Memo

[redacted]

Purpose

This is a DRAFT memo seeking review and support from NZTA Lead Advisor (Structures) before issuing to the CEAG. Refer section at end of memo

This paper provides the rationale (context and affordability drivers) behind draft Seismic Resilience Philosophy (SRP) reports prepared for the Petone to Grenada (P2G) Investment Case design and Cross Valley Link (CVL) feasibility level designs.

Further detail will be required in future stages of each project to fully document the minimum requirements and design criteria (including the seismic design criteria).

Two separate SRP documents have been prepared (one for each project), however the nature of the departure is generally consistent for both projects, hence the rational provided in this memo covers both projects.

Background

Prior P2G studies have demonstrated the affordability challenge of this proposed transport corridor which traverses liquefiable soils and steep topography in a high seismicity environment. Recent changes in our understanding of earthquake hazard is set out in the National Seismic Hazard Model (NSHM), and when combined with the current seismic performance requirements in the NZTA Bridge Manual, will further increase project design requirements and costs for the P2G structures beyond what has already been established to be unaffordable.

The Riverlink and Melling Bridge projects, currently in early design stages, have highlighted the technical and affordability challenges that the CVL project will face for bridges crossing the Hutt River due to the recent updates to the seismic hazard from the NSHM.

The Departure from the NZTA BM that is set out in the SRP is considered essential to meet the project affordability threshold, while appropriately mitigating the seismic risk. The rationale behind the Departure has been approved in principle by the Chief Engineers Advisory Group (CEAG)[1]. This memo documents the project context and rationale for the Departure.

Seismic Resilience Philosophy

The seismic resilience philosophy is set out in the project SRP document that has been prepared in accordance with Section 2.3.1.2 of the NZTA Roads of National Significance Standardised Designs document (RoNS Standard[2]).

A holistic approach has been taken for determining the appropriate seismic resilience, considering:

- the One Network Framework (ONF) route status that has been agreed with CEAG[1] (this is an Urban / Rural Connector for CVL and P2G respectively),
- the balance of seismic performance versus cost (as highlighted in later section of this paper),
- the resilience of the regional network (particularly the resilience of local assets delivered in the last 10 years).

This holistic approach considers the guidance set out in the RoNS Standard.

Basis for Departure

Network Resilience

The proposed departure considers the new corridors as a part of the overall network resilience and incorporates the NSHM updates to a level that is considered to be appropriate in this context.

The seismic performance of other recently constructed NZTA assets on SH1 and SH2 in the Wellington region are reviewed and compared.

Affordability

The departure seeks to avoid a significant step change in costs to deliver structures (i.e. larger, stiffer piles and an increased extent of ground improvement) that would be required to meet current NZTA design criteria.

[1] Refer attached Meeting Minutes dated 29/1/25

[2] Waka Kotahi NZTA Standardised design solutions for use on State Highway Roads of National Significance, August 2024 v2.0.

As an example, the increase in cost for a larger extent of ground improvement and additional stiffer piles is estimated to be in the order of >$40M[3] for the Petone Interchanges structures alone (see later sections for detail).

Post Earthquake Repairs

The additional investment required to meet current NZTA BM requirements would reduce displacement under the low frequency earthquake events but this is not considered as value-for-money because:

- there is expected to be negligible difference in performance under events up to 1/500 year AEP and so it does not remove the need for some temporary closure of the assets after an earthquake as they are inspected and repaired
- it does not remove the challenge in inspecting and verifying the post-earthquake condition of the stiff buried structures
- the additional upfront capital costs would likely exceed the cost to repair / re-build a more flexible structure that is designed in accordance with the proposed Departure.

With appropriate detailing and by using robust structural forms in simple geometric arrangements, collapse under higher accelerations can still be avoided even if the structures require significant repair or replacement. This follows the RONS philosophy of reducing seismic loads while providing additional seismic resilience.

Route Context

The P2G and CVL routes are classified as Rural and Urban connectors respectively. These corridors are not intended as lifeline routes and investment in structures that limit displacement and damage in low frequency seismic events is not aligned to the ONF category and intended use of the corridor.

Proposed Seismic Design Criteria

We have compared the latest NZTA criteria to the proposed departure (refer later sections of this paper for details). This is to be applied to the design of bridges retaining structures as well as soil structures.

