BRIDGE MANUAL WATERWAY DESIGN: AN UPDATE

I. Smith (Beca Ltd) & N. Lloyd (NZ Transport Agency)

ABSTRACT

Bridge and major culvert (>3.4m² waterway area) design in New Zealand has long used the NZ Transport Agency's Bridge Manual, currently in its 3rd edition. Within it, Section 2.3 deals with waterway design which in turn heavily references the Austroads Waterway Design Guide – A Guide to the Hydraulic Design of Bridges, Culverts and Floodways for understanding hydraulic conditions, and Bridge Scour (Melville & Coleman, 2000) for the assessment of scour and design of countermeasures.

The development of design guidance for minor culverts and stormwater systems in the Transport Agency's Highway Structures Design Guide revealed updated design practices that were also relevant to major culverts and bridges. Furthermore, the Waterway Design Guide has now been withdrawn and replaced by the Austroads Guide to Road Design Part 5B: Drainage – Open Channels, Culverts and Floodways and more recently, the Austroads Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures. In response to this Beca, for the Transport Agency, have reviewed Section 2.3 of the Bridge Manual and many revisions are proposed that will affect the way that bridges and major culverts are designed for waterway actions in the future.

The purpose of this paper therefore is to report on the outcomes of the review including the issues identified and the updates proposed. The updates proposed will:

i. Include references to recent Austroads documents and fish passage and debris assessment guides

ii. Emphasise the influence of design constraints derived from environmental and river management practices

iii. Recognise the relevant local/regional council's role in setting levels of service, determining what is an acceptable effect and determining hydrological and hydraulic methods (including modelling)

iv. Expand the hydrological clauses for the use of HIRDS rainfall data, the use of maximum probable development conditions and clarify runoff coefficient/time of concentration references

v. Clarify climate change requirements, including sea level rise

vi. Include further performance requirements for major culverts

vii. Recognise the importance and influence of downstream boundary conditions on the performance of a design, and

viii. Include guidance for scour assessments where the bed materials are cohesive.

During the review, several residual issues were identified that the Transport Agency is taking under consideration, including:

i. The need for a stand-alone waterways design guide rather than cross-referencing multiple guidelines and documents

ii. Removing the Serviceability Limit State (SLS 1) requirements pertaining to rip rap design

iii. Confirming the Transport Agency's expectation of scour protection under Ultimate Limit State (ULS) conditions

iv. Interpretation of the 2018 Ministry for the Environment climate change guidance for use in design

v. Inclusion of guidance for bridges subjected to coastal and marine conditions

vi. Inclusion of requirements relating to waterway diversions, and

vii. Preparing a technical specification for rock rip rap including materials testing and standard size/mass grading envelopes.

KEYWORDS

Waterway design, bridge design, culvert design

PRESENTER PROFILE

Iain Smith is a chartered professional engineer with 19 years' experience in stormwater engineering projects with a breadth of scale, stage and technical complexity. He has designed the waterway for numerous bridges and culverts and is currently involved with assessing and designing scour remedial works for many bridges across the Waikato region.

1 INTRODUCTION

Design of bridges and major culverts (culverts with a waterway area greater than 3.4m²) in New Zealand relies on the Bridge Manual (NZ Transport Agency, 2013a), currently in its 3rd edition. Within it, Section 2.3 deals with the waterway design requirements needed for these structures and it is on this subject that this paper focuses.

Section 2.3 of the Bridge Manual ("Section 2.3") is not a standalone design guide and it relies on several other documents of which Austroads (1994) and Melville & Coleman (2000) are the most significant. Austroads (1994) is referenced in the very first clause of Section 2.3 but this has now been withdrawn and replaced by a range of other Austroads documents including Austroads (2018).

Over recent times the Transport Agency has prepared other design documents that are also relevant to designing bridge and major culvert waterways and so Section 2.3 now needs to be revised for consistency. Development of design guidance for minor culverts and stormwater systems in NZ Transport Agency (2016a) revealed updated design practices and levels of service that should be reflected in the Bridge Manual. Similarly, NZ Transport Agency (2016b) and NZ Transport Agency (2013b) have significant implications on waterway design, relating to levels of service and fish passage respectively. While NZ

Transport Agency (2016b) deals with minor culverts and drainage networks, consistency in approach for major culvert design is needed.

