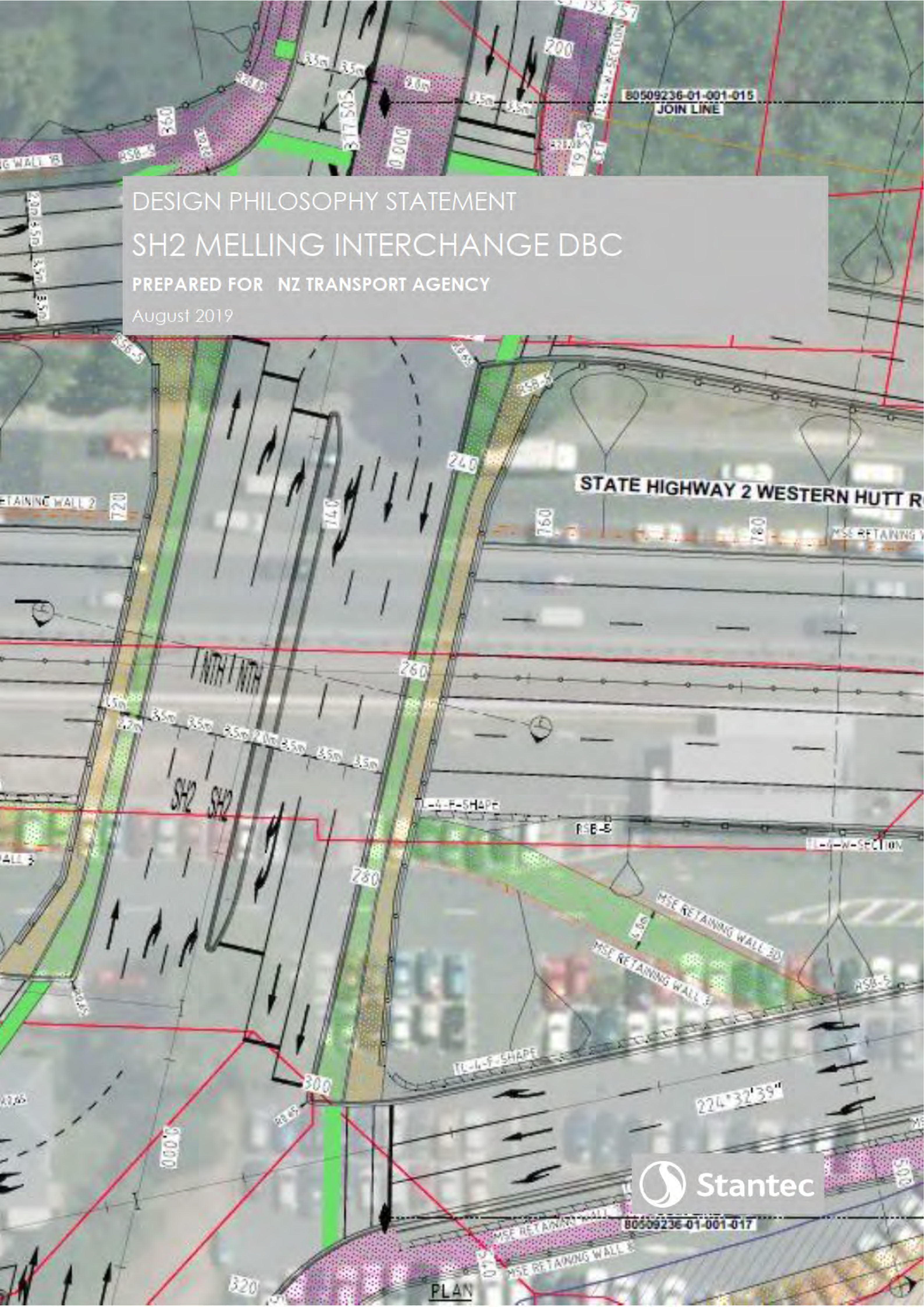
DESIGN PHILOSOPHY STATEMENT

SH2 MELLING INTERCHANGE DBC

PREPARED FOR NZ TRANSPORT AGENCY

August 2019



Stantec

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REVISION SCHEDULE

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			Prepared by	Checked by	Reviewed by	Approved by
1	08/05/18	DPS update following Stakeholder Feedback	9(2)(a) [redacted]			
2	30/08/19	DPS update for final DBC Report				

Abbreviations

ASD	approach sight distance
CBR	California bearing ratio
CPTED	crime prevention through environmental design
DBC	detailed business case
DPS	design philosophy statement
ESAs	equivalent single axles
FWD	falling weight deflectometer
GRD	Austroads guide to road design
GWRC	Greater Wellington Regional Council
HCC	Hutt City Council
IBC	indicative business case
MCA	multi criteria assessment
MGSD	minimum gap sight distance
MOTSAM	manual of traffic signs and markings
MSE	mechanically stabilised earth
NZTA	NZ Transport Agency
RAMM	road asset and maintenance management (software)
RE	reinforced earth
SISD	safe intersection sight distance
SSD	stopping sight distance
SUP	shared use path
LIDAR	light detection and ranging (topographical survey data
RLTP	regional land transport programme

NZ Transport Agency

SH2 Melling Interchange DBC

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1 Introduction

The NZ Transport Agency (Transport Agency) engaged Stantec to complete a Detailed Business Case (DBC) for the SH2 Melling interchange. This Design Philosophy Statement details the standards, guidelines, key criteria and assumptions that have been adopted to complete the design.

2 Background

2.1 Study Area

The study area is located at the intersection of SH2 with Harbour View Road and Melling Link, which extends north to the intersection of SH2 and Tirohanga Road and east across the Hutt River to the Hutt City central business district (CBD).[1]

The Transport Agency is working in partnership with Hutt City Council (HCC) and Greater Wellington Regional Council (GWRC) to develop a preferred design solution that supports HCC's long term public transport (PT) and CBD revitalisation objectives and integrates with GWRC's RiverLink flood protection (stopbank raising) project.

2.2 Previous Project Phases

This DBC phase follows on from an earlier Indicative Business Case (IBC) phase completed by Stantec in 2017.

2.3 Project Problem and Objectives

During the IBC phase the Transport Agency project team and stakeholder panel identified and agreed the following problem and benefit map for this project.