NZTA BM

- Requires use of a SSSHA with the most recent seismic hazard model (2022 National Seismic Hazard Model) and Importance Levels / probabilities set out in the current Bridge Manual
- The DCLS PGA for IL3 structures constructed on the CVL and P2G project is approximately 1.2g
- This is almost double the PGA used in design of the SH2/58 Intersection at Haywards (2015) and the immediately adjacent SH2 Dowse Interchange (2009)

[3] There are expected to be 3 no. bridge structures in the southern portion of the Petone interchange. Cost estimated is the base cost to add two no. twin bored piles at each abutment (with associated protection of the Waiwhetu aquifer) instead of the proposed MSE abutments on shallow ground improvement

Proposed Departure

- Combine the most recent seismic hazard model (2022 NSHM) with a reduced probability earthquake as set out in Table 1 below.
- Increase the timeframes for post earthquake repair beyond the strict application of the limits in the BM
- This provides seismic accelerations and performance expectation that are similar to that used in the PP2O and O2NL projects as well as the adjacent SH2 Dowse and Haywards interchanges

Table 1 - Proposed Annual Exceedance Probabilities (Departure from NZTA BM)

	Design Seismic AEP		
Importance level[4]	IL1	IL2	IL3
SLS	1/25	1/50	1/50
DCLS	1/100	1/175	1/250
CALS	1/250	1/500	1/500

To inform the decision on an appropriate seismic design criteria, the bridge structures required for the Petone Interchange have been used for the purposes of comparison. Table 2 at the end of this document summarises the expected performance.

Option 1 – Design using current NSHM and BM

To accommodate the increase in horizontal and vertical acceleration, all the bridges are expected to be piled with substantial ground improvement below the approaches and abutments which will result in cost increase of >$40M (costs exacerbated by the construction challenges of piling within the Waiwhetu aquifer in the Hutt valley which applies to the CVL corridor as well).

Option 2 – Design using the Departure set out in the SRP

Using the reduced AEP set out in Table 1 and the increased displacement limits is expected to remove the need for piles to support the single span bridges, instead relying on small areas of targeted ground improvement immediately under each bank seat abutment. Displacement exceeding the limits in the BM could be expected but the bridge deck can be reinstated onto rebuilt approach embankments and abutments for less than the investment that would be required for Option 1.

Future Design Development

Future project stages will need to develop a more detailed design criteria and project minimum requirements.

[4] This is the Importance level as defined in Section **Error! Reference source not found.** of this SRP which is a Departure f rom the BM

Design of the structures (bridges, retaining walls and soil structures) will be in accordance with the Departure from the BM that is set out in the SRP. Design will need to detail the structures to have reserve capacity for seismic events exceeding the CALS loading. This will likely be achieved through use of established design practices to develop simple well-detailed bridge forms that have been known to perform well in previous seismic events. Structures will need to be detailed to provide a robust seismic load path from centre of mass into substructure and into the ground using a capacity design approach to avoid unintended seismic load paths occurring.

Single span bridges will be used wherever possible and these need to accommodate additional sliding allowance beyond the CALS level event and superstructure appropriately connected to accommodate vertical accelerations that exceed the CALS loading.

Where multi-span bridges are necessary, these will need to be detailed to accommodate relatively large horizontal displacements through leaving the pile casings in place and/or providing a higher-than-normal level of confinement in the columns. This is expected to satisfy the no collapse criteria but damage to the columns/piles would require significant repair or replacement.

Additional Considerations from NZTA Lead Advisor (Structures)

S7(2)(b)(i)