The purpose of this paper is to report on the review of Section 2.3 and the proposed amendments. These touch on the fundamental practices for environmental, hydrological, hydraulic, scour and resilience design. In one instance, the review also found that current industry practice is not strictly being carried out in accordance with the Bridge Manual.

While the amendments, if adopted by the Transport Agency, will mean a significant rewrite to Section 2.3, which in turn will have a definite influence on the design of these structures, it is acknowledged that good design should already account for the majority of these issues and experienced practitioners will already be well aware of the issues identified.

Also, while the proposed amendments will address many gaps, there remain some significant residual issues that the Transport Agency need to consider further as to how best to address. These may be addressed in future revisions of the Bridge Manual or Highway Structures Design Guide, or through the development of other design guidance documents.

2 DISCUSSION

2.1 PROPOSED AMENDMENTS

The following table summarises the issues found in Section 2.3 and how they are proposed to be addressed. The more significant issues are discussed further in the following sections:

Table 1: Summary of issues found and the proposed amendments.

No.	Issue	Proposed Amendment
1	Waterway Design Guide (Austroads, 1994) has been withdrawn.	Include references to: Hydraulic Design of Waterway Structures (Austroads, 2018), Drainage – General and Hydrology Considerations (Austroads, 2013a) and Drainage – Open Channels, Culverts and Floodways (Austroads, 2013b)
2	Hydraulic Design of Waterway Structures (Austroads, 2018) has been released.	
3	Council requirements need to be better accounted for and often complied with.	Emphasise the need for Council approval as part of obtaining resource consent.
4	Little guidance for structures in the coastal marine area.	Included a requirement to obtain expert coastal engineering input.

No.	Issue	Proposed Amendment
5	No direction where water levels are controlled by large waterbodies downstream. Nor are combined probabilities addressed.	Defer to Council standards and include some high-level guidance.
6	Climate change section is too brief and more recent advice is available. Does not match P46's (NZ Transport Agency, 2016b) sensitivity testing of a "high" climate change scenario for high risk sites.	References have been updated and a high climate change sensitivity scenario added.
7	The hydrological clauses need to be expanded and updated.	Updates include: ▪ A preference for Council models. ▪ Allowing other methods e.g. SCS based etc. ▪ Using a maximum probable development scenario. ▪ Carrying out a high climate change sensitivity test. ▪ Using HIRDS V4 for rainfall. ▪ Referencing E1 VM1/AS1 (MBIE, 2017) and Austroads for rational method catchment size limitations and runoff coefficients. ▪ Using the Ramser Kirpich equation for rural time of concentration calculations.
8	No guidance given on what is an acceptable hydraulic effect.	Added in requirement to consider this in consultation with Councils.
9	No recognition of Council hydraulic models.	Added in a preference to use of Council models.
10	Freeboard definitions need to be refined.	Refined freeboard references. Added in a new freeboard requirement for major culverts larger than $6m^2$. Amended the debris scenario for major culverts.

No.	Issue	Proposed Amendment
11	Major culverts have other criteria needed for design.	Added in requirements for: ▪ Limits on heading up and flood levels during lesser events. ▪ Providing fish passage. ▪ Debris impacts to be assessed using a risk-based approach. ▪ Natural bed sediment transport processes to be maintained.
12	Scour in cohesive material beds is not addressed in detail.	Reference added to Hydraulic Design of Waterway Structures (Austroads, 2018) and HEC18 (Federal Highway Administration, 2012).
13	Scour protection and countermeasures for major culverts not covered.	Reference added to Drainage – Open Channels, Culverts and Floodways (Austroads, 2013b)
14	Use of Reno mattresses and Gabion baskets risks damage from abrasion and debris.	Cautionary comment added.

2.1.1 MAIN UPDATED REFERENCES

Several of the main references within Section 2.3 have changed with the most significant being the withdrawal of Austroads (1994) and the subsequent release of Austroads (2018). Austroads (1994) was used for hydrological and hydraulic assessments but not for scour assessments or countermeasures design for which Melville & Coleman (2000) is referenced. Other design guides relevant to waterway design have been recently released by the Transport Agency and should be referenced in the Bridge Manual; namely, NZ Transport Agency (2013b) and NZ Transport Agency (2016b). The latter document includes criteria for minor culverts that are relevant to major culverts also.