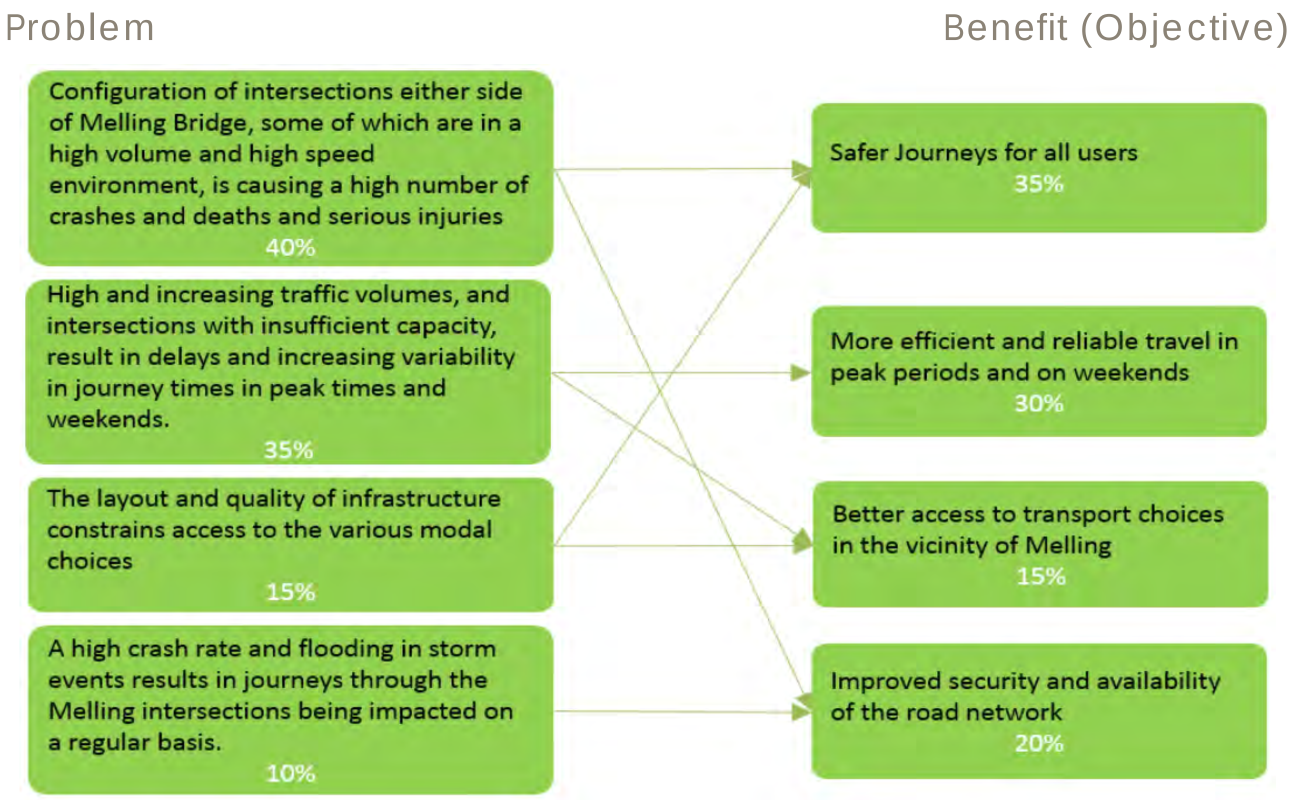

Figure 2-1: Problem and Benefit Map

[1] The cardinal directions in this document observe the convention that SH2 runs from north to south.

2.4 Option Development

The IBC phase of the project initially considered 11 options, each of which had various sub-component options. A multi-criteria analysis (MCA) workshop held in March 2017 reduced that long list to four options (Options 6, 7, 9 and 11), most of which also had sub-component options.

At the outset of the DBC phase, additional technical analysis (traffic modelling), road safety audit and a second MCA workshop in February 2018 further reduced the list of options. All options that included Tirohanga Road crossing over SH2 to join Pharazyn Street and the new interchange on the eastern side of SH2 were abandoned. All options that included any form of roundabout were also abandoned. The concerns that excluded these options from further consideration or ranked them low on the list of preferred options were mainly:

- traffic capacity constraints due to closely spaced intersections;
- traffic capacity constraints due to placing roundabout(s) and signalised intersections in close proximity to one another;
- safety, legibility, and signposting concerns with roundabouts with more than four legs and with closely spaced exits;
- space constraints at and north of the existing Melling Bridge due to limited width between the western hills and the Hutt River; and
- the preference for not building any more infrastructure in the river than was absolutely necessary to cross the river, as the number and the size of bridge piers has an impact on river hydraulics. This precluded any options that significantly encroached over the stopbanks and into the river channel.

A new sub-option that was suggested by the safety audit team (and is based on a development of a previously rejected layout), was re-introduced. This combined the Pharazyn Street intersection with the southbound ramp terminal intersection.

Based on the MCA and subsequent Transport Agency decision processes, the final three potential options were reduced to one preferred option which can be described as follows.

2.4.1 Diamond Interchange connecting straight to Queens Drive

The preferred option proposes a diamond interchange (DI) south of the current SH2/Harbour View Road intersection with a direct (straight) connection to a new bridge across the Hutt River, landing in Queens Drive. Tirohanga Road is connected to Harbour View Road via a new link adjacent to the northbound entrance ramp. Pharazyn Street connects to the interchange at a combined intersection with the southbound entrance and exit ramp terminal intersection on the eastern side.

Figure 2-2: Preferred option

The preferred option is the most compliant solution (from a geometric design perspective) given the general layout of the adjoining road network. The key benefits of the preferred option over the alternative options considered, are that it:

- reduces the number of signalised intersections at the interchange from three to two;
- provides an alignment into Hutt City that is direct, easy to understand, and easy to sign;
- shortens the overall road network and reduces the need for additional work on or over the stopbank (or in the river flood plain);
- and that it minimises the area of land required, maximising the future development potential for the Pharazyn Street area.

2.4.2 Capacity Assessment

A separate report discusses the capacity assessment (modelling) of the signals and the wider network. Refer to the DBC report.

3 Design Constraints

3.1 Available Land

The site is significantly constrained with limited land available between the river and the steep hillside and the immovable river corridor. Within that narrow width there is a need to accommodate a diamond interchange, a cycle network and a road link between Tirohanga and Harbour View. This results in closely spaced Intersections, and a situation where decisions to accommodate one thing will impact on other aspects. The lack of available land has necessitated the use of retaining structures to limit the footprint of the project.

3.2 Hillside Topography

The preferred option avoids as much encroachment into the hillside on the western side of SH2 as possible to limit geotechnical instability risks, and to minimise visual impact on the heavily vegetated hillsides above SH2.

3.3 Wellington Fault

The Wellington seismic fault runs parallel to both the Hutt River and SH2 and lies somewhere between the two. The aim is to avoid spanning the fault with any structures. This is a significant constraint on the layout of the intersections and the derivation of options. Although it cannot be guaranteed that a structure would not span the fault, as its precise location and breadth of influence are unlikely ever to be pinpointed, a best effort has been made to separate the Hutt River Bridge from the interchange bridge over the motorway as much as possible.