SEISMIC PGA AND EXPECTED PERFORMANCE									
	Proposed Departure as set out in the SRP							Bridge Manual / NZSHM 2022 requirements	
Seismic Performance	**SLS (Bridge Manual)**		**DCLS (Departure)**		**CALS (Departure)**			**DCLS (Bridge Manual)**	CALS (Bridge Manual)
AEP (NSHM2022)	**1/25 (IL1)**	**1/50 (IL2 & IL3)**	**1/100 (IL1)**	**1/175 (IL2)**	**1/250 (IL3)**	**1/250 (IL1)**	**1/500 (II2 & IL3)**	**1/1000 (IL3)**	**1/2500 (IL3)**
PGA likely for Petone to Grenada main alignment. Vs30 = 1000 m/s (500 to 1500 m/s)	**0.10g** (0.08g to 0.13g)	**0.26g** (0.14g to 0.22g)	**0.27g** 0.23g to 0.36g)	**0.41g** (0.36g to 0.51g)	**0.50g** (0.43g to 0.63g)	**0.50g** (0.43g to 0.63g)	**0.74g** (0.65g to 0.91g)	**~1.05g**	**~1.55g**
PGA likely for Petone Interchange and west side Hutt Valley. Vs30 = 400 m/s (275 to 500 m/s)	**0.15g** (0.13g to 0.16g)	**0.23g** (0.22g to 0.26g)	**0.38g** (0.38g to 0.39g)	**0.53g** (0.51g to 0.53g)	**0.64g** (0.62g to 0.64g)	**0.64g** (0.62g to 0.64g)	**0.92g** (0.84g to 0.92g)	**1.15g**	**1.7g**
PGA likely for Hutt River Bridge and most of Hutt Valley. Vs30 = 250 m/s (175 to 350 m/s)	**0.17g** (0.16g to 0.18g)	**0.26g** (0.24g to 0.27g)	**0.39g** (0.38g to 0.39g)	**0.52g** (0.50g to 0.53g)	**0.62g** (0.57g to 0.64g)	**0.62g** (0.57g to 0.64g)	**0.82g** (0.73g to 0.90g)	**~1.1g**	**~1.6g**
AEP (NZS 1170.5)	**1/40**	**1/100**	**1/250**	**1/500**	**1/1000**	**1/1000**	**1/2500**	**>1/2500**	>>1/2500
Likelihood event occurs in 100 years (based on NSHM 2022)	*98%*	*87%*	*63%*	*44%*	*33%*	*33%*	*18%*	*9.5%*	*<4%*
Attribute	**Expected Performance (to be confirmed in later stages of design)**								
Single span bridges and abutment	No Collapse Fully elastic, minimal damage. Minor settlement and lateral displacement of MSE abutment in the order of 100mm possible Usable by emergency traffic		No collapse. Abutments expected to have in the order of: • 200mm vertical settlements, • 400mm lateral displacement. Bridge deck may need to be relevelled to restore vertical clearance. Usable by emergency traffic within 3 days at reduced speed		No collapse. Abutments expected to have significant vertical and lateral displacement. Bridge deck may need to be removed or temporarily supported to reconstruct abutments and re-establish vertical clearances. Reduction in shoulders of carriageway underneath may be expected due to lateral displacement of abutments Usable by limited emergency traffic following repairs and with temporary propping.			Similar to CALS (Departure)	Collapse unlikely Significant horizontal displacement and settlements. Bridge likely needs to be replaced after seismic event Not expected to be usable by emergency traffic without significant repairs and / or temporary structures.
Multi-span bridges and bridge abutments	No Collapse Fully elastic, minimal damage Usable by emergency traffic		No Collapse Piles may hinge but with repairable damage expected. Usable by emergency traffic within 3 days.		No Collapse Extensive damage to bridge expected. Abutments expected to have significant vertical and lateral displacement. Usable by limited emergency traffic following repairs which may include temporary propping.			Similar to CALS (Departure)	Collapse unlikely. Bridge will need to be replaced. Not expected to be usable by emergency traffic without significant repairs / temp. structures.
Underpass & culverts	No Collapse Fully elastic, minimal damage Usable by emergency traffic		No Collapse Repairable damage Usable by emergency traffic within 3 days		No Collapse Extensive damage expected with replacement likely Usable by limited emergency traffic following repairs and including temporary propping.			Similar to CALS (Departure)	Collapse possible. Not expected to be usable by emergency traffic without temporary structures installed. Replacement required
Retaining walls not supporting bridges and soil structures (including Cut and fill slopes)	No Collapse Slope debris restricted to dedicated maintenance shoulders Usable by emergency traffic		No Collapse of retaining structures. Embankment displacement or slope debris could be expected with repairs limited to debris removal and reshaping of surfaces. One lane usable by emergency traffic within 3 days after repairs and debris removal		Damage throughout possible. Usable by limited emergency traffic following earthworks and slope protection to repair embankments and slopes.			Refer note [2]. Similar to CALS (Departure)	Significant displacement of embankments and large failures of cut slopes should be expected.
Overall New Rural Connector Route Functionality	*Functional with minor damage as set out for individual asset types*		Useable by emergency traffic within three days. Feasible to economically reinstate to a capacity sufficient to avoid collapse under a repeat design-level earthquake, and for serviceability for traffic		Useable by emergency traffic after temporary repair. Some assets may need replacement before traffic can be reinstated, as set out above.			Similar to CALS departure	Life safety principals achieved. Replacement of a number of assets will be required to re-establish the corridor.

[1] = The seismic demands presented are those applicable to structural design (i.e., magnitude weighted). Geotechnical design for the abutments / approach embankments will adopt the appropriate non-magnitude weighted demands for each limit state. The geotechnical design will be carried out as appropriate to support the structures design in achieving the performance outcomes for each limit state.

[2] = The DCLS displacements are likely to be higher than Bridge Manual limits. The expected displacement at each site, and associated proposed displacement limit, will be documented during subsequent design stages and incorporated within the final draft of the project MRs (and would be subject to NZTA final review).