The review also found a wider range of issues and gaps relating to other referenced standards, for example, Melville & Coleman (2000) does not cover scour in cohesive bed materials so other design documents need to be brought in. The proposed main reference documents now proposed are listed in Table 2 below. It is noted that for major culvert debris and blockage assessments, Australian Rainfall and Runoff (AR&R) now references their e-book publication (AR&R, 2016) that covers blockage of all hydraulic structures (i.e. catchpits, culverts, bridges etc). The Transport Agency is considering if this is a more appropriate reference for the Bridge Manual.

Table 2: Main reference documents and their use.

No.	Updated References	Use
1	Drainage – General and Hydrology	General design considerations

	Considerations (Austroads, 2013a)	Rational Method hydrology
2	Drainage – Open Channels, Culverts and Floodways (Austroads, 2013b)	Design of major culverts Design of culvert scour protection
3	Hydraulic Design of Waterway Structures (Austroads, 2018)	General design considerations for bridges Bridge backwater/afflux Bridge scour assessment in cohesive bed materials
4	Bridge Scour (Melville & Coleman, 2000)	General scour design considerations Bridge scour assessment in non-cohesive materials Design of bridge scour countermeasures
5	Blockage of Hydraulic Structures (AR&R, 2015)	Assessment of debris blockage for major culverts
6	Fish Passage Guidance for State Highways (NZ Transport Agency, 2013b)	Fish passage design for major culverts
7	Countermeasures to Protect Bridge Piers from Scour (Transportation Research Board, 2007)	Design of bridge scour countermeasures when using reno mattresses and gabions
8	Evaluating Scour at Bridges (Federal Highway Administration, 2012)	Pier scour in cohesive bed materials

2.1.2 COUNCIL REQUIREMENTS

Council standards and requirements need to be adopted to obtain a resource consent. These can be complimentary to the Bridge Manual or require more stringent design standards.

It is not unusual for these issues to relate to non-hydrological/hydraulic criteria, such as Council's own river management and maintenance practices and environmental constraints. For example, these types of requirements set the arrangement of the Waikanae River bridge, the largest bridge on the MacKays to Peka Peka Expressway project. Here the clearance for Regional Council maintenance plant moving up and down the river determined the height of the bridge rather than freeboard from a flood event. Also the Council's requirement for piers to be placed outside of a central 35m wide "design" river corridor set the span arrangement for the bridge and heavily influenced the type of deck system used (as only limited systems are capable of spanning 35m etc).

Similarly, environmental constraints regularly influence waterway design of a bridge or major culvert. The obvious example here is fish passage through major culverts. However, this can also extend to not having piers in the stream bed, types and arrangement of scour countermeasures, other habitat features and riparian planting. A more peculiar example from MacKays to Peka Peka was the requirement to include a Fern bird passage feature (best described as a steel cage like tunnel) fixed to the bridge abutment above the normal flow water level but below the design flood level.

The majority of these issues are normally addressed when obtaining a resource consent and the proposed amendments to Section 2.3 acknowledge the importance of obtaining Council input early in the design process.

2.1.3 BACKWATER CONTROL

Section 2.3 currently does not recognise the potential influence of larger downstream waterbodies (rivers, lakes or the sea) in controlling waterlevels at the structure. Often the catchments can be very different in terms of size and hydrological response and it would be too conservative to design to the same return period. That is, the combination of return period probabilities ends up being much less than the structure's level of service. For example, designing for a peak flow in the Waikato River to be coincident with the peak flow in a small tributary would have a much lower probability of occurring than just a 1 in 100 year ARI flood in the watercourse in question given the large difference in the times of concentration. In this case a lesser return period for the downstream Waikato River should be used to determine design flows (lower tailwater gives higher velocity etc) but perhaps not necessarily to determine the flood level used to set the bridge height. It may follow that a 1 in 100 year ARI flood in the Waikato River gives the highest flood level in the tributary from backwater effects.

