
2.0 Design - General requirements

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2.1 Design philosophy

2.1.1 General

Highway structures shall be designed to satisfy the requirements of both the ultimate and the serviceability limit states when acted on by any of the combinations of loading defined in this document.

During the design process all relevant factors affecting the design, such as those listed in broad terms in section 2 of a structure options report, shall be taken into account to ensure compliance with all relevant legislation and regulations. Detailing shall be such that it promotes ease of construction and ease of maintenance. Specifically, the Waka Kotahi Transport Agency *Health and safety in design minimum standard*⁽¹⁾ shall be adopted for health and safety in design processes to be utilised on state highway projects. The processes may result in additional or modified design requirements for highway structures.

Construction methods shall be considered, in order to avoid undue expense due to unnecessarily complicated procedures. However, methods shall not be specified unless they contain features essential to the design assumptions.

2.1.2 Definition of terms

Serviceability limit state (SLS): The state beyond which a structure becomes unfit for its intended use through deformation, vibratory response, degradation or other operational inadequacy.

Ultimate limit state (ULS): The state beyond which the strength or ductility capacity of the structure is exceeded, or when it cannot maintain equilibrium and becomes unstable.

Design working life: The design working life of a structure is that life beyond which the structure will be expected to have become functionally obsolete or to have become uneconomic to maintain in a condition adequate for it to perform its functional requirements.

Major renovation: Maintenance work costing more than 20% of the replacement value of the structure, necessary to maintain the strength, ductility capacity, or serviceability of a structure to enable it to fulfil its functional requirements.

Note also the definitions of **damage control limit state (DCLS)** and **collapse avoidance limit state (CALC)** in 5.1.2 for the design of structures for earthquake resistance.

2.1.3 Basis of design

Design to this document is based on limit state principles adopting where possible a statistical approach to the derivation of design loads and material strengths.

Design actions other than earthquake, wind, snow and floodwater are based on a statistical distribution appropriate to a 100-year design working life. Where statistical distributions are not available, design actions are based on judgment and experience. For dead and live load, the target probability of exceedance within 100 years that has been adopted is 5%.

For wind, snow, floodwater and earthquake actions, bridges, earth retaining structures and earth slopes shall be categorised into an importance level for which the assigned annual probabilities of exceedance for these actions shall be as given in tables 2.1, 2.2 and 2.3 respectively. For the categorisation into importance level and assignment of annual probabilities of exceedance, major culverts, stock underpasses and pedestrian or cycle subway shall be treated as bridges.

2.1.3 continued

Both the structure and non-structural elements shall remain undamaged following wind, snow and flood events up to an SLS 1 event, and the bridge, major culvert, stock underpass, pedestrian or cycle subway, or earth retaining structure shall remain operationally functional for all highway traffic during and following flood events up to an SLS 2 event. SLS 1 and SLS 2 events are serviceability limit state events defined by the annual probabilities of exceedance given in tables 2.1 and 2.2. Performance requirements during and following an earthquake are presented in section 5.

All bridges, other than footbridges, that span other roads or railways shall be designed for an importance level being the greater of their own importance level and that of the road or railway crossed.

Footbridges shall be designed for the greater of their own importance level and an importance level one category less than the importance of the road or railway crossed. For the requirements of this clause the importance level of a railway shall be taken as importance level 3.

Non-integral bridge abutment walls and independent walls associated with bridges (as defined in 6.6.1(a)(i)) shall be designed for the same annual probability of exceedance events as adopted for the bridge and earth slopes on which a bridge depends for its support and stability. This requirement applies similarly to other forms of structure such as major culverts, stock underpasses and pedestrian/cycle subways.

Where a slope failure may impact on property of significant value or importance the slope shall be assigned an annual probability of exceedance for the ultimate limit state event corresponding to that for retaining walls protecting property of similar value.

2.1.4 Design standards

This document defines design loadings, load combinations and load factors, together with criteria for earthquake resistant design, and other miscellaneous items. It does not define detailed design criteria for the various materials, but refers to standards such as those produced by Standards New Zealand, Standards Australia and the British Standards Institution. The standards referred to shall be the editions referenced, including all current amendments. The specified portions of these standards are to be read as part of this document but any references in such standards to specific loads or load combinations shall be disregarded.

2.1.5 Design working life requirements

For the purpose of assessing probabilistic effects of live load fatigue, and for consideration of long-term effects such as corrosion, creep and shrinkage, the design working life of a bridge or an earth retaining structure is assumed to be 100 years in normal circumstances.

This may be varied by the controlling authority if circumstances require it, for example for temporary structures, for strengthening of existing structures or for increasing the design life of landmark or high value structures. It should be noted that the 100-year design working life exceeds the minimum requirement of the *Building code*⁽²⁾.

The design working life of a major culvert shall be assumed to be as above for a bridge except when designed on the basis of specific provision for future rehabilitation, as set out in 4.10.1. The reduced design working life of the initial construction may be adopted as the basis for assessing the probabilistic effects of live load fatigue, and for consideration of long-term effects such as corrosion, creep and shrinkage.

Guidance for determining the design working life of other highway structures is given in the *Highway structures design guide*⁽³⁾.

Table 2.1: Importance level and annual probabilities of exceedance for wind, snow, floodwater and earthquake actions for bridges

Bridge categorisation	Importance level (as per AS/NZS 1170.0 ⁽⁴⁾)	Bridge permanence*	Annual probability of exceedance for the ultimate limit state		Annual probability of exceedance for the serviceability limit state	
			ULS for wind, snow and floodwater actions	DCLS† for earthquake actions	SLS 1 for wind, snow and floodwater actions	SLS 2 for floodwater actions
Bridges of high importance to post-disaster recovery (eg bridges in major urban areas providing direct access to hospitals and emergency services or to a major port or airport from within a 10km radius). Bridges with a construction cost (including associated ground improvements) exceeding \$18.0 million (as at December 2021)‡.	4	Permanent	1/2500	1/2500	1/25	1/100
		Temporary	1/1000	1/1000	1/25	1/100
Bridges on highways classified as National (High Volume) in the One Network Road Classification§ (ONRC).	3+	Permanent	1/1500	1/1500	1/25	1/100
		Temporary	1/700	1/700	1/25	-
Bridges on highways classified as National, Regional, Arterial, Primary Collector or Secondary Collector in the ONRC.	3	Permanent	1/1000	1/1000	1/25	1/100
		Temporary	1/500	1/500	1/25	-
Bridges on highways classified as Access or Access (Low Volume) in the ONRC. Bridges, not falling into other levels. Footbridges.	2	Permanent	1/500	1/500	1/25	1/50
		Temporary	1/250	1/250	1/25	-
Bridges where failure would not be likely to endanger human life and the loss of which would not be detrimental to post-disaster recovery activities for an extended period.	1	Permanent	1/250	1/250	1/25	1/25
		Temporary	1/50	1/50	-	-

Notes:

* Permanent bridge: design working life = 100 years assumed (see 2.1.3, 2.1.5). Temporary bridge: design working life ≤ 5 years.

† DCLS - damage control limit state. See 5.1.2 (a) for definition.

‡ Values shall be adjusted to current value. For the relevant cost adjustment factor refer to the Waka Kotahi NZ Transport Agency *Procurement manual*, Procurement manual tools, Infrastructure and public transport contract price adjustment indexes, Latest index values for infrastructure cost indexes - original 1991 series, Waka Kotahi NZ Transport Agency Bridge index⁽⁵⁾.

§ The One Network Road Classification (ONRC) is a classification system, which divides New Zealand's roads into six categories based on how busy they are, whether they connect to important destinations, or are the only route available (see *One network road classification*⁽⁶⁾). See figure 2.1(a), 2.1(b) and 2.1(c) herein for the classification of state highways or *Tables of state highways in each ONRC classification category*⁽⁷⁾.