3.4 RiverLink Stopbanks

The proposed new positions and crest levels of the RiverLink stopbanks are major constraints and are, for all intents and purposes, non-negotiable. The only exception is the position and height of the stopbank on the right bank north of the existing Melling Bridge (i.e. near the skateboard park). Notwithstanding, the preferred alignment of the interchange southbound exit ramp has been refined to follow the inner edge of the proposed RiverLink stopbank, such that the exit ramp works do not encroach into the future river corridor.

The GWRC has expressed the desire that, where possible, no hard infrastructure should be incorporated into the stopbanks to enable and maximise the space available for the river to pass the design flood. The preferred design, does, however propose to incorporate the eastern bridge abutment for the new river crossing into the stopbank on the eastern side. It is expected that this will necessitate specific investigation and specialist design during the detailed/final design phase.

3.5 River Hydraulics

The current Melling Link Bridge is a significant constriction on river hydraulics as it coincides with the narrowest section of the river corridor (measured between stopbanks). The GWRC RiverLink project has expressed a desire to limit, if not remove, all infrastructure (e.g. bridge piers) in the vicinity of the current Melling Bridge.

3.6 Pharazyn Street

Pharazyn Street must be retained and must tie into the new interchange and bridge over the Hutt River. Pharazyn Street forms part of the Hutt City proposed ring road on the right bank of the Hutt River, and is an integral part of the HCC CBD renewal programme.

3.7 Pharazyn Street Residences and Businesses

All the existing residential, commercial and retail properties along Pharazyn Street have been identified for purchase as part of the RiverLink programme and therefore do not constrain the scheme.

3.8 Melling Station, Car Park, and PT Interchange

The existing rail line, Melling Station, and car park are not constraints. They can be moved southwards as far as is needed, provided that the new location integrates with the proposed pedestrian bridge across the Hutt River. The layout and design of the new Melling Station and any associated park-and-ride and/or PT (bus) interchange facility has not been advanced beyond recognising that they need to be relocated for the construction of interchange and providing the following conceptual sketch options for discussion. To date, a clear preferred option has not yet been identified. This is considered to be a project for GWRC to consider.

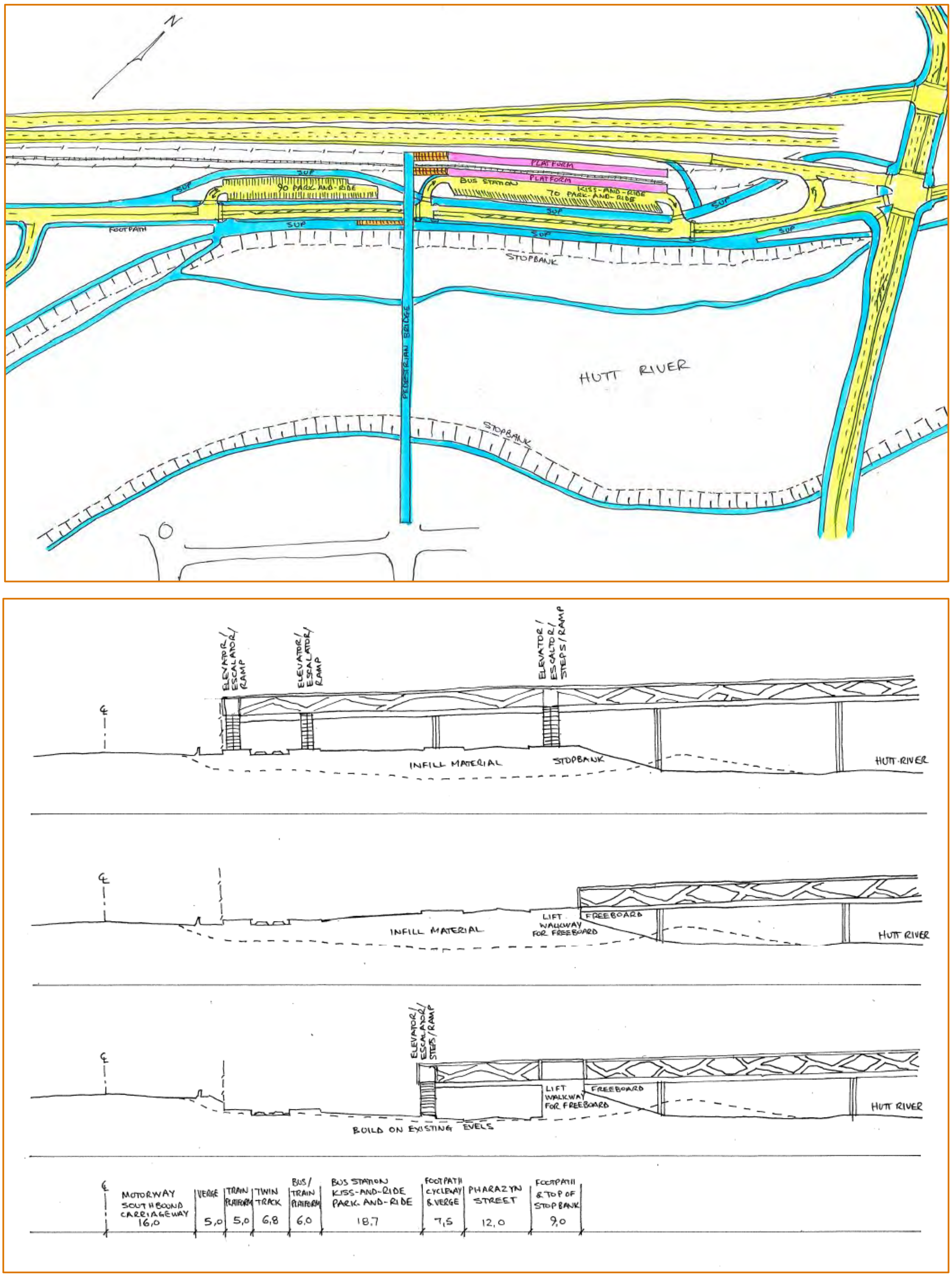

Figure 3-1: Possible options for relocated Melling Station

3.9 Queens Drive

The constraint at Queens Drive is to land the bridge at the intersection of Queens Drive and Rutherford Street at a low enough level that makes it possible to tie into adjacent property accesses. The properties surrounding the intersection are not to be considered to be insurmountable constraints. Given that the new bridge will direct significant traffic volumes into Queens Drive, there is a need to widen Queens Drive between Rutherford Street and High Street. The preferred alignment shows this widening occurring on the north-eastern side of Queens Drive.

3.10 Extending Rail North

The preferred layout of the interchange does impact on the ease of extending the Melling rail line to the north, however it does not preclude it.

