the inspection. RailCorp, Network Rail and NZTA clearly define detailed inspections in terms of closeness to the structure being examined.

Bridge inspections are undertaken by bridge inspectors in all organisations reviewed, but in some organisations specialist steel bridge inspectors are required to carry out inspection of steel bridges, and regional bridge engineers or structures managers are responsible for the inspections undertaken in their regions. Some authorities also carry out auditing of bridge inspections from head office engineering departments to ensure that standards are being met.

## Assessment of standards

### Methodology

The assessment of appropriate bridge inspection standards for KRN was undertaken by first considering specific risks related to their bridges based on the findings of the above research, from the site inspections undertaken and the discussions held with KRN engineers and inspectors. The extent to which these risks could be mitigated by adoption of appropriate standards for bridge inspection was then considered and from this recommended standards for bridge inspection derived. The methodology adopted was empirical and experience based rather than using statistical methods that can be used for this type of assessment, but which require extensive data on the reliability and maintenance history of the assets being considered. This data was unlikely to be available for KRN's bridges, hence the approach taken.

Following the risk-based assessment, the proposed standards for bridge inspection were then benchmarked against standards adopted by other similar organisations.

An overall assessment was then made of the bridge inspection standards to be recommended for adoption by KRN based on the combination of findings from these two approaches.

### Risks related to bridge inspection standards

The risks to KRN's bridges that were identified in relation to bridge inspection and the proposed mitigation by adoption of modified standards for bridge inspection are discussed below. The risk assessment was carried out using the KRN risk matrix in the National Rail System Standard/4 – Risk Management, 2004. This document uses standard definitions based on ALARP (as low as reasonably practical) principles to manage risk.

The risk assessment identified a number of risks associated with bridge inspection standards and current practice for the inspection of KRN's bridges. The risks identified were related to:

- The frequency of inspections
- The definition of detailed inspections
- Access for inspection
- Drilling of timber members to investigate white rot and other forms of decay
- Underwater inspections
- The focus on timber bridges to the possible detriment of other materials due to the large number of timber bridges on the network.

Mitigation measures were then identified to address the identified risks and these were assessed using the risk matrix and found to reduce the level of risk for most risks to be ALARP.

The proposed mitigation measures to address the risks identified were:

- Increase detailed inspection frequency for timber bridges to four years and for high risk bridges increase frequency on case by case basis
- Increase detailed inspection frequency for steel and concrete bridges to six years
- Define requirements for close-up inspection of components in detailed inspections to ensure that members are inspected at close quarters on a regular basis, even when access is difficult
- Drilling to investigate white rot and other forms of decay in timber to continue at 8 year intervals but investigate availability of alternative non-destructive methods of detecting white rot and other forms of decay that do not require destructive drilling, to be carried out at four year intervals if available
- Specify the type and frequency of underwater inspections required for bridges with supports that are permanently underwater
- The use of specialist steel bridge inspectors for inspection of steel bridges.

## Benchmarking inspection standards with other similar organisations

Comparison of KRN's bridge inspection standards with other similar organisations indicated that there were some differences of approach and different standards adopted by the various organisations reviewed. All of the road and railway authorities reviewed undertook detailed inspections more frequently than KRN, but most carried out general inspections less frequently.

Most authorities carry out general inspections at either one or two year intervals and detailed examinations at six year intervals except for RailCorp and ARTC, which carry out detailed inspections at two year intervals for underbridges and four year intervals for overbridges. These organisations, however, place less emphasis on general inspections than organisations with more widely spaced detailed inspections.

In comparing organisations it is important to factor in the type and age of the bridge stock and the different requirements of road and railway bridges in terms of their use and the consequences of structural failure. In this respect KRN has a large number of timber bridges, or bridges with timber components, when compared with most of the organisations reviewed, and also has a higher proportion of older bridges than many of them.

KRN's bridge inspections are undertaken by area structures inspectors with no formal process for review or auditing of the inspections by professional engineering staff, although it is understood that some review is undertaken and that there is close liaison between the regional staff and engineering group. Other organisations reviewed either have professional engineers based in the regions who are responsible for the bridge inspections or have formal procedures for audit of the bridge inspections by professional engineers from the head office engineering group. It is considered that these approaches provide increased assurance of the integrity of the asset and it was recommended that KRN should instigate a formal audit process for bridge inspections using professional engineers to provide assurance that standards are being complied with.

It was therefore proposed that KRN's bridge inspection standards should be revised as follows on the basis of comparison with other similar organisations:

- Detailed inspections of concrete and steel bridges at 6 year intervals
- Detailed inspection of timber bridges and timber components of other bridges at four year intervals
- Underwater inspections at six year intervals
- Arrange formal audit of bridge inspections by professional engineers
- Use specialist steel bridge inspectors for inspection of steel bridges.