Table 2.2: Importance level and annual probabilities of exceedance for storm*, floodwater and earthquake actions for earth retaining structures

Retaining structure categorisation	Importance level (as per AS/NZS 1170.0 ⁽⁴⁾)	Height H [†] (m)	Area A [†] (m ²)	Annual probability of exceedance for the ultimate limit state		Annual probability of exceedance for the serviceability limit state	
				ULS for storm and floodwater actions	DCLS for earthquake actions	SLS 1 for storm and floodwater actions	SLS 2 for storm and floodwater actions
Retaining structures associated with bridges	As for the associated bridge						
Retaining structures providing route security Retaining structures critical to post-disaster recovery (eg retaining walls, the failure of which could completely close important roads in major urban areas providing direct access to hospitals and/or emergency services, or to a major port or airport from within a 10km radius).	4			1/2500	1/2500	1/25	1/100
Retaining structures on highways classified as National (High Volume) in the One Network Road Classification (ONRC).	3+	≥ 5 and	≥ 100	1/1500	1/1500	1/25	1/100
	3	< 5 or	< 100	1/1000	1/1000	1/25	1/100
Retaining structures on highways classified as National, Regional, Arterial, Primary Collector or Secondary Collector in the ONRC.	3	≥ 5 and	≥ 100	1/1000	1/1000	1/25	1/100
	2	< 5 or	< 100	1/500	1/500	1/25	1/50
Retaining structures on highways classified as Access or Access (Low Volume) in the ONRC.	2	≥ 5 and	≥ 50	1/500	1/500	1/25	1/50
	1	< 5 or	< 50	1/250	1/250	1/25	1/25
Retaining structures the failure of which would not be likely to endanger human life or would not affect the use of the road; or the loss of which would not be detrimental to post-disaster recovery activities for an extended period.	1			1/250	1/250	1/25	1/25
Retaining structures providing protection to adjacent property Retaining structures protecting against loss or significant loss of functionality to adjacent property categorised as:							
having special post disaster functions (ie importance level 4 or above as listed in AS/NZS 1170.0 ⁽⁴⁾ table 3.2).	4			1/2500	1/2500	1/25	1/100
importance level 3 by AS/NZS 1170.0 ⁽⁴⁾ table 3.2.	3			1/1000	1/1000	1/25	1/100
importance level 2 by AS/NZS 1170.0 ⁽⁴⁾ table 3.2.	2			1/500	1/500	1/25	1/50
Retaining structures protecting adjacent property, the consequential reinstatement cost of which would exceed \$1.6 million (as at December 2021) [‡] , not otherwise an importance level 3 or 4 structure.	2			1/500	1/500	1/25	1/50
Retaining structures the failure of which would not significantly endanger adjacent property.	1			1/250	1/250	1/25	1/25
Retaining structures not falling into other levels	2			1/500	1/500	1/25	1/50

Notes:

* Storm includes the effects of rainwater (ie ponding and groundwater pressure).

† The maximum height H shall be measured to where a line from the ground level at the front of the wall, inclined at 45°, intersects the ground surface behind the wall. The face area A shall be calculated using the height H defined thus.

‡ Values shall be adjusted to current value. For the relevant cost adjustment factor refer to the Waka Kotahi NZ Transport Agency *Procurement manual*, Procurement manual tools, Infrastructure and public transport contract price adjustment indexes, Latest index values for infrastructure cost indexes - original 1991 series, Waka Kotahi NZ Transport Agency Construction index⁽⁵⁾.

Table 2.3: Importance level and annual probabilities of exceedance for storm*, floodwater and earthquake actions for earth slopes

Earth slope categorisation	Importance level (as per AS/NZS 1170.0 ⁽⁴⁾)	Slope type	Annual probability of exceedance for the ultimate limit state	
			ULS for storm and floodwater actions	DCLS for earthquake actions
Earth slopes affecting bridges[†]	As for the bridge affected			
Earth slopes providing route security				
Earth slopes on routes critical to post-disaster recovery (eg routes in major urban areas providing direct access to hospitals and/or emergency services, or to a major port or airport from within a 10km radius).	4	Fill > 6m high	1/2500	1/2500
		Fill ≤ 6m high and all cuts	1/1000	1/1000
Earth slopes on highways classified as National (High Volume) in the One Network Road Classification (ONRC).	3+	Fill > 6m high	1/1500	1/1500
		Fill ≤ 6m high and all cuts	1/700	1/700
Earth slopes on highways classified as National, Regional, Arterial, Primary Collector or Secondary Collector in the ONRC.	3	Fill > 6m high	1/1000	1/1000
		Fill ≤ 6m high and all cuts	1/500	1/500
Earth slopes on highways classified as Access or Access (Low Volume) in the ONRC.	2	Fill > 6m high	1/500	1/500
		Fill ≤ 6m high and all cuts	1/100	1/100
Earth slopes the failure of which would not be likely to endanger human life or would not affect the use of the road; or the loss of which would not be detrimental to post-disaster recovery activities for an extended period.	1	Fill > 6m high	1/100	1/100
		Fill ≤ 6m high and all cuts	1/50	1/50
Earth slopes providing protection to adjacent property				
Earth slopes protecting against loss or significant loss of functionality to adjacent property categorised as: having special post disaster functions (ie importance level 4 or above as listed in AS/NZS 1170.0 ⁽⁴⁾ table 3.2).	4	All	1/2500	1/2500
	3	All	1/1000	1/1000
	2	All	1/500	1/500
Earth slopes protecting adjacent property, the consequential reinstatement cost of which would exceed \$1.6 million (as at December 2021) [‡] , not otherwise an importance level 3 or 4 slope.	2	All	1/500	1/500
Earth slopes the failure of which would not significantly endanger adjacent property.	1	Fill > 6m high	1/100	1/100
		Fill ≤ 6m high and all cuts	1/50	1/50
Earth slopes not falling into other levels	2	Fill > 6m high	1/500	1/500
		Fill ≤ 6m high and all cuts	1/100	1/100

Notes:

Where achieving the specified level of performance results in excessively high cost, an approach based on an assessment of the risks versus the cost may be promoted to the road controlling authority for their acceptance.

* Storm includes the effects of rainwater (ie ponding and groundwater pressure).

† Slopes affecting bridges are those that have the potential to collapse onto a bridge or to result in loss of support of a bridge if the slope fails.

‡ Values shall be adjusted to current value. For the relevant cost adjustment factor refer to the Waka Kotahi NZ Transport Agency *Procurement manual*, Procurement manual tools, Infrastructure and public transport contract price adjustment indexes, Latest index values for infrastructure cost indexes – original 1991 series, Waka Kotahi NZ Transport Agency Construction index⁽⁵⁾.