There is limited nationwide guidance on this issue but some councils, such as the Bay of Plenty Regional Council, do recommend event combinations (Bay of Plenty Regional Council, 2012).

The key issue relating to tailwater/runoff combinations is the need to consider the risk and consequences on both the structure itself and nearby sensitive infrastructure/property (i.e. house floor levels, hospitals, schools, pump stations, substations etc). For structures close to the confluence of two waterways, issues such as the relative size of the two catchments, hydrological characteristics of each catchment and the proximity to the structure, need to be considered. Very high tailwater conditions may require additional design features to manage the impact of the structure (such as provision of relief overflows or flood storage).

2.1.4 CLIMATE CHANGE

The Ministry for the Environment's (MfE) guidance on climate change (MfE, 2018) proposes a range of emission scenarios (and therefore rainfalls) without recommending a specific scenario for use in design. Some guides, such as Waikato Regional Council (2018), have set aside this advice (for design) until more specific and practical guidance is provided.

The Bridge Manual currently references MfE's earlier advice (MfE, 2008) and so this needs to be updated in Section 2.3. But to what remains unclear, as while the MfE advice is relatively straightforward for sea level rise (MfE, 2017), for rainfall it is far from clear. The MfE (2018) advice introduces a series of new scenarios and time horizons than the ubiquitous "2.1°C to 2090". Now the time horizons available are broader and the various emission scenarios have been changed.

For a designer it is no longer a case of just picking a temperature increase from a guide. This has been reflected in NIWA's HIRDs version 4 (https://hirds.niwa.co.nz/) where the user must select one of four Relative Concentration Pathways (RCPs), i.e. an emissions scenario that generates climate change, but no guidance is given on which should be used for what. In the absence of this advice some authorities are adopting RCP8.5 for design rainfall on the basis that it is the "closest to the old 2.1°C degrees 2090 from HIRDS V3". This is fundamentally flawed as it discounts the additional data that has gone into HIRDS V4 and the logic is not sound either. In a simplified case, it could be considered appropriate that as the 2.1°C increase came from a "medium to bad" climate scenario it would suggest RCP6 should be used for engineering design purposes given it is similarly a "medium to bad" emission scenario. It is not a case of just getting the closest match to the rainfall from before. It could then follow that RCP8.5 would be used as a sensitivity test for a high scenario case.

The proposed amendments would also seek to address climate change when using flood frequency derived hydrology. Again, there is little industry advice on this. However, the Bay of Plenty Regional Council (2012) recommends a 20% increase in peak flow and in Beca's experience from other projects a figure of 25% is justifiable (Klukowska et al., 2013).

Overall, further guidance is needed on this issue as it has wider implications for the Transport Agency than just the proposed amendments to Section 2.3. This needs to be consistent with a wider, national approach.

2.1.5 HYDROLOGY

The clauses in Section 2.3 relating to hydrology are proposed to be expanded for the following amendments:

i. Include an acknowledgment and preference for use of the relevant Council methods and models (if available). It is much simpler and preferable to be consistent when it comes to obtaining resource consents.

ii. Recognising hydrological methods including Auckland's TP108 (Auckland Regional Council, 1999) and other regional variants such as those used by Kapiti District Council, Waikato Regional Council and Queenstown Lakes District Council. These are all based on the US Department of Agriculture, National Research Conservation Service's Technical Release 55 (US Department of Agriculture, 1986) which is more commonly known as "Soil Conservation Service" (SCS) or "curve number" based method. Similarly, Pearson (1991) has also been included for use in catchments smaller than 30km^2.

iii. Include a requirement to design to a maximum probable development scenario for the greater catchment. This is already required for minor culverts by NZ Transport Agency (2016b).

iv. Include a high climate change sensitivity check for high risk sensitive sites (i.e nearby to hospitals, schools, critical infrastructure etc). Again, to be consistent with NZ Transport Agency (2016b).

v. Using HIRDS V4 to obtain rainfall data as a preference over (but not excluding) specific rain gauge analysis.

vi. Changing the Rational Method catchment limitations for area to $1km^2$ for urban and up to $25km^2$ for rural areas. This is consistent with E1 VM1/AS1 (MBIE, 2017) and Austroads (2013a).

vii. Amend the references for rational method runoff coefficients to refer to E1 VM1/AS1 (MBIE, 2017) and enable adjustments based on storm frequency and catchment steepness.

viii. Use the Ramser Kirpich equation for rural catchment time of concentration calculations.