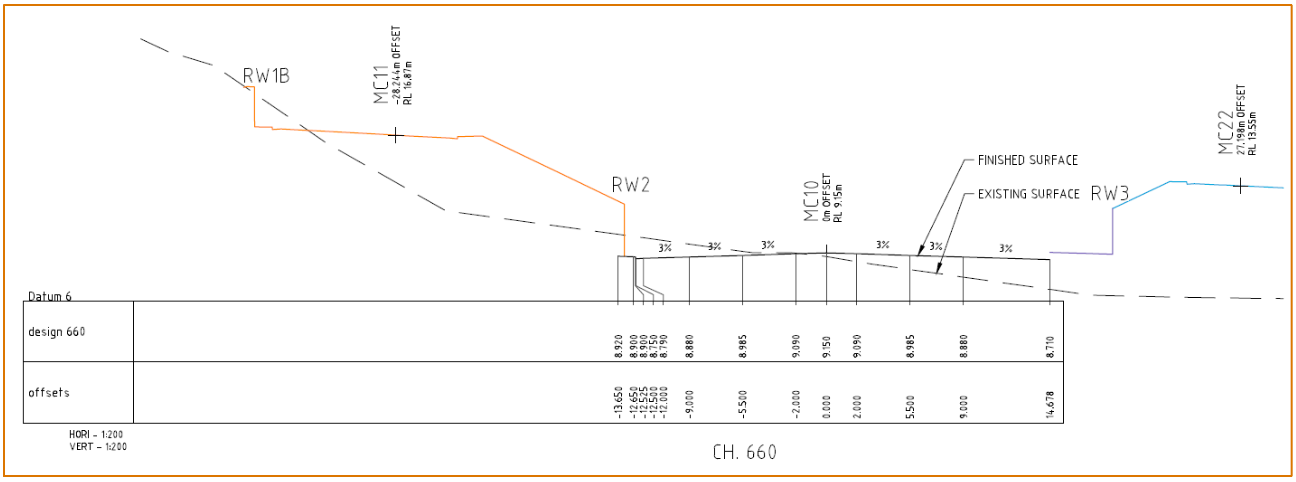

Figure 3-2: SH2 cross-section near interchange bridge

The span of the interchange bridge has been maximised to provide enough width and height to thread a single-track envelope through the interchange alongside SH2 (refer to the blue berm area adjacent to SH2 on the above figure). Nevertheless, extending the rail line north would be a costly and technically challenging exercise due to (amongst other things):

- the need to construct two significant box culverts under the southbound entrance and exit ramps, likely necessitating the full reconstruction of both ramps and rerouting the cycleway/share use path along the riverbank;
- the location and interaction with the Wellington seismic fault; and
- the need to transition the rail line over the stopbank north of the interchange to a position within the river flood plain, which could have an impact on the resilience of the stopbank system.

3.11 Skateboard Park

The existing skateboard park north of the Melling Bridge is not a constraint and will be decommissioned or relocated when the project proceeds.

3.12 Heritage Building

There is a heritage building located on the western side above SH2, between Harbour View Road and Tirohanga Road. The building has been scheduled in the City of Lower Hutt District Plan as "Lochaber / Prospect College". It is also listed as a Category 2 Building in the Heritage New Zealand, Heritage List / Rārangi Kōrero. Nevertheless, the preferred option for new interchange does not affect the heritage building or property directly, although access to the heritage building will need to be adjusted to tie into the realigned Tirohanga Road. The Transport Agency owns this building/property.

3.13 Notable Trees

There are two notable trees that have been scheduled in the City of Lower Hutt District Plan. The first is a pohutukawa (metrosideros excelsa) located on the corner of Harbour View Road/ State Highway 2 opposite Melling Railway Station. It is a mature spreading specimen, providing dominant tree cover in the area and is about a hundred years old. The second is a silver fir (abies alba) also located on the corner of Harbour View Road/ State Highway 2 opposite Melling Railway Station. It is a relatively rare specimen that is healthy, has reasonable form and is about a hundred years old.

The trees are not considered as insurmountable constraints as they are located within the existing state highway designation and could therefore be removed without the need to obtain resource consent. There could however be reputational issues with the public over the removal of the trees.

4 Road Design

4.1 General

The main road transport aspect of the project involves the replacement of the two signalised at-grade intersections of SH2/Harbour View Road/Melling Link and SH2/Tirohanga Road with a grade-separated interchange to create a safer, less congested junction. The project also includes the realignment of local roads, a new river crossing into Hutt City and the upgrade of PT and walking and cycling infrastructure. Generally, existing intersections and movements have been retained, however some re-routing has been required to replace the existing dual signalised intersections with one interchange.

4.2 Standards and Guidelines

The table below lists the standards that have been and will be used in the design of the project.

Table 4-1: Design standards and guidelines

Design element	Standards and guidelines
Road alignments	Austroads Guide to Road Design Part 1: Introduction to Road Design Austroads Guide to Road Design Part 2: Design Considerations Austroads Guide to Road Design Part 3: Geometric Design Transport Agency DRAFT State Highway Geometric Design Manual (SHGDM)
Intersections	Austroads Guide to Road Design Part 4: Intersections and Crossings – General Austroads Guide to Road Design Part 4A: Unsignalised and Signalised Intersections Austroads Guide to Road Design Part 4C: Interchanges
Road cross-section	Austroads Guide to Road Design Part 3: Geometric Design Transport Agency DRAFT State Highway Geometric Design Manual (SHGDM) Austroads Guide to Road Design Part 6: Roadside Design, Safety and Barriers Austroads Guide to Road Design Part 6A: Paths for Walking and Cycling Austroads Guide to Road Design Part 6B: Roadside Environment
Road safety barriers	Transport Agency M23 Road Safety Barrier Systems AS/NZS 3845: 1999 Road Safety Barriers Austroads Guide to Road Design Part 6: Roadside Design, Safety and Barriers
Road signs and markings	Transport Agency Manual of Traffic Signs and Markings (MoTSAM Parts 1, 2 & 3) Transport Agency Traffic Control Devices Manual (TCD Manual) https://www.nzta.govt.nz/resources/motsam/part-3/ • Figure 12.3 for standard exit markings and Figure 12.4b for the nose details. • 600 mm offset of the gore and 4.0 m width of the exit lane at the gore. • The exit taper is therefore 4.6/57.5 = 0.080 (i.e.1:12.5). • The width at the nose is 140/12.5 = 11.2 m made up of 4.5 m offset to nose + 1.2 width of nose + 2.0 m off set to nose + 3.5 m lane width. The lane width tapers from 4.0 m to 3.5 m over 57.5 m. • The entrance ramp details on Figure 12.7 and the 925 m radius. The 925 m radius can change depending on the main line alignment but the offsets at point 0, Y (265 m) and Z (317 m) must be observed. • The setting out of these points is shown in more detail on Figure 2.6(a). • The design philosophy assumes that ramp metering may be required at some point in the future. Accordingly, enough ramp pavement width will be provided to allow ramp metering markings to be put in place (if required). • Figure 2.6(b) (Figure 2.6A-2) shows a typical ramp metering layout.