Figure 2.1(a): North Island One Network Road Classification for state highways

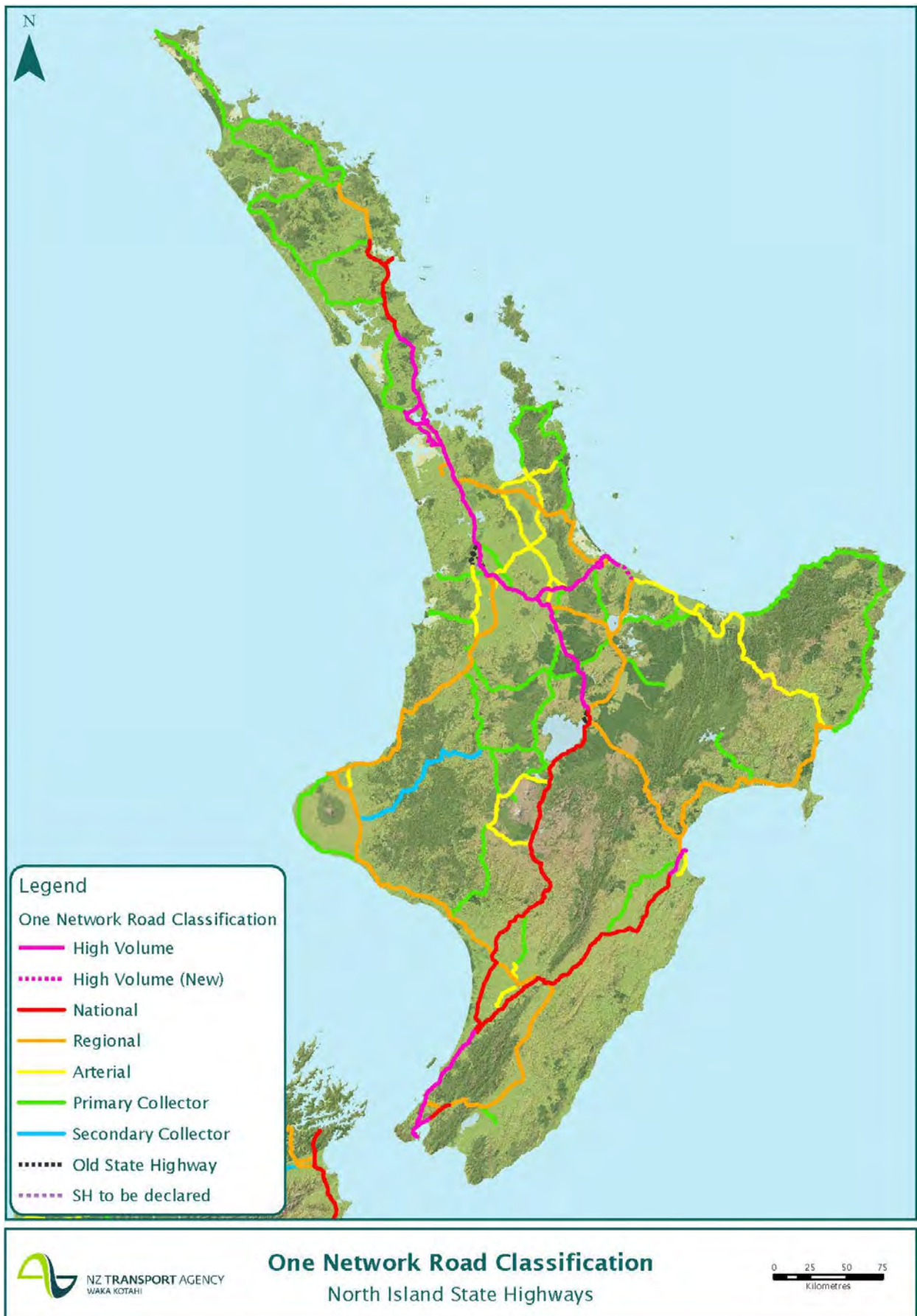
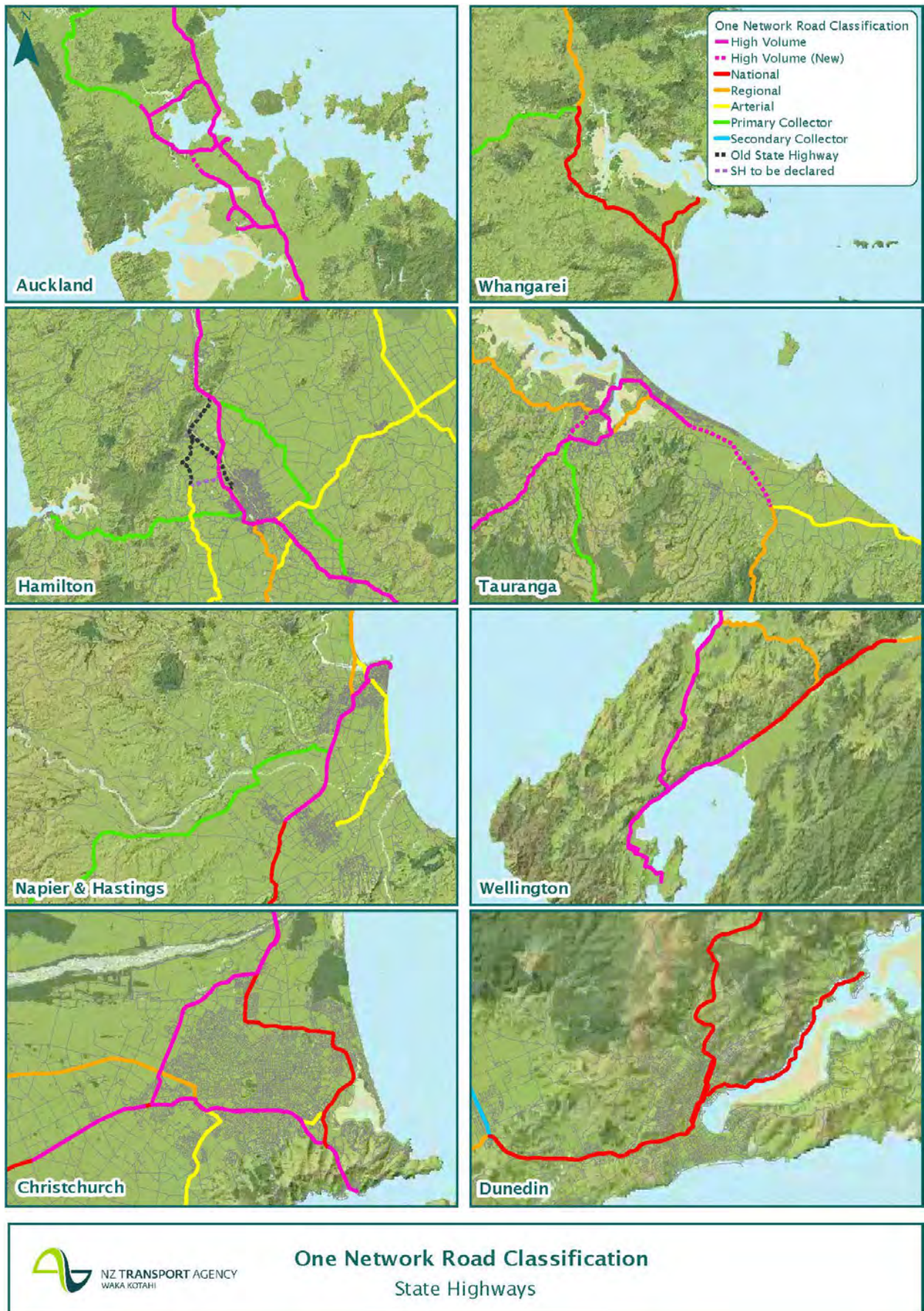


Figure 2.1(b): South Island One Network Road Classification for state highways



Figure 2.1(c): Selected urban areas One Network Road Classification for state highways



2.1.6 Durability requirements

a. General

The structure and its component members shall be designed to provide adequate durability in accordance with the requirements of the material design standards, except where specific requirements are included in this document, which shall take precedence.

Structures shall be sufficiently durable to ensure that, without reconstruction or major renovation, they continue to fulfil their intended function throughout their design life.

b. Replaceable elements

Replaceable elements of a structure (eg proprietary bridge deck movement joints, bearings, seismic restraints) shall have a minimum life of 40 years to major maintenance or replacement, and shall be replaceable without the need for major modification to adjacent elements. Corrosion protection systems shall satisfy the requirements of 4.3.6.

c. Cast-in items

Cast-in items shall have a design life of 100 years. For cast-in portions that are sealed from exposure to the atmosphere by concrete cover complying with NZS 3101.1&2 *Concrete structures standard*⁽⁸⁾ table 3.7 or by the attachment plates of the fixed hardware (with grout or mortar present between attachment plates and concrete), hot dip galvanized cast-in items and fixings may be used. For cast-on portions and cast-in items that are not sealed from exposure to the atmosphere grade 316 stainless steel or other suitable non-ferrous material that does not introduce bimetallic corrosion shall be used unless otherwise explicitly stated in this manual or referenced Waka Kotahi NZ Transport Agency specifications.

d. Water staining

Where appropriate, the edges of concrete elements shall include drip details to avoid water staining and to keep the locations of bearings, seismic restraints and post-tensioning hardware dry.

2.1.7 Structural robustness

All parts of the structure shall be interconnected, in both horizontal and vertical planes, to provide the structure with the robustness to adequately withstand unanticipated extreme loading events such as extreme flood, earthquake or vehicle collision.

In detailing the various elements of a structure, the effect of that detailing on the robustness of the structure as a whole to unanticipated extreme loading events shall be considered and robustness of the structure shall be ensured.

Hold-down devices shall be provided at all supports of bridges where the net vertical reaction under damage control limit state conditions for earthquake, or ultimate limit state design conditions for flood, wind or collision by a vehicle, train or ship is less than 50% of the dead load reaction. In the case of propped cantilever spans and in-span structural hinges, hold-down devices shall be provided regardless.

The hold-down device shall have sufficient strength to prevent uplift of the span from its support under the above damage control limit state or ultimate limit state design conditions as appropriate but not less than sufficient strength to resist a force equal to 20% of the dead load reaction. In the case of a cantilever span, free or propped, the minimum design strength of the hold-down device at the end of the cantilever shall be calculated on the basis of 20% of the dead load reaction which would exist if the cantilever span was simply supported. The restraint against lift and buoyancy forces imposed by flood flow shall also be not less than that specified by 3.4.8. An elastomeric bearing shall not form part of a hold-down device.