2.1.6 FLOOD IMPACT

It is not appropriate require a design to have "no impact" on flood levels as a blanket performance statement as this is firstly, often impractical and even impossible, but secondly there are instances where an increase is an acceptable and preferred outcome. For example, on the MacKays to Peka Peka Expressway the Transport Agency and Greater Wellington Regional Council agreed to allow flood levels in a large area of downstream rural land to increase with the benefit of flood levels in an upstream residential area decreasing. This is clearly a more desirable outcome. However, had a "no increase" position been adhered to then an opportunity to relieve existing flood hazard for the benefit of the community would have been missed.

Deciding an acceptable flood impact is entirely subject to Council requirements and site specific/location issues. Similar can be said for drain down situations where a reduction in flood (or more commonly low flow water levels) can have unwanted effects. For example, it would not be desirable to drain down an upstream ecological wetland. And putting in a large culvert that drains down peat land will cause land settlement that could damage infrastructure and property as well as causing ongoing drainage problems and worsening flooding.

2.1.7 HYDRAULIC MODELS

Similar to hydrological models noted above, Councils often have hydraulic or flood models covering the watercourse and the surrounding catchment. It is normally preferable to use these to prove or test a design, if possible. If the models are not able to be shared out then at least boundary condition information should be obtained to inform a design. However, a word of caution is noted: prior to using one, a clear understanding is needed of its original purpose, its schematisation and its limitations.

2.1.8 ADDITIONAL CRITERIA FOR MAJOR CULVERTS

As with minor culverts there is a range of secondary performance requirements that are now common to culvert design practice that Section 2.3 needs to recognise. Currently minor culverts (less than $3.4m^2$ in cross sectional area) are covered by NZ Transport Agency (2016b) which lists more comprehensive criteria so for consistency of approach, Section 2.3 needs to be amended. The proposed amendments are:

i. The Serviceability Level State (SLS 2) flood does not head up more than 2m above the soffit level of the culvert inlet

ii. Flood levels do not head up above the soffit of the culvert in a:

    a. 1 in 10 year ARI storm for Importance Level 3 or 4 structures

    b. 1 in 5 year ARI storm for Importance Level 2 structures

    c. 1 in 2 year ARI storm for Importance Level 1 structures.

iii. Fish passage to be provided, where required, in accordance NZ Transport Agency (2013b) or other relevant Regional Council or Territorial Authority guidance.

iv. Debris risk be assessed in accordance with AR&R (2015) and if necessary countermeasures designed. Design of major culverts shall assume these are maintained and are not blocked by debris when determining afflux. Blockage scenarios, if required, shall be treated as an over-design event to inform risk management decisions.

v. Natural sediment transport processes are to be maintained, and

vi. Resource consent conditions are to be complied with.

2.1.9 SCOUR IN COHESIVE MATERIALS

Section 2.3 refers to Melville & Coleman (2000) for scour calculations and countermeasures. However, Melville & Coleman (2000) does not directly cover scour for structures in cohesive bed materials nor does it cover culverts.

Scour of cohesive materials is not as simple as for cohesionless materials. In cohesive materials the critical shear stress is higher due to cohesion and it may be more of a long-term scour condition is needed, rather than a response to a single event, before the ultimate scour depth is reached. The ultimate scour depths may still be represented by scour calculations assuming cohesionless materials. Either way, scour in cohesive beds will need input from a geotechnical specialist.

The recently released Austroads (2018) includes sections on scour in cohesive beds although it omits pier scour in such materials. To address these gaps it is proposed to reference both this document and Federal Highway Administration (2012).

Similarly, Melville & Coleman (2000) does not (and nor was it its intent) cover scour at culverts. For this it is proposed to reference Austroads (2013b).

2.2 RESIDUAL ISSUES

While reviewing Section 2.3 and drafting the proposed updates, several issues were found that need further consideration by the Transport Agency and these are discussed in the following sections.