Design element	Standards and guidelines
Tracking curves and design vehicles	LTNZ RTS 18 New Zealand on-road tracking curves for heavy motor vehicles http://www.nzta.govt.nz/resources/road-traffic-standards/rts-18.html • Semi-trailer design vehicle. For double right or left turns a semi-trailer turning next to an 11 m rigid truck is the design criterion adopted. • For local roads to the west of the interchange an 11 m rigid truck is the design vehicle.
Bridges	Transport Agency Bridge Manual 3rd Edition
Drainage	Refer to stormwater section.

4.3 Road Geometry

4.3.1 Speed environment and sight distance

The current speed limit on SH2 is 100 km/h. Given the classification of SH2, its general alignment, and the recent adjacent grade separation work along the route, it is envisaged that the posted speed limit will remain at 100 km/h. Although SH2 north of Ngauranga operates as an expressway, the design has adopted standards that would be applicable to a motorway. Therefore, a design speed of 110 km/h has been adopted for the SH2 (motorway) alignment through the interchange and 80 km/h for the interchange ramps.

The local road network has a speed limit of 50 km/h, but likely operates at a slower speed to the west due to the tight winding alignment and the mountainous terrain. To the east speeds are moderated by the number of closely spaced intersections, the relatively narrow bridge and the urban CBD environment of Hutt City. On that basis a design speed of 50 km/h will be retained for the local road network, recognising that at speeds of 50 km/h and less it is criteria such as tracking, vehicle rollover and safe intersection visibility that drives design geometry, less so design speed, superelevation, comfort criteria, and stopping distance. Stopping sight distance of at least 55 m from 1.1 m to zero target height will be maintained throughout the local road network.

The minimum parameters adopted for calculating stopping sight distance (SSD) are given in the table below. Calculated sight distances will need to be grade corrected as appropriate.

Table 4-2: Stopping sight distance parameters

Design Speed	Coefficient of deceleration	Reaction time	Stopping sight distance
110 km/h	0.36 g	2.5 s	209 m
80 km/h	0.36 g	2.5 s	126 m
50 km/h	0.36 g	2.0 s	55 m

The standard object and driver heights from Austroads Guide to Road Design: Part 3 have been adopted for the project.

Priority controlled intersections will be designed to ensure they meet the requirements for stopping sight distance (SSD), safe intersection sight distance (SISD), approach sight distance (ASD) and, where possible, minimum gap sight distance (MGSD). Values are shown for cars below.

Table 4-3: Sight distance values for cars for a design speed of 50 km/h

Criterion	Distance	Indicative K-value
SISD	97 m	10
ASD	55 m	14
MGSD	55 m – 139 m (depending on critical gap acceptance time)	N/A
CSD	13.9 m x [critical safe gap (crossing length x walking speed)]	N/A

The interchange exit ramps will be designed in accordance with Austroads GRD Part 4C Section 7.3. This results in the following sight distance requirements.

- 10 s to the start of the exit taper; start of the gore; to the nose; and to 60 m beyond the nose on the ramp (nominal 310 m) - All measurements are from 1.1 m to road surface level i.e. zero target height.

4.3.2 Road cross-section

Typical cross-section dimensions are given in the table below. These are indicative only and are subject to change depending on specific contextual requirements.

Table 4-4: Cross-section elements

Element	Width
SH2	
Traffic lanes	3.5 m
Sealed shoulders	3.0 m
Median	4.0 m between edge lines. This provides 1.5 m min inside shoulders and 1.0 m for a rigid barrier, or 2.0 m inside shoulders if the preferred wire rope median is adopted.
Clearance envelope to structures	10 m wide x 6.0 m high per carriageway
Melling Link / Queens Drive Bridge	
Traffic lanes	3.5 m
Median	2.30 m (widened where right-turn pockets are required)
Shoulders	0.30 m or channel width as applicable. No Stopping lines will be required. Cyclists will be on an adjacent shared path.
Tirohanga Road	
Traffic lanes	3.5 m
Shoulders	0.30 m or channel width as applicable to match existing cross-section width. The existing road is about 8 m to 8.5 m wide, so the new road will be consistent with that. The shoulders will not be specifically marked; however, No Stopping lines may be required on both sides.
Harbour View Road	
Traffic lanes	3.5 m
Shoulders	1.75 m to match existing cross-section width with the removal of the climbing lane
Pharazyn Street	
Traffic lanes	3.5 m
Shoulders	1.50 m. No Stopping lines will be required. Pedestrians will be on an adjacent footpath.
Footpaths and cycleways	
Refer to Chapter 8.	

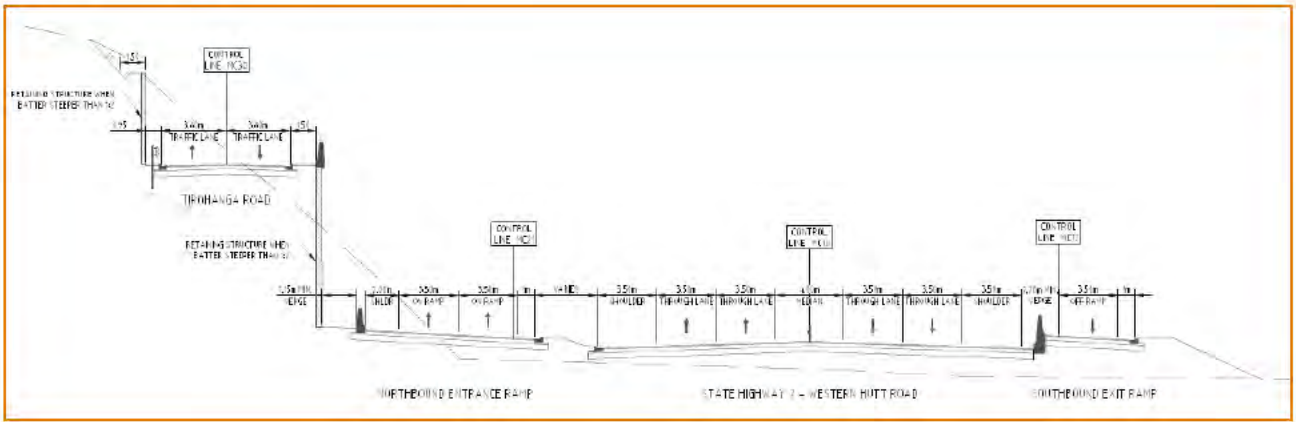

Figure 4-1: SH2 Design Cross-section

4.3.3 Barrier design

The project comprises median and side protection barriers on the state highway in accordance with a safe system philosophy. Barriers on the inside of horizontal curves may restrict forward sight distance. Rather than provide artificially wide shoulders which can have negative implications (for instance vehicles parking in the widened area reducing sight distance or vehicles impacting safety barriers at angles greater than the system has been designed for), suitable, but not excessive, shoulder widths have been provided. On the state highway a minimum outer shoulder width of 3.0 m has been adopted.