2.1.7 continued

A positive lateral restraint system shall also be provided between the superstructure and the substructure at piers and abutments, except at abutments that satisfy the overlap requirements of 5.7.2(d). The restraint system for each continuous section of the superstructure shall be capable of resisting an ultimate design horizontal force normal to the bridge centreline of not less than 500kN or 5% of the superstructure load at that support, whichever is greater. The requirements of 5.7.2 shall also be complied with. For continuous superstructures, lateral restraints may be omitted at some supports provided that each continuous section of the superstructure between expansion joints is at least equivalently restrained. Supports providing this lateral restraint shall also be designed to resist this design force.

Restraints shall have sufficient lateral clearance to allow thermal movements unless the structure is specifically designed for the induced forces from thermal expansion and contraction arising from lack of lateral clearance.

2.1.8 Tolerances on bridge alignment, profile and level over the design life

The design and construction of bridges shall be such that any long-term time related changes to the vertical profile of the bridge deck from the specified design levels (eg creep and shrinkage for a concrete structure, settlement of foundations and long term subsidence) are such that they do not exceed the following during the design life of the bridge:

- $\pm 25\text{mm}$ from the specified design levels for the substructure, and
- span/1000 from the specified design vertical alignment for the superstructure.

2.1.9 Access and provisions for inspection and maintenance

All parts of structures except buried surfaces shall be accessible for the purposes of inspection and maintenance. Details of proposed arrangements for inspection and maintenance, including provisions for access shall be given in the structure options report and the structure design statement.

Access shall generally be achievable using readily available proprietary mobile inspection equipment (including elevated work platforms, under bridge inspection units and roped access), with no need for fixed scaffolding.

Where this is not reasonably possible for a bridge (eg where the superstructure extends above deck level on through-truss and arch spans or where the superstructure is greater than 20m wide) a means of providing access to all areas of the superstructure soffit and pier tops shall be installed on the bridge (eg permanent walkways and working platforms), unless agreed otherwise by the road controlling authority.

A means of enabling the construction of a temporary working platform for the maintenance of structures shall be installed on structures where this cannot be readily achieved from the ground or no such permanent provision is present. This may require the provision of permanent fixing points.

Permanent access ladders and fittings shall be limited to locations that are not visible to the public and shall be provided as required to access bearings, expansion joints and other maintainable parts of the structure. In all cases, access provision shall consider any requirements for safety from falling protection as discussed in 6.6.1(c)(ii) for the top of retaining structures within the highway reserve but remote from the road, where there may be the occasional presence of people.

Access points shall only be located in areas where access does not require traffic management of any highway or railway, and particularly they shall not be located directly above any carriageway or railway line.

2.1.9 continued

For abutments the following elements shall be accessible for inspection and reachable for maintenance, generally from in front of the abutment:

- the front face of integral or semi-integral abutments or the front face of superstructure end diaphragms where the abutment is non-integral
- bearings to enable extraction and replacement, and also to position and withdraw jacks
- any drainage channel at the base of the abutment backwall, to enable accumulated debris to be cleared
- linkage bolts, and any rubber buffers installed on them.

At abutments with spill-through slopes or mechanically stabilised earth walls or slopes in front of the abutment sill beam, this may be achieved by providing a level walkway access and working area at least 600mm wide in front of the abutment sill beam over the full length of the abutment. Where the abutment sill is supported on a vertical or near vertical retaining wall or vertical or near vertical mechanically stabilised earth wall and access to the abutment sill area and bearings can readily be gained using proprietary mobile inspection equipment, provision of the 600mm wide working area in front of the sill may be omitted.

Unbonded prestressing tendons or bars shall be accessible for inspection and shall be replaceable without the need for modification to adjacent structural elements.

At all supports where the bridge superstructure is supported on bearings, other than solid or voided deck slab bridges on strip bearings, provision shall be made for the superstructure to be able to be jacked for bearing replacement without the positioning of jacks unduly impeding access to the bearings for their removal and replacement. Bearings shall be replaceable under full HN live load, ie load combination 1A as defined in table 3.3.

Multi-beam bridge superstructures shall be provided with diaphragms or an equivalent permanent structure at the ends of each span designed to facilitate jacking of the bridge superstructure using the minimum number of jacks practicable. (As a guide, for simply supported spans of up to 35m this should be no more than one jack per 3.0m width of bridge deck, per support.) Design for jacking of the bridge shall accommodate continued use of the bridge by traffic while the jacking of spans is undertaken.

Hollow box girders, hollow piers, abutments and similar hollow components shall be accessible on the inside for inspection and maintenance. Suitable access penetrations of minimum aperture specified in section 19 of *AASHTO Guide specifications for design and construction of segmental concrete bridges*⁽⁹⁾, shall be provided through diaphragms, slabs or end walls for such cases. Apertures through box girder diaphragms shall be sized, positioned and detailed to allow practical access for personnel and all required maintenance plant and equipment without any need for ladders, lifting equipment, or other assistance.

Access manholes shall not be located in the upper flange of bridge superstructures. All doors and access manholes shall have efficient waterproof seals, be self-closing and have security locks with at least three spare keys per lock, all uniquely identified to the associated lock.

Major culverts located in rivers or streams that transport significant amounts of gravel or debris that is expected to accumulate within the structure on a relatively frequent basis and require clean-out shall be provided with sufficient internal working room to enable access by mechanical plant, subject to road controlling authority approval.

2.2 Geometric and side protection requirements

Carriageway and footpath widths, and horizontal and vertical clearances shall comply with appendix A as a minimum. Clearances over railways shall comply with the requirements of KiwiRail – New Zealand Railways Corporation.

Requirements for pedestrians, cyclists and equestrians shall be agreed with the road controlling authority. Guidance on criteria that may be appropriate may be found in appendix A. As a general principle, the widths of traffic lanes and shoulders, together with any additional facilities for pedestrians and cyclists on bridges or adjacent to retaining structures shall match, wherever practicable, those of the road on the approaches. This also applies where roads cross over culverts, stock underpasses and subways.

Side protection to all new structures, or replacement of side protection on existing structures, shall be provided in accordance with the requirements of AS/NZS 3845 *Road safety barrier systems and devices part 1 Road safety barrier systems*⁽¹⁰⁾ as implemented by the NZTA M23 *Specification for road safety hardware*⁽¹¹⁾ and modified by appendix B. Barrier replacements shall, as far as practicable and as appropriate, utilise standard bridge barrier systems as detailed in NZTA M23⁽¹¹⁾ appendix B.

Side protection is defined as the rail or barrier systems by which road users are restrained from leaving the carriageway or structure in an uncontrolled manner. A risk management approach to side protection selection is described in appendix B, clause B3. Means of compliance with the requirements, which are mandatory for work funded by the Waka Kotahi NZ Transport Agency, are given in clauses B4 to B6.

2.3 Waterway design

2.3.1 General

The waterway design requirements and criteria specified in this section reference and amend various key documents. These documents, and what they are to be used for, are summarised in table 2.4. The waterway design of bridges and major culverts shall comply with the requirements of these documents except as amended in 2.3. For minor culverts refer to the *Highway structures design guide*⁽³⁾.

Note that pier scour in cohesive bed materials is not addressed in the documents listed in table 2.4, and for this situation *Evaluating scour at bridges*⁽¹²⁾ provides additional guidance.

The clauses in 2.3 do not address in detail all potential cross reference inconsistencies or duplications between these documents. Where such an inconsistency is found to have a potentially significant effect on the proposed design, then it shall be addressed in the structure options report or alternatively in the structure design statement, in accordance with the *Highway structures design guide*⁽³⁾.

It is noted that regional council or territorial authority requirements may need to be adopted and that these may override the requirements of the *Bridge manual*. Similarly, resource consents shall be complied with. These requirements could be more onerous and relate to other waterway specific constraints derived from environmental or waterway and flood management practices. Where they are less onerous, then the *Bridge manual* provisions are likely to govern, although reporting performance under the council or territorial authority standards might still be required.