2.2.1 COMPLEXITY

Given the increased number of separate publications referenced (now 7 main documents where previously there were 4) and often with only partial applicability and/or with inconsistencies across them, interpretation and design using Section 2.3 will be made even more complex to work through.

Alternatively, a new standalone guide could bring together and consolidate all of the relevant requirements. While there seems to be some merit in this, the Transport Agency is not considering this at this stage given the scale of the undertaking involved.

2.2.2 SLS AND ULS EVENTS

The current Bridge Manual can be confusing with respect to the various hydraulic performance statements. It uses subtly different language in different locations making consistent interpretation challenging. There are two separate issues involved, the first relates to protection works performance under SLS 1 events and the other to how Ultimate Limit State (ULS) events are considered in practice.

In the first, the difference between the terms "undamaged" in an SLS 1 event and not "significantly damaged" in an SLS 2 flood becomes too nuanced for design methods to cope with. SLS 1 events are defined as 1 in 25 year Average Recurrence Interval (ARI) events and SLS 2 floods 1 in 100 year.

Consider an example of a rock rip rap revetment protecting a bridge abutment, there is no reliable way of telling how much rock will be lost from the armour layer in conditions that exceed an SLS 1 event and then there is no reliable way to tell when this becomes a critical failure of the armour leading to a failure of the structure itself. This approach is too complicated, subjective and risky given the requirements of SLS 2 performance. Current design practice is to just design to the more severe SLS 2 hydraulic conditions ignoring the SLS 1 conditions, making them redundant.

At least one Regional Council (Bay of Plenty Regional Council) designs scour protection works to a lesser return period than that used for the sizing of the culvert/bridge (Bay of Plenty Regional Council, 2012). However, this type of approach was not recommended for the Bridge Manual without further review of the consequences. For a start, the smaller rock sizes resulting would likely result in needing more frequent inspections and maintenance.

It was therefore recommended that the Transport Agency consider removing the flood performance requirements under an SLS event.

In the second issue, ULS floods that vary from a 1 in 500 year ARI up to 1 in 2,500 year ARI storm (depending on the Importance Level of the structure) are not used in practice to design major culverts as the industry does not have standard methods or responses to such severe events. This is not such an issue for bridges that are elevated, by nature of topography, well above the flood level. For example, it will be difficult to accurately predict the 1 in 2,500 year ARI storm conditions (tailwater conditions, catchment flow rates or flood extents) given such an extreme event and the widespread inundation that would result. Councils do not typically have flood information such an extreme event as they more commonly do for a 1 in 100 year ARI flood.

Strictly following the requirements to design for ULS floods for culverts and low-lying bridges will also lead to more heavy armouring of road embankments to protect against the effects of overtopping ULS flows (with consequential increase in construction cost and visual/environmental based objections from stakeholders during resource consent applications). Also in the case of a long, low lying reach of highway subject to widespread overtopping in a ULS event, the question is raised about how far along the road embankment from the structure should such protection extend? And how are the ends detailed? This is on the assumption that it is acceptable for the road embankment to wash out a relatively short distance away from the structure so long as the structure itself remains in place. A similar issue is encountered for seismic slope stability, and in this case it is common to allow the embankment to fail provided the bridge stays standing. This is on the premise that rebuilding an earthworks embankment post-disaster is easier than a rebuilding a bridge. The outcome of the above is still unclear.

Therefore, a recommendation was made to have the ULS performance requirements addressed in the Structure Options report or alternatively in the Structure Design Statement where such matters can be considered on a project specific basis. These documents are required to be prepared by NZ Transport Agency (2016a).

Clearly, the Transport Agency need to consider if ULS performance requirements are really required for major culverts/low lying bridges and then provide guidance on how this requirement should be interpreted and practically applied.

2.2.3 COASTAL STRUCTURES

Bridges and major culverts that are exposed to coastal and marine conditions (i.e. scour from wave action, marine bed movements and associated countermeasure design) are not addressed in detail in Section 2.3 or in any of the referenced documents. For example, the design of a new Auckland Harbour bridge will need significant coastal engineering input which is not implicitly covered in current Bridge Manual.