Other barrier design parameters adopted include:

- median wire rope barrier that transitions to a TL-5 concrete median at the northern end to tie into the existing split level between the two carriageways;
- TL-5 side barriers on the interchange bridge and river bridge;
- 1.1 m sway allowance from toe of barrier to face of bridge column or retaining walls;
- wire rope barriers (WRB) on SH2 for outside shoulder protection, except for a short section of TL-5 back to back barrier where the southbound offramp alignment runs parallel with the SH2 shoulder; and
- semi-rigid barriers on ramps, but WRB where possible.

4.3.4 Lighting design

Given the preference for a WRB in the central median, street lighting is proposed to be placed in the berm areas or on the edge of structures or within the rigid barrier where available width is limited along the railway line.

The lighting design, to be confirmed during final design, should be based on relevant sections of the AS/NZS 1158 Lighting for Roads and Public Spaces (Parts 1.1 and 3.1) standard and any local requirements. All electrical installations will need to comply with the New Zealand Wiring Rules AS/NZS 3000. Local Road luminaires to be approved by Local Authority so they are compatible with existing lighting. This includes things like the need to have 7 pin NEMA socket.

The following lighting category assumptions have been assumed at this stage, based on the criteria from Part 1.1: Table 2.1 and Part 3.1: Tables 2.1 and 2.9 of AS/NZS 1158:

SH2	Category 'V3'
Shared use path along SH2	Category 'P3'
Signalised intersections and signalised crossings	Illumination in accordance with AS/NZS 1158
Interchange bridge, new river crossing, Pharazyn Street	Category 'V2'
Harbour View Road, Tirohanga Road	Category 'P2'
Shared use paths outside SH2	Category 'P2'

4.4 Intersection Treatments

The design seeks to reduce conflicts and achieve a safe system. Changes are proposed to all intersections within the study area, through change in form, control or restriction of certain movements. No specific access restrictions are proposed; however, some connections have become more (or less) circuitous as a result of consolidating two intersections into one and the relocation of the river crossing to a more southerly location.

4.4.1 Interchange

A grade-separated interchange is proposed to replace the following at-grade signalised intersections:

- SH2/Harbour View Road/Melling Link, and
- SH2/Tirohanga Road/Block Road.

4.4.2 Signalised Intersections

Signalised intersections are proposed at the following locations:

- the ramp terminal intersections either side of the interchange (including the consolidated intersection with Pharazyn Street); and
- the four local road intersections of:
    - Melling Link / Rutherford Street
    - Melling Link / High Street
    - Queens Drive / Rutherford Street
    - Queens Drive / High Street

4.4.3 Priority-controlled Intersections

A priority-controlled intersection is proposed at the new Tirohanga Road / Harbour View Road intersection.

4.5 Pavement Design

No pavement investigation work (or design) has been completed to date. The preferred option scheme design assumes the following pavement composition.

- SH2 Main alignment
    - 40 mm SMA or OGPA
    - 200 mm of AC20
    - 250 mm of GAP65
    - Subgrade of 3.5%

High volume side roads (Interchange ramps, HCC CBD streets, Pharazyn street)

- 40 mm SMA
- 180 mm of AC20
- 200 mm of GAP65
- Subgrade of 3.5 %

Low volume side roads (Tirohanga Road and Harbour View Road)

- 40 mm SMA
- Membrane seal
- 180 mm of M4
- 200 mm of GAP65
- Subgrade of 3.5 %

The above assumptions will need to be refined during final design by looking at the traffic volume, estimating the growth in traffic and investigating/testing the subgrade. Given the location there is a risk that the subgrade might be worse than the CBR of 3.5 assumed above, which would necessitate thickening up the pavement and/or providing subgrade improvement layers. At this stage, the cost estimate has included provision for removing about 600 mm of unsuitable material below the subbase in cuttings and replacement with subgrade improvement layers. The design philosophy for the final pavement design should include:

- analysing historic RAMM data to determine the current pavement structure on SH2 and the affected surrounding local network;
- confirming areas for new pavement construction and the interface with existing pavement (the design should ensure that any interface is not along wheel tracks);

- developing an inspection and test plan (pavement test pits, LABs, CBRs, FWD deflection testing) to confirm material parameters;
- confirming new material properties (e.g. quarry and asphalt);
- confirming the design ESA for SH2 and the local network roads; and
- developing pavement design options and analysing them using CIRCLY software.

The final pavement design should also be developed with reference to Austroads Guide to Pavement Technology (AGPT02-12) and the New Zealand Guide to Pavement Structural Design (NZTA, 2017). Local road pavement types and designs will need to be approved by the HCC Road Asset Manager.

4.6 Signs and Markings

The philosophy adopted has been to design a road and lane layout that is clear and legible for all road users and can be signed in a straightforward manner.

As part of the DBC only key destination road signs have been detailed in accordance with Figure 2.8 of MOTSAM Part 3: Motorways and Expressways. These include overhead interchange exit signs for the exit ramps, as the expressway is deemed to be urban, and overhead lane assignment signs for Harbour View Road / Queens Drive crossing the Hutt River.

All additional signage (e.g. regulatory signs, information signs, warning signs, etc) should be detailed during the final design phase and will necessarily need to comply with the TCD Rule. It is further envisaged that additional SH2 signage will conform to the Transport Agency TCD Manual (and any relevant MOTSAM documents that have yet to be superseded) and that local roads will conform to HCC signage standards and MOTSAM Part 1.

A road marking design has been detailed for the preferred option. It is anticipated that all SH2 markings will conform to MOTSAM Part 3 and that both ATP and RRPMs will be required. All local roads will conform to MOTSAM Part 2.

5 Geotechnical and Earthworks Design

Geotechnical assessment to date has been limited to a Stantec Preliminary Geotechnical Appraisal Report (PGAR) which included a review of readily available historical information at the site.