2.3.1 continued

Table 2.4: Key reference documents for waterway design

Document	To be used for
Austrroads <i>Guide to road design</i> part 5 Drainage – General and hydrology considerations ⁽¹³⁾	General design considerations Rational method hydrology
Austrroads <i>Guide to road design</i> part 5B Drainage – Open channels, culverts and floodways ⁽¹⁴⁾	Design of major culverts Design of culvert scour protection
Austrroads <i>Guide to bridge technology</i> part 8 Hydraulic design of waterway structures ⁽¹⁵⁾	General design considerations for bridges Bridge backwater/afflux Bridge scour assessment in cohesive bed materials
<i>Bridge scour</i> ⁽¹⁶⁾	General scour design considerations Bridge scour assessment in non-cohesive materials Design of bridge scour countermeasures
<i>Blockage of hydraulic structures</i> ⁽¹⁷⁾	Assessment of debris blockage for major culverts.
<i>Fish passage guidance for state highways</i> ⁽¹⁸⁾ <i>NZ fish passage guidelines for structures up to 4 metres</i> ⁽¹⁹⁾	Fish passage design
<i>Countermeasures to protect bridge piers from scour</i> ⁽²⁰⁾	Design of bridge scour countermeasures when using reno mattresses and gabions

Attention is drawn to the importance of understanding any wider scale regional council waterway maintenance practices as these may determine the structural arrangement (orientation, skew, span, clearances, pier type and abutments etc) of the bridge or major culvert and in doing so impact the nature of the bridge superstructure and/or substructure.

It is noted that 2.3 does not address waterway and scour countermeasure design requirements for bridges and major culverts in the coastal marine environment or exposed to wave action. In these instances, specialist coastal engineering advice shall be obtained and reflected in the structure options report or the structure design statement.

2.3.2 Design floods

a. General

The annual exceedance probability (AEP) performance standards specified in this *Bridge manual* take precedence over those listed in *Austrroads Guide to road design* part 5⁽¹³⁾ and *Austrroads Guide to bridge technology* part 8⁽¹⁵⁾.

Note that the terms annual exceedance probability used in this section and annual probability of exceedance used elsewhere in this chapter are interchangeable. The slight difference in terminology arises from adhering to the different standard naming conventions for each technical discipline.

All flows approaching the structure and road need to be managed including both in and out of channel flows. This requires an understanding of the context of the structure and associated earthworks within the wider river and floodplain, and the impact of the structure on the various flow paths. For example, features such as deeply incised channels, stopbanks, dams, large upstream floodplains and existing road approaches that overflow will all influence the hydraulic performance of a structure. The flood peak flow rates and flow paths may behave quite differently during an ultimate limit state flood compared to a serviceability limit state flood.

2.3.2 continued

For bridges and major culverts near the confluence of two waterways or close to the coast, the hydraulic conditions at the structure will be affected by the tide, storm surge or backwater from the waterway downstream as well as flood flows in the waterway itself. In these circumstances the design flood shall be identified by determining the critical combination of tailwater and design flow in accordance with regional council or territorial authority guidance where available. This may involve differing AEPs for tailwater and design flow acting in combination to determine the design flood flow and level. Where no such advice exists then the event combination, and its justification, shall be documented in the structure options report or the structure design statement.

It is noted that the combination of tailwater and design flow will be different for the various aspects of the design. Requirements for freeboard, afflux, debris impacts, scour and countermeasure designs will each have a different critical combination that dictates performance and influences design. It may be that high tailwater conditions at a downstream confluence or due to tidal influence dominate flood levels at the bridge, whereas low tailwater conditions will likely be critical for scour assessment and design.

The tailwater/design flow combination shall consider the risk and consequences on both the structure itself and nearby sensitive infrastructure and property (ie 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 such as storm response and timing 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). For further guidance on this issue refer to *Hydrological and hydraulic guidelines*⁽²¹⁾.

b. Overall design of total waterway

In the design of a waterway crossing, the total waterway shall be designed to pass an SLS 2 flood given in table 2.1 without significant damage to the road, the protection works and the waterway structure.

Damage from a SLS 2 flood shall be minor, with no more than minimal disruption to traffic (eg temporary speed restrictions and temporary lane closures to facilitate repairs such as the reinstatement of rock rip rap) and be repairable within a period of one month.

c. Design for climate change effects

Climate change shall be allowed for in both hydrology and tailwater conditions (whether this is in terms of sea level rise or increased flow and level in a downstream river).

Assessment of the effects of climate change on rainfall shall be based on the Ministry for the Environment *Climate change projections for New Zealand*⁽²²⁾ and other material based on more recent research published by reputable sources accepted by the road controlling authority, relevant regional council or territorial authority.

Climate change scenarios used for design shall be in accordance with regional council or territorial authority requirements or resource consent conditions. In the absence of specific advice, then climate scenario RCP 6.0 shall be used for design with sensitivity testing to RCP 8.5. For high risk sites or where there is a severe consequence of failure, then RCP 8.5 shall be adopted. The projected climate date horizon shall match either the design life of the structure or the requirements of the regional council or territorial authority.

2.3.2 continued

Where relevant to the site, changes in sea level shall be assessed based on regional council advice and the Ministry for the Environment manual *Coastal hazards and climate change*⁽²³⁾.

It is noted that specialist advice is required if resource consent conditions require a climate change projection to a date that is beyond that published by the Ministry for the Environment or NIWA.

Flows derived from historical flood frequency analysis must also be increased to account for climate change. Increases based on the rainfall-runoff relationship for the catchment can be used to estimate climate change increases. However, this relationship is normally non-linear, with higher volumetric and peak flow runoff coefficient for the climate increase than for the historical data. Non-linear hydrological models calibrated to flow records can provide a basis for the estimated increase in flows from climate change increases in rainfall.

Change in general land wetness from climate change effecting antecedent conditions also needs to be considered.

Where it is practicable and economic for a bridge or culvert structure to be retrofitted at a later date to accommodate the increased flows arising from the effects of climate change, the structure need not initially be designed to accommodate the increased flood flows. Where future retrofitting is not practicable or does not reflect value for money, future climate change impacts shall be taken into account in the design.

d. Serviceability limit state (SLS)

The waterway design of the bridge or major culvert shall be designed to the ultimate limit state and serviceability limit state events listed in table 2.1.

Level of serviceability to traffic: State highway waterway crossings shall pass SLS 2 flood events given in table 2.1 while complying with the freeboard as specified in table 2.5.

On existing roads where the road overflows and so does not meet the level of serviceability to traffic requirements, it may not be practicable for new structures to meet the standard, or in meeting the standard there may be adverse effects on other infrastructure, property or the environment. In that case the impacts caused by changes to the overflow and possible changes to flood flow rates and levels need to be assessed and documented in the structure options report. Mitigation of these effects may be required subject to regional council or territorial authority requirements.

Damage avoidance: Bridges, major culverts and their approaches shall be designed to withstand the effects of a 4% AEP flood without sustaining damage (SLS 1 flood event given in table 2.1).

e. Ultimate limit state (ULS)

For the ultimate limit state, the overall total waterway of the bridge or major culvert shall be designed for the effects of the AEP flood corresponding to the importance level of the bridge given in table 2.1. Collapse shall be avoided under the ultimate limit state event.

In situations where the design flood for the ultimate limit state will substantially overtop the bridge or major culvert structure, the intermediate stages in the flood height shall also be investigated and those stage heights that are most critical considered.

2.3.2 continued

In situations where the bridge or major culvert is integral with adjacent flood protection works, the design flood for the ultimate limit state could be substantially larger than the design flood for the flood protection works. In estimating the design flood level for the ultimate limit state, cognisance therefore needs to be taken of the potential for such protection works to be overtopped and for a proportion of the peak flood flow to bypass the bridge or major culvert.

Similarly, where a bridge or a major culvert structure is sited on a floodplain with no upstream flood protection works present, estimation of the flood level for the ultimate limit state should take account of the potential for flood breakout upstream of the structure with consequential bypassing of the structure by a proportion of the peak flood flow.

2.3.3 Hydrology

a. Flood flow estimation methods

Where possible, design flood estimates shall be obtained from a flood frequency analysis of data from a hydrological gauging station in the vicinity of the bridge site. The hydrological flow record used for this analysis should preferably be at least 20 years long (aside from having sufficient duration of record for statistical robustness, this will also cover climate cycles such as the interdecadal pacific oscillation). The flood frequency analysis should use the probability analysis method that best fits the annual maxima series. Recognised probability analysis methods include the Gumbel, Log Pearson 3 and Generalised Extreme Value (GEV) methods. Probability analysis methods are described in the *Handbook of hydrology*⁽²⁴⁾.

If there is no hydrological information available in the vicinity of the bridge site, then a gauge site on the same river or in a hydrologically similar nearby river should be used. If there is not a suitable site to use, the structure options report or the structure design statements shall document how the potential differences between catchments have been addressed.