There is limited, high level guidance on this issue in NZ Transport Agency (2016a). It is therefore proposed that the Transport Agency seek specialist coastal engineering input and review the need for more detailed clauses/separate guidance to address this. In the interim, the requirement for specialist coastal engineering advice to be obtained and documented in the Structure Options Report and the Structure Design Statement is proposed.

2.2.4 FREEBOARD FOR MAJOR CULVERTS LARGER THAN 6m^2

Austroads (2013b) has a freeboard requirement of 300mm for culverts over 6m^2 in cross-sectional area. This is to make some allowance for debris passage. Although Austroads does not provide detailed reasoning, presumably it is because waterways that require larger structures are also more capable and likely to carry large debris and the consequences of blockage are typically more severe. This also addresses an issue where freeboard can be circumvented for small bridges by calling a structure a “culvert” or contriving to minimise freeboard requirements by pouring a base slab to what would otherwise be a small bridge.

This freeboard demarcation requirement is proposed to be introduced into Section 2.3. It is acknowledged, this will likely result in higher road embankments over the structure relative to what is currently required (in the order of 500mm to 700mm) with the associated increase in construction cost. Although, this will greatly depend on the geometry/topography of individual sites and the specifics of each structural design. For example, there will be no change for culverts that are already beneath deep embankments or in deep gullies/waterways whereas roads will need to be higher for culverts in low lying, flat land where roads often run close to existing ground levels. It is in these latter areas however, where the consequence of blockage or lower freeboard is often more severe.

2.2.5 WATERWAY DIVERSIONS

Section 2.3 does not address waterway diversion requirements (river/stream geomorphology, bank stability/scour protection, habitat features, riparian planting etc) but these issues commonly need to be addressed as part of a bridge/major culvert design. This could involve identifying an appropriate existing guide to reference, drafting a substantial additional clause to Section 2.3 or preparing separate guidance. Such a guide would also be relevant to waterway diversions not involving any structures as well as those involved with minor culverts, both of which are common on Transport Agency projects, there is merit in such an approach.

2.2.6 ROCK RIP RAP SPECIFICATION

When designing scour countermeasures using rock rip rap, there is no guidance or specifications for rock quality (i.e. density, strength, abrasion resistance etc) in the Bridge Manual or in any other Transport Agency documents. The other various referenced documents, such as Austroads, are limited and in Beca's experience not often used in New Zealand. Similar can be said of the size/mass gradings in Austroads. While it may not be appropriate for these items to be included in the Bridge Manual, a standard rock technical specification is needed.

3 NEXT STEPS

At the time of writing (February 2019) the proposed amendments to the Bridge Manual, and the residual issues discussed, are undergoing internal review within the Transport Agency and external peer review through WSP-Opus. Confirmed clauses will be included in the next amendment to the Bridge Manual (amendment 4), likely to be in late 2019 or early 2020. Significant or critical clauses could be introduced earlier through the use of a Technical Advice Note if required.

As with all clauses in the Bridge Manual, once implemented, the new Section 2.3 will be subject to ongoing monitoring and review of its use.

4 CONCLUSIONS

Section 2.3 of the Bridge Manual is used to design bridge and major culvert waterways and needs to be revised. Chiefly this is to update it for the withdrawal of Austroads' Waterways Design Guide and the release of Hydraulic Design of Water Structures. In the course of making these updates several other gaps and inconsistencies were identified and it is proposed to address these issues in the same revision. Mainly these changes are to:

i. Include references to recent changes in Austroads documents and new fish passage and debris assessment guides

ii. Emphasise the influence of design constraints derived from environmental and river management practices

iii. Recognise the relevant Council's role in setting levels of service, determining what is an acceptable effect and determining hydrological and hydraulic methods (including modelling)

iv. Expand the hydrological clauses for the use of HIRDS rainfall data, the use of maximum probable development conditions and clarify runoff coefficient/time of concentration references

v. Clarify climate change requirements, including sea level rise

vi. Include further performance requirements for major culverts

vii. Recognise the importance and influence of downstream boundary conditions on the performance of a design, and

viii. Include guidance for scour assessments where the bed materials are cohesive.