A high level Transport Agency ground investigation has been completed in the general locations of the proposed large structures (interchange at SH2 and bridge over the Hutt River), consisting of one fully cored borehole and cone penetration testing at several locations. The locations for the Transport Agency ground investigations have been chosen to incorporate the proposed Greater Wellington Regional Council (GWRC) stopbank investigation and upgrade in the area. Sharing of ground information has been agreed between the Transport Agency and GWRC.

The design parameters stated below should be viewed as an initial guide only. Design parameters should be revised following each stage of ground investigation and interpretation. Significant geotechnical risks at this stage of the project include variable ground conditions, the location of the Wellington Fault, which is understood to be between the proposed interchange and bridge, and constructing deep foundations into the artesian gravel aquifer.

All geotechnical investigations will comply with the Bridge Manual.

5.1 Cut Slope Stability

No significant cut slopes are likely at this stage. If cut slopes in natural materials are required, then the cut batter angle will depend upon the nature of the cut material and height. At this stage, cuts in slightly to moderately weathered greywacke rock should be capable of supporting slope angles of 0.5H:1V (64°). Superficial soil layers such as colluvium and alluvial deposits may stand up at between approximately 1H:1V (45°) to 2H:1V (26°).

Adequate protection will need to be provided to the road to ensure the life safety of customers in design events. This may require reduced slope angles and/or slope protection.

5.2 Fill Slope Stability

Fill slopes under 3m should remain stable unsupported between 2H:1V (26°) and 1.5H:1V (32°) depending upon the nature of the fill material and proximity to the Wellington Fault zone. Slopes steeper than this should be reinforced or retained while fill slopes adjacent to the Wellington Fault zone may require reinforcing.

One of the key considerations of the design will be integration with GWRC's proposed stopbank upgrade and the proximity of structures to the Wellington Fault zone. Stopbanks are present on both sides of the Hutt River. Bridging, interchanges and buried services will need to take account of stopbank locations and proposed heights.

The Wellington Fault zone is understood to be near the current Melling Bridge, roughly following Block Road. Structures such as bridges and key retaining walls should be located as far away from the fault zone as possible. A more accurate location of the fault zone is proposed to be investigated as part of the GWRC ground investigation. The resilience of any embankments or retaining walls that are near or cross the fault zone will be specifically considered as part the design development process.

6 Structural Design

6.1 Structural Design Approach

- All bridge and retaining structure designs are in accordance with the NZ Bridge Manual 3rd Edition, Amendment 3.
- Mechanically Stabilised Earth (MSE) retaining structures have been used where possible and are highly tolerant to seismic movements.
- Box culvert underpass structures are seismically tolerant with very little damage expected following a Damage Control Limit State (DCLS) earthquake.
- With liquefiable ground present it is expected that following a DCLS earthquake extensive damage will occur to all existing major infrastructure in the immediate area and beyond. Integral Super-T beams on bankseats sat on MSE abutments are highly tolerant of these expected settlements/movements. They are capable of being reinstated very quickly via jacking. Longitudinal seismic actions will be resisted by a combination of friction beneath the abutment beam and passive resistance behind the abutment. Transverse seismic actions will be resisted largely by friction beneath the abutment beam, although some passive resistance will be provided by the wingwalls. Where the longitudinal and transverse seismic actions exceed the friction and passive resistance in a DCLS or Collapse Avoidance Limit State (CALS) event, it is intended that the bridge slides on top of the RE wall, thus resulting in only minor relevelling and surface reinstatement post-earthquake.
- No deck joints or bearings are proposed as the structures will be designed fully integral where possible thereby minimising whole-of–life costs.
- Due to the close proximity of the Wellington Fault a site-specific seismic hazard assessment is recommended during final detailed design.
- If deemed necessary, ground improvements, such as stone columns, may be considered or perhaps discussions with the Transport Agency held to consider a departure from standard to minimise the high costs associated with such extensive resilience work on approaches. Where necessary any Departures from Standard that are deemed necessary will be applied for via standard Transport Agency processes.
- 3D models of the structures will be analysed using time history analysis to establish cost-effective bridge design.
- Settlement slabs will be provided on approaches to all structures.
- The bridges spanning SH2 will have appropriate clearances in accordance with Appendix A of the NZ Bridge Manual.
- Edge protection (barriers) will be to the appropriate Test Level in accordance with Appendix B of the NZ Bridge Manual.
- Full hydraulic design will be considered at the detailed design stage for the piers present in the watercourse. It is proposed that the river bridge soffit level will generally be arched well above the top of stopbank level (i.e. Q440) apart from locally near the stopbank on the city (Rutherford Street) side where the road surface ties in with the top of stopbank to permit tie in to the existing roading network.
- The design will need to consider the interface and interaction with flood protection structures and the resulting earth pressures and potential failure modes resulting from the design flood.
- Careful consideration will be required at the detailed design stage to ensure appropriate design details are implemented at the "hard" abutment structure/"soft" stopbank interface such that the stopbank is not compromised through thermal, flood or seismic actions.

6.2 Bridges

6.2.1 Interchange bridge

The bridge deck comprises 35 m precast pre-stressed concrete Super-T beams with in situ concrete deck on reinforced concrete bankseats on MSE abutments. Dead and live loads are transferred through the girders directly into the abutment beam and into the MSE abutment retaining walls.

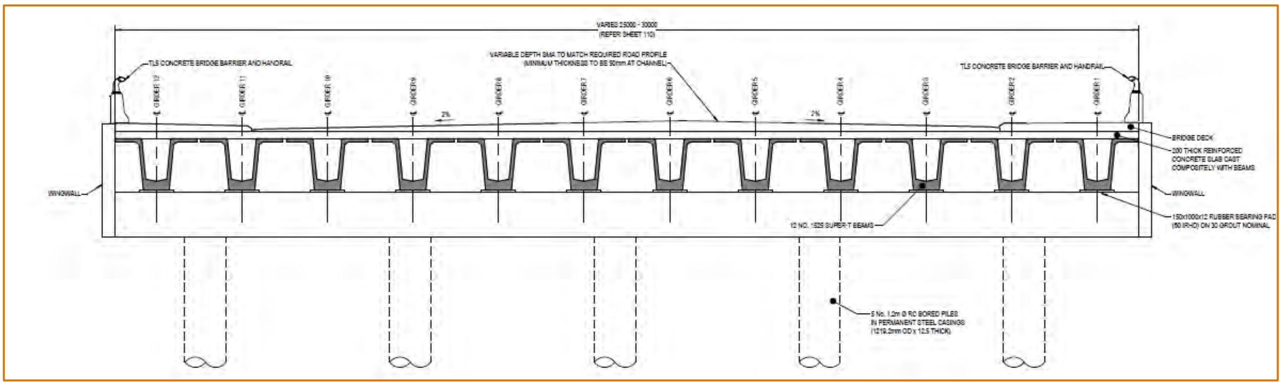

Figure 6-1: Proposed Interchange Bridge typical cross-section

6.2.2 Cycleway subways

The pedestrian/cycle underpass providing access to and from the relocated railway station comprise reinforced concrete off-the-shelf box culvert/subway units. The path alignment is relatively straight on all options therefore visibility through the underpass structure is good and public safety not compromised. Lighting will be provided for night-time use. A CPTED assessment will be required as part of the final detailed design process.