The flood estimates can be scaled by the ratio of the catchment areas to the power of 0.8 as discussed in *Flood frequency in New Zealand*⁽²⁵⁾, section 3:

$$Q_1/Q_2 = (A_1/A_2)^{0.8}$$

Where: Q = flood discharge

A = catchment area.

Hydrological models are often held by the relevant regional council or territorial authority and these can be used to inform and test the design. These models will vary in purpose, limitations, type and accuracy. They may also be calibrated to flow record information or not. These factors shall be considered prior to using a model as a source of flood flow and level estimation for design. Where models are available and fit for purpose, then they shall be used in preference of carrying out a separate hydrological analysis.

Where there is no hydrological gauging station present on the river nor an approved model available, flood estimates shall be obtained by using one:

- the rational method - in which a peak flow of a selected AEP is estimated as a function of the average rainfall intensity of the same AEP
- the regional method - *Flood frequency in New Zealand*⁽²⁵⁾
- the Soil Conservation Service (SCS) method detailed in *Urban hydrology for small watersheds*⁽²⁶⁾ (or approved regional variant)
- another hydrological methodology as approved by the relevant regional council or territorial authority.

2.3.3 continued

Where hydrology is determined by the calculation methods detailed in 2.3.3(b) and (d), then the relevant regional council and/or territorial authority advice should be followed. In the absence of this, design rainfall shall be obtained from a suitable rain gauge selected and reviewed for suitability given its context within the catchment. Otherwise rainfalls can be obtained from NIWA's *High intensity rainfall design system (HIRDS)*⁽²⁷⁾. For large catchments the variation of *HIRDS*⁽²⁷⁾ rainfall across the catchment needs to be reviewed to determine the appropriate rainfall representative of the catchment. It is noted that regional council and/or territorial authority requirements for design rainfall may take precedence over gauge or *HIRDS*⁽²⁷⁾ data.

Rainfall gauge data shall only be used in circumstances where it provides the road controlling authority with a significant benefit over the use of *HIRDS*⁽²⁷⁾ data. This analysis must first confirm that the data is of sufficient quality with an appropriate duration of record.

For catchments containing significant urban development the maximum probable development extent shall be used for determining flood flows. The development extent shall be in accordance with the district plan provisions, including any structure plans for future growth.

b. Sensitivity testing

For high risk sites or sites where the consequence of failure could be severe, sensitivity testing shall be undertaken assuming higher rainfall based on *HIRDS*⁽²⁷⁾ standard errors or another approved methodology.

The sensitivity approach to testing the impacts of higher rainfall and/or design flows shall be used where there is significant uncertainty in the catchment or in the predicted hydrology. Sensitivity testing shall give consideration to what the uncertainty in question relates to and shall be agreed with the road controlling authority and the relevant regional council or territorial authority. Design flows shall be based on the best estimate of the variables involved with the sensitivity testing then based on an increase in this flow. This shall be documented in the structure options report or alternatively in the structure design statements.

Refer also 2.3.2(c) for sensitivity testing requirements for climate change increases.

c. Rational method

The rational method is only applicable to small catchments because of its inability to account for the effects of catchment storage in attenuating the flood hydrograph. The recommended maximum catchment size for this methodology is 1km² in urban catchments, and 25km² for rural catchments. The rational method is described in *Austrroads Guide to road design* part 5⁽¹³⁾ and the *Handbook of hydrology*⁽²⁴⁾.

Runoff coefficients shall be as specified in *New Zealand building code* verification method E1/VM1⁽²⁸⁾. These coefficients shall also be adjusted for catchment slope in accordance with E1/VM1⁽²⁸⁾. Regional council or territorial authority approved coefficients may also be used. The coefficients in E1/VM1⁽²⁸⁾ relate to 10% AEP storms so for different return periods these shall be factored in accordance with clause 6.6.3 of *Austrroads Guide to road design* part 5⁽¹³⁾.

The time of concentration for rural catchments shall use the Ramser Kirpich equation as listed in table 6.1 of *Austrroads Guide to road design* part 5⁽¹³⁾ and the Modified Taylor Schwarz method, as detailed in chapter 2 appendix A of the *MWD Culvert manual* volume 1⁽²⁹⁾, shall be used to determine channel slope.

2.3.3 continued

d. Regional method

Flood frequency in New Zealand⁽²⁵⁾ is a regional method suitable for all rural catchments except those in which there is snow-melt, glaciers, lake storage or significant ponding. It should be used for rural catchments greater than 10km². It can also be used for rural catchments between 3km² and 10km² but should be checked against another method referenced in this clause.

Regional flood frequency analysis for small New Zealand basins⁽³⁰⁾ is a refinement to *Flood frequency in New Zealand*⁽²⁵⁾ and should be used for catchments less than 30km² in area.

It is noted that regional method derived peak flows shall also be increased for climate change effects.

e. Soil Conservation Service (SCS) based methods

Several regional councils and territorial authorities have well established hydrological methods based on the SCS rainfall-runoff model detailed in *Urban hydrology for small watersheds*⁽²⁶⁾.

These methods use curve numbers and initial abstraction to represent catchment hydrological processes and apply a distributed 24-hour rainfall depth with a unit hydrograph to generate a catchment hydrograph.

It is noted that some of these methods are specific to the region where they were developed and as such are not appropriate for use outside of that region.

f. Estimation of the ultimate limit state design flood

The estimation of the ultimate limit state design flood shall be made based on a flood frequency analysis of available data as described in 2.3.3(a), if available. Wherever possible the data shall be obtained from a hydrological flow gauging station at or near the site of the proposed bridge. It should be noted that the accuracy of design flood estimates depends on the length of flow record. Predictions beyond the 1% AEP are not precise. Estimates for the ultimate limit state event shall be checked against gauging station data from other nearby catchments with similar hydrological characteristics.

If there is no hydrological flow data available at the bridge or major culvert site, then a site on the same river, or alternatively a gauging site on a nearby river with similar hydrological characteristics, should be used as described in 2.3.3(a). Data from more than one site should be used to ensure that a degree of smoothing of extreme values occurs.

If there is no suitable hydrological flow data available at all, then the ULS flows shall be determined based on one of the above approved hydrological methods.

2.3.4 Hydraulics

a. Hydraulic estimation methods

Hydraulic estimation of flood levels, flow conditions and impacts on these resulting from the design can involve calculations or the use of complex computer models.

Similar to hydrological models, hydraulic models (also known as stormwater or flood models) are often held by regional councils or territorial authorities. Where possible these shall be used to inform and test the design and to determine the impacts of that design. These models will vary in scale, purpose, limitations, type and accuracy. They may also be calibrated to flow record information or validated with other flood records. These issues shall be considered prior to using a model or its results for design. Where models are available and fit for purpose, then they shall be used in preference of carrying out a separate hydraulic analysis.

2.3.4 continued

It is noted that these models can also provide upstream and downstream boundary conditions as inputs to a smaller, localised model or for traditional calculations carried out as part of a design. When determining an appropriate design methodology, consideration must be given to the topography of the site, the anticipated effects and the scale of the structure and works being designed.

b. Increase in flood risk

The bridge or major culvert shall not cause an unacceptable increase in flood risk on properties outside of the designation both upstream and downstream of the structure. This shall be in accordance with regional council or territorial authority requirements.

Conversely the structure shall also not adversely drain down upstream areas where doing so could result in unacceptable impacts on land use, sensitive habitat or land stability.

c. Debris

Designs that result in a significant change in risk of debris accumulation at the structure or at structures downstream, shall be assessed on an effects basis. The risks and consequences shall be considered for adjacent properties and for maintenance activities. Debris countermeasures will be required at medium and high debris potential sites.

For flood impact assessments, an all-clear condition shall be assumed with a sensitivity check undertaken for the effects of debris blockage.

d. Freeboard for level of serviceability to traffic

When considering the level of serviceability to traffic required by 2.3.2(d), the freeboards given in table 2.5 shall be used.