There remain several residual issues for the Transport Agency to consider further and address in the future, such as:

i. Removing the Serviceability Limit State (SLS 1) requirements pertaining to rip rap design

ii. Confirming the Transport Agency's expectation of scour protection under Ultimate Limit State (ULS) conditions

iii. Interpretation of the 2018 Ministry for the Environment climate change guidance for use in design

iv. Inclusion of guidance for bridges subjected to coastal and marine conditions

v. Inclusion of requirements relating to waterway diversions, and

vi. Preparing a technical specification for rock rip rap including materials testing and standard size/mass grading envelopes.

Upon completion of internal and external peer reviews confirmed clauses from the proposed amendments and residual issues will be incorporated into the in the next amendment to the Bridge Manual (amendment 4).

ACKNOWLEDGEMENTS

Nigel Lloyd (NZ Transport Agency) who co-authored this paper and is responsible for revisions to the Bridge Manual, Graham Levy, Mike Law, Angela Pratt and Roger Seyb (all from Beca) who provided technical input into the Bridge Manual review or reviewed this paper.

REFERENCES

Auckland Regional Council (1999) 'Guidelines for Stormwater Runoff Modelling in the Auckland Region' Technical Publication 108 (TP108).

Australian Rainfall and Runoff (2015) 'Blockage Guidelines for Culverts and Small Bridges', Project 11: Blockage of Hydraulic Structures, Stage 3.

Australian Rainfall and Runoff (2016) 'A Guide to Flood Estimation', Book 6: Flood Hydraulics, Chapter 6. Blockage of Hydraulic Structures, http://arr.ga.gov.au/arr-guideline.

Austroads (1994) 'Waterway Design Guide – A Guide to the Hydraulic Design of Bridges, Culverts and Floodways'.

Austroads (2013a) 'Guide to Road Design Part 5: Drainage – General and Hydrology Considerations'.

Austroads (2013b) 'Guide to Road Design part 5B: Drainage – Open Channels, Culverts and Floodways'.

Austroads (2018) 'Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures'.

Bay of Plenty Regional Council (2012) 'Hydrological and Hydraulic Guidelines'.

Federal Highway Administration, (2012) 'Evaluating Scour at Bridges' Hydraulic Engineering Circular No. 18 (HEC 18), fifth edition, publication HIF-12-003.

Klukowska, A., Law, M., Levy, G., and Smith, I. (2013) '2115 Climate Change', MacKays to Peka Peka Expressway Alliance (M2PP Alliance).

McKerchar, A.I., and Pearson, C.P. (1989) 'Flood frequency in New Zealand', Publication No. 20, Hydrology Centre, Department of Scientific and Industrial Research.

Melville, B.W. and Coleman, S.E. (2000) 'Bridge Scour', Water Resources Publications.

Ministry of Business, Innovation & Employment (MBIE) (2017) 'Acceptable Solutions and Verification Methods for New Zealand Building Code Clause E1 Surface Water'.

Ministry for the Environment (MfE) (2008) 'Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand', 2nd edition.

Ministry for the Environment (2017) 'Coastal Hazards and Climate Change: Guidance for Local Government'.

Ministry for the Environment (2018) 'Climate Change Projections for New Zealand', 2nd edition.

NZ Transport Agency (2013a) 'Bridge Manual', 3rd Edition, Amendment 3.

NZ Transport Agency (2013b) 'Fish Passage Guidance for State Highways'.

NZ Transport Agency (2016a) 'Highway Structures Design Guide'.

NZ Transport Agency (2016b) 'P46 Stormwater Specification'.

Pearson, C.P. (1991) 'Regional Flood Frequency Analysis for Small New Zealand Basins: 2. Flood Frequency Groups', Journal of Hydrology, (New Zealand), Vol. 30, No. 2, pp. 77-92.

Transportation Research Board (2007) 'Countermeasures to Protect Bridge Piers from Scour', National Cooperative Highway Research Program Report 593.

United States Department of Agriculture (1986) 'Urban Hydrology for Small Watersheds', Technical Release 55, Natural Resources Conservation Service, Conservation Engineering Division.

Waikato Regional Council (WRC) (2018) 'Waikato Stormwater Runoff Modelling Guideline', report TR 2018/02.