6.2.3 Hutt River bridge

The approximate length of a new Hutt River bridge from stopbank to stopbank is approximately 175 m. It is proposed to span this distance with a five-span Super-T superstructure with spans of approximately 35 m on piled foundations. This type of structure is tried and tested in New Zealand and has proven to be a cost-effective solution with low whole-of-life costs.

Bridge piers would generally follow the river alignment and be parallel with the flow of the river to minimise river disturbance and scouring effects. Given the proposed width of the bridge (4 x 3.5 m traffic lanes + 2 x 3 m shared paths + raised median) a solid slab pier is proposed as this reduces the likelihood of debris entrapment and the lateral loading effects when the river is in spate.

The required hydraulic capacity of the river influences the size and shape of the piers and the height of the underside of the bridge (required freeboard at points across the river).

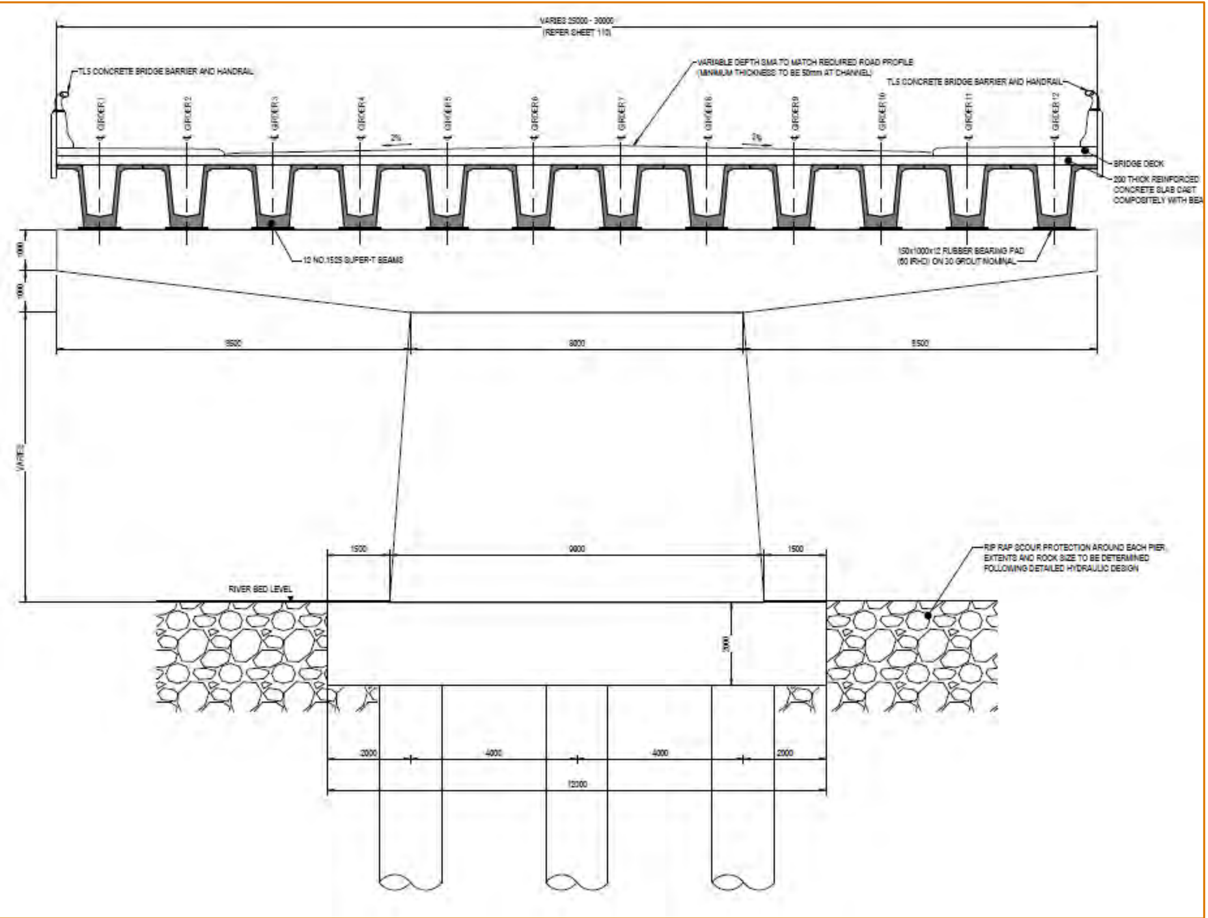

Figure 6-2: Proposed Hutt River bridge typical cross-section at pier

6.3 Retaining Walls

The design intent is to avoid interchange ramp retaining walls on the river side. The design philosophy is to locate the ramps slightly outside the stopbank alignment such that any ramp fill slopes tie into the top of the stopbank.

6.3.1 Interchange ramps

MSE type structures are the proposed retaining method for the entrance and exit ramps. This is in keeping with other recently constructed sections along the SH2 route.

6.3.2 Tirohanga Road

Retaining structures above the northbound exit ramp and Tirohanga Road are proposed to be soldier pile and precast concrete infill panel walls tied back with grouted anchors.

6.4 Visual Amenity

Given the height and the scale of the structures required to form the interchange and the new Hutt River crossing there is likely to be an impact on the built environment and visual amenity of Hutt City.

As part of the design development process it will be important to ensure:

- that the design integrates with proposed Hutt amenity improvements, and
- considers the need for an iconic bridge and how any extra costs associated with delivering an iconic bridge would be met.

To achieve an elegant solution for a 'proper front door' to the central city HCC has suggested that a robust design review process, similar to that used for the SH2/SH58 project, should be adopted. The SH2/SH58 model informed decision making for site planning, engineering, aesthetics, and public safety. It also included an agreed design review team which comprised skills for urban design, architecture, landscape, and public safety.

Experience from SH2/SH58 suggests it would be most productive to utilise these skills from an early stage and to peer review each stage of final design development, contract procurement, and through construction (incl. value engineering and contract variations) to practical completion.

6.5 Construction Challenges

The following challenges apply to the design and/or construction.

- Soft, weak, compressible founding materials that are potentially susceptible to liquefaction.
- Proximity to the Wellington Fault – exact location unknown - although the new river bridge would appear not to span the fault as currently mapped