Table 2.5: Freeboard allowance for the level of serviceability to traffic

Waterway structure	Situation	Freeboard	
		Measurement points	Depth (m)
Bridge	Normal circumstances	From the predicted SLS 2 flood level to the underside of the superstructure	0.6
	Where the possibility that large trees may be carried down the waterway exists		1.2
Major culverts	Normal circumstances (unaffected by debris)	From the predicted SLS 2 flood level to the outer edge line level	0.5
	Cross-section larger than 6m ²	From the predicted SLS 2 flood level to soffit of culvert	0.3

e. Further design criteria for major culverts

Major culverts shall also be designed such that:

- the SLS 2 flood does not head up more than 2m above the soffit level of the culvert inlet
- flood levels do not head up above the soffit of the culvert in a:
 - o 1%AEP storm for importance level 3 or 4 structures
 - o 20%AEP storm for importance level 2 structures
 - o 50%AEP storm for importance level 1 structures

2.3.4 continued

- fish passage is provided for, where required, in accordance with *Fish passage guidance for state highways*⁽¹⁸⁾ and *NZ Fish Passage Guidelines for Structures up to 4 metres*⁽¹⁹⁾ or other relevant regional council or territorial authority guidance
- debris risk is assessed in accordance with *Blockage of hydraulic structures*⁽¹⁷⁾ and countermeasures designed for medium to high risk debris potential sites. Design of major culverts shall assume they 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
- natural sediment transport processes are allowed for by maintaining the natural bed width, cross sectional area and stream gradient wherever practicable.

f. Waterways

In low-gradient silt- and sand-bed rivers determinations of Manning's n roughness shall be derived from sets of photographs, for example from *Roughness characteristics of New Zealand rivers*⁽³¹⁾. Tables of values such as table 2.2 of *Austrroads Guide to road design* part 5B⁽¹⁴⁾, should be taken as approximate only. Any possible backwater effects from downstream features should be investigated. Direct measurements should be obtained whenever possible.

In gravel-bed rivers, estimates of Manning's n shall be made using at least one formula, for example one of the 'rigid bed' formulae by Griffiths given in 2.3.4(g), as well as using *Roughness characteristics of New Zealand rivers*⁽³¹⁾. Table 2.2 of *Austrroads Guide to road design* part 5B⁽¹⁴⁾ is not appropriate to New Zealand rivers with gravel beds and shall not be used. If the formula in *Open channel flow*⁽³²⁾ is used, a factor of 1.2 should be applied to the calculated values of Manning's n .

In all other rivers the estimation of Manning's n shall be the subject of a detailed hydraulic investigation.

g. Griffiths formulae

The Griffiths formulae noted above are taken from *Flow resistance in coarse gravel bed rivers*⁽³³⁾. The two 'rigid-bed' formulae recommended by Griffiths are:

$$1/\sqrt{f} = 1.33(R/d_{50})^{0.287}$$

$$1/\sqrt{f} = 1.98 \log_{10}(R/d_{50}) + 0.76$$

Where: f = Darcy-Weisbach friction factor

R = hydraulic radius

d_{50} = size for which 50% of the bed material is smaller.

is related to Manning's n by the following formula:

$$n = 0.113\sqrt{f}R^{1/6}$$

h. Bed aggradation/degradation

The impact of long-term changes in river bed levels from aggradation or degradation shall be considered. However, in the absence of suitable historical or predictive information, allowances shall be agreed with the relevant regional council or territorial authority.

2.3.5 Scour

The estimation of scour in non-cohesive bed materials should be based on *Bridge scour*⁽¹⁶⁾. However, this publication does not directly cover scour in cohesive bed materials, so for these situations *Austrads Guide to bridge technology part 8*⁽¹⁵⁾ shall be used.

Note however that *Austrads Guide to bridge technology part 8*⁽¹⁵⁾ does not include a method for estimating local scour at piers in cohesive bed materials. In this situation *Evaluating scour at bridges*⁽¹²⁾ provides additional guidance.

The pier scour depth induced by debris rafts as shown in figure 2.2 shall be estimated using an equivalent pier width a_d^* defined in *Effects of debris on bridge pier scour*⁽³⁴⁾ by the equations:

$$a_d^* = \frac{K_{d1}(TW)(L/y)^{K_{d2}} + (y - K_{d1}T)a}{y} \quad \text{for } L/y > 1.0$$

$$a_d^* = \frac{K_{d1}(TW) + (y - K_{d1}T)a}{y} \quad \text{for } L/y \leq 1.0$$

Where: K_{d1} = 0.79 for rectangular debris, 0.21 for triangular debris.

K_{d2} = -0.79 for rectangular debris, -0.17 for triangular debris.

L = length of debris upstream from pier face (m). L shall be taken as lying within the range $0.4W < L < 1.3W$.

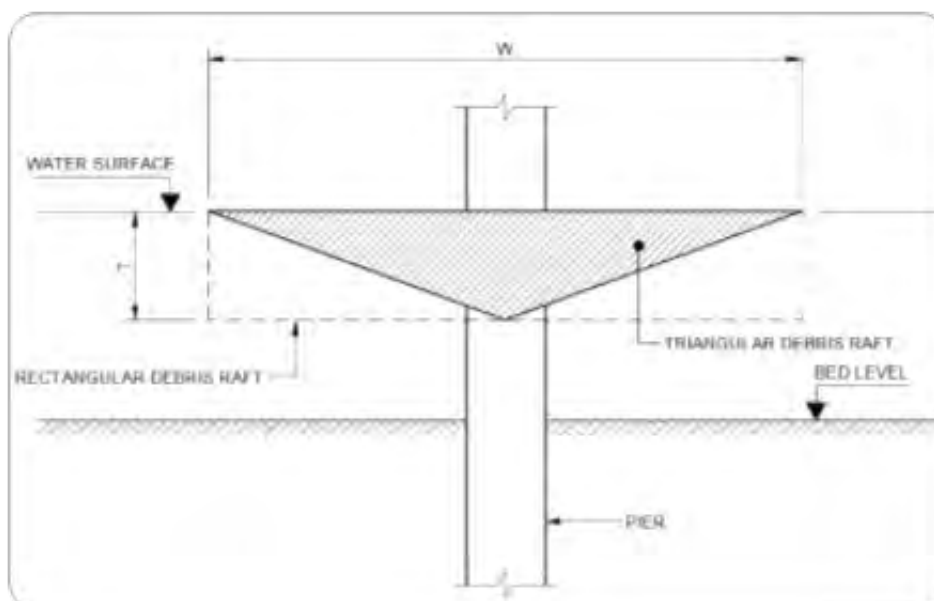
y = depth of approach flow (m).

T = thickness of debris normal to flow (m), which shall be taken as the maximum rootball diameter of a tree likely to be transported by the river, (typically up to ~2m), or half the depth of the upstream flow, whichever is the greater, but not greater than 3.0m.

W = width of debris normal to flow (m), equal to the average of the span lengths either side of the pier, but not greater than the length of the largest tree likely to be transported by the river, or greater than 15m.

a = pier width (without debris) normal to flow (m).

Figure 2.2: Debris raft for pier scour assessment



2.3.6 Scour protection works

The security of the bridge or major culvert structure shall be ensured for all flood events up to that of the design ultimate limit state event specified in table 2.1 for the importance level of the structure.

The design of scour protection works for bridges shall generally comply with the guidance provided in *Bridge scour*⁽¹⁶⁾. The design of scour protection works for major culverts shall generally comply with the guidance provided in *Austrroads Guide to road design* part 5B⁽¹⁴⁾ and shall also consider impacts on fish passage, debris risks, maintenance access and safety in design.

Where the use of gabion baskets or reno mattresses is proposed for scour protection works, the design shall comply with the design procedure given in appendix F of *Countermeasures to protect bridge piers from scour*⁽²⁰⁾.

When using gabion baskets or reno mattresses, consideration must be given to the risk of tearing and corrosion or abrasion of the cage wire and the consequential maintenance implications of such damage. It is recognised that in situations with severe spatial constraints, they can offer a favourable solution that minimises the constriction of the waterway.

2.4 Site investigations

All structure sites shall be subject to appropriate geotechnical and geological investigations, sufficient to enable a geotechnical assessment to be undertaken to ensure that a safe, economical and practical design can be developed. The purpose of a geotechnical assessment is to:

- Identify and manage geotechnical risks that may influence the performance of the structure (eg liquefaction, slope instability).
- Provide geotechnical input into the design of the structure (eg soil loads, soil strength and stiffness).

The investigations shall be conducted in accordance with the *New Zealand ground investigation specification* volume 1 Master specification⁽³⁵⁾ to establish the characteristics of the surface and subsurface soils and rocks, their behaviour when loaded and during construction, the nature and location of any faulting, and the groundwater conditions. Site conditions and materials affecting the construction of the structure shall also be determined.