## Assessment of inspection frequency

It was proposed that the frequency of general inspections for all KRN bridges should remain at one year as this is in line with other similar organisations and would maintain current practice for general inspections which had been shown to be effective.

It was proposed that the frequency of detailed inspections for steel and concrete bridges should change from eight years to six years which would bring KRN into line with other similar organisations. Supplementary inspections would still be required at a higher frequency for particular high risk structures as determined on a case by case basis.

The frequency of detailed inspection of timber bridges was proposed to be changed from eight years to six years, rather than four years as described above. This took account of the greater frequency of KRN's general inspections and an assessment of the rate of deterioration of timber bridges.

Given that the low maintenance life of a timber bridge is typically in the range of 50 to 70 years, and that older timber bridges deteriorate at a faster rate than new structures, it was considered that a frequency of eight years was too low, as there may be a risk that serious defects would not be detected prior to them becoming critical. It was considered that a six year inspection frequency would be sufficient to detect defects in timber members before they become a significant structural risk.

This assessment was verified by analysing a selection of timber bridge records to assess the rate at which deterioration has occurred on bridges with known defects. From these records, the rate of increase in the size of the internal voids increased against time. This demonstrated that even on some of the worst effected members, the rate of deterioration was such that inspection at six year intervals would detect the majority of defects before they became structurally critical. Once defects had been detected, it was recognised that the frequency of inspection could be increased by using the supplementary inspections to monitor the rate of further deterioration.

It was therefore proposed that the frequency of detailed inspection for timber bridges should be six years, but with supplementary inspections undertaken at a higher frequency as required on a case by case basis.

The frequency of underwater inspections was proposed as six years based on the frequency adopted by RailCorp. It was noted that Network Rail adopted a three year frequency, but this was considered high in the context of the frequency of other inspections to be undertaken and current practice, which does not specify a requirement to undertake underwater inspections except for bridges in tidal areas. It was also noted that underwater inspections are of limited value to identify scour risk, as scour can be episodic with the risk occurring during the flood event rather than being visible during the steady state when scour holes can be filled again.

### Proposed revisions to ONTRACK bridge inspection standards

It was proposed that KRN's bridge inspection standards should, based on the combined findings of the risk assessment and the comparison of standards with other organisations, be revised as shown in Table 2 below.

Table 2 - Proposed revisions to KRN bridge inspection standards

Category	Requirement
Detailed inspections for steel and concrete bridges	6 year intervals
Detailed inspections for timber bridges and timber components	6 year intervals except for deteriorated bridges increase frequency on case by case basis
Underwater inspections for all structural elements that are permanently underwater	6 year intervals
Definition of detailed inspections	Close up inspection within touching distance of all components
Drilling of timber members	6 year intervals but investigate use of non-destructive methods of detecting white rot and other forms of decay. All drill holes must be permanently plugged.
Audits of bridge inspections	Regular formal audits to be undertaken by professional engineers
Definition of general inspections	Clarify requirements when detailed inspections are not scheduled
Inspection of steel bridges	Use of specialist steel bridge inspectors for inspection of steel bridges

### Conclusions

The review of KRN's bridge inspection standards has been undertaken to benchmark current KRN standards for bridge inspection against other similar organisations and in relation to current practice with respect to risk management and bridge safety.

The review has covered KRN's bridge inspection standards and operating environment for bridges, site inspection of a sample of existing KRN bridges at various locations around New Zealand, a literature search of international bridge inspection standards for similar organisations and assessment of appropriate bridge

inspection standards for use by KRN. The review covered bridges only and excluded culverts, tunnels, retaining walls and other railway structures.

The review has proposed revised bridge inspection standards in relation to the frequency of inspections, underwater inspections, definitions for detailed inspections, independent audits, use of specialist steel bridge inspectors, and has recommended that alternative methods of investigating defects in timber bridges to drilling be investigated.

KRN is currently in the process of adopting the revised standards described in this paper.

### References

- KiwiRail Network Structures Inspection Manual (W200)
- KiwiRail Network Structures Code Section W004: Structures
- KiwiRail Network National Rail System Standard/4 – Risk Management 2004
- RailCorp Standard ESC 100 – Civil Technical Maintenance Plan
- RailCorp Standard TMC 110 – Structures Services Schedule
- RailCorp Structures Examination Manual – TMC 301
- Australian Rail Track Authority BES 01 – Bridge and Structure Examination: General Requirements.
- Australian Rail Track Authority BEP 03 – Examination of Bridges and Structures Handbook
- New Zealand Transport Agency Bridge Inspection Policy: TNZ S6:2000
- Network Rail Briefing Note PP204 2005.
- Network Rail Railway Group Standard GC/RT 5100 – Safe Management of Structures 2004

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