Investigations normally consist of three phases:

- a. Preliminary investigations, consisting of compilation of general data, walkover survey and, where appropriate, some boreholes and laboratory tests.
- b. Detailed field investigations and laboratory tests, before final design.
- c. Investigations during construction, as appropriate.

Information obtained from site investigations shall be presented within a factual report. Borehole logs, soil descriptions and testing shall comply with current practice, as presented in documents published by Standards New Zealand, New Zealand Geotechnical Society, British Standards Institution or similar.

2.4 continued

The investigations shall include interpretation of all available data by suitably qualified personnel and recommendations as to foundation and retaining structure types, cut and fill slopes and design parameters, and the need for proof testing, pilot drilling or other confirmatory investigation during construction, presented in a geotechnical interpretative report or geotechnical design report.

2.5 Influence of approaches

The influence of approach embankments and cuttings on all types of structures (bridges, culverts, underpasses, subways and retaining structures) shall be considered, including:

- immediate gravity effects
- seismic effects
- long-term settlement effects
- loading from slope material, which may fall onto a deck.

The effects of approach settlement and stability on the riding characteristics, traffic safety, landscape treatments and performance of abutment components shall be considered.

2.6 Urban design

2.6.1 What is urban design?

Urban design is a design discipline that seeks to create desirable places for people to live, work and play. It involves the design and placement of buildings, roads, rail, open spaces, towns and cities. It focuses on the relationship between built form, land use and open space, natural features and human activity. Good urban design creates spaces that function well, have a distinctive identity and visual appeal.

As a signatory to the New Zealand Urban Design Protocol, Waka Kotahi NZ Transport Agency is committed to planning for, developing and promoting quality urban design. The challenge is to incorporate this commitment into all aspects of business for Waka Kotahi. The Waka Kotahi *HNO environmental and social responsibility manual*⁽³⁶⁾ requires that good urban design be integrated into all Waka Kotahi activities. This extends to the placement and design of bridges and other highway structures.

2.6.2 Aesthetics vs function

The design and placement of bridges and other highway structures that form part of the highway network influence the quality of the environment, both in terms of visual appearance and how these areas function. Urban design is concerned with both these dimensions of highway structures design.

The appearance or aesthetics of highway structures depends on their overall form and proportions, on the design coherence of their various components (abutment walls, side barriers, piers, soffit, etc) and on the quality of their detailing and finishes.

The functional aspects of highway structures that have an urban design dimension relate to how the structures support local movements by foot, cycles and vehicles and how they complement the scale and use of the surrounding land, buildings and spaces.

2.6.2 continued	<p>Further guidance on function and aesthetics of highway structures is provided by the Waka Kotahi <i>Bridging the gap: Urban design guidelines</i>⁽³⁷⁾ and other references as noted in 2.6.4.</p>
2.6.3 Urban design assessment for bridges and major retaining walls	<p>New or replacement bridges and major retaining walls that are visible from surrounding communities, public open spaces or the highway itself, and bridges that are located in landscape sensitive areas (eg along scenic routes or in areas identified as outstanding landscape in the district plan) will require an urban design assessment or a landscape and visual assessment.</p> <p>The urban design bridge assessment matrix in table 2.6 (also table 1 in appendix 5 of <i>Bridging the gap: Urban design guidelines</i>⁽³⁷⁾) is to guide urban design decision making in relation to bridges. The aim of the matrix is to assist in the high level assessment of the urban design considerations for a bridge. The matrix may also be used for major retaining walls.</p> <p>The urban design assessment and landscape and visual assessment will then guide the subsequent stages of design. The assessment shall be undertaken once a preferred route option has been chosen and shall be reported in the preliminary structure options report and updated in the subsequent structure options report and structure design statement. On large or complex projects, the urban design considerations that have influenced the structure design and any design principles proposed to guide the detailed design must also be documented in the project's <i>Urban and landscape design framework</i>.</p> <p>It is expected that the urban design response for a specific structure will be appropriately calibrated to the outcome of the assessment. It is important that the design rationale for a structure design response can be communicated and understood. That urban design response should refer to the guidance in <i>Bridging the gap: Urban design guidelines</i>⁽³⁷⁾ and the other references noted in 2.6.4.</p> <p>The matrix assessment will be undertaken by an appropriately qualified landscape architect or urban designer.</p> <p>Both the visual and functional aspects of bridges and major retaining walls require consideration in terms of sections 6 and 7 of the Resource Management Act 1991⁽³⁸⁾ (RMA) when seeking a designation or resource consents. This typically involves an assessment of the structure under both the <i>Landscape and visual assessment of effects</i> and the <i>Urban design assessment of effects</i>. Both these technical reports underpin the <i>Assessment of environmental effects</i> for the project.</p>
2.6.4 Appearance	<p>Careful consideration shall be given, in line with <i>Bridging the gap: Urban design guidelines</i>⁽³⁷⁾, to the appearance or aesthetics of the structure.</p> <p>Further guidance on the principles involved in designing for aesthetics may be obtained from the following references:</p> <ul style="list-style-type: none"> • NSW Roads and Maritime Services <i>Bridge aesthetics: Design guidelines to improve the appearance of bridges in NSW</i>⁽³⁹⁾. • Fédération Internationale du Béton <i>Guidance for good bridge design</i>⁽⁴⁰⁾. <p>UK Highways Agency <i>The appearance of bridges and other highway structures</i>⁽⁴¹⁾.</p>

Table 2.6: Urban design bridge assessment matrix

Urban design bridge assessment matrix <i>Comment in each column for each bridge location (there may be more than 2 locations on any section of roading project - add further columns as required) as to the level of importance and a brief explanatory comment</i>				
Assessment matter	Explanation as to importance for urban design attention	Measure types that may be used to gain an understanding of importance	Location A	Location B
Underlying natural environment	Does the context have underlying characteristics that will be affected by the bridge or suggest a certain form of bridge response? For example consider topography, natural features such as vegetation, ecology or landscape	Planning documents (district or regional plans) Landscape assessments Urban design contextual analysis Preliminary assessment undertaken as part of project		
Circulation	Is there an existing or likely future (eg from planned urban development) circulation pattern or network that will be affected by the bridge or suggest a certain form of bridge response? For example consider what level of use occurs (or may be planned to occur) in the bridge location? Demographic profile also of interest as older people/children more vulnerable to level changes/safety and less likely to have access to a vehicle.	LAMS (Local Area Movement Surveys) Counts including school travel plans Network monitoring Demographic profile for area Urban growth plans		
Activities	Are the existing or likely future (eg from planned development) activities in the vicinity affected by the bridge or suggest a certain form of bridge response? For example consider access to existing properties, accessibility to activities of local importance such as schools.	District Plan Urban growth plans, transport strategies Urban design contextual analysis Preliminary assessment undertaken as part of project		
Built form	Is the existing or likely future (eg from planned development) urban form affected by the bridge or suggest a certain form of bridge response? For example consider whether the bridge is at a key nodal point in the network (eg at an interchange, town centre, key turn off)? What is the fit with the scale of the built form in the area?	Network analysis (transportation plans) Urban growth plans Urban design contextual analysis		
Amenity	Is the location amenity affected by the bridge or suggest a certain form of bridge response? For example consider how many people will view the bridge- ie live near the location or pass by frequently? What is the visibility of the bridge from the point of view of the highway user? What is effect on shading or tranquility of the location?	Inter visibility assessment Landscape assessments Urban design contextual analysis Preliminary assessment undertaken as part of project		

2.7 Special studies

Special studies are required when:

- a structural form or method of construction is proposed which is not covered by accepted standards or design criteria (eg to determine design parameters, safety factors or durability)
- non-conventional materials are to be applied, the technology of which is still undergoing significant development (conventional materials include concrete, steel, timber, engineered soils, natural soils, geogrid reinforcements and geotextiles)
- site-specific studies are undertaken to define the exposure classification associated with durability requirements or the seismic hazard spectra for earthquake response analysis.

Special studies shall be documented in complete reports, included as appendices to the structure options report or structure design statement. This documentation shall include, as appropriate:

- the source of all data
- demonstration that the study has provided appropriate evaluation of the particular structural performance being investigated
- reference to relevant national and international standards and guidelines, and published peer reviewed papers
- comparison of the results with other data
- a description of the analytical methods used
- details of the organisation/individual who has undertaken the special study

a brief outline of the experience and capability of the agency and personnel undertaking the special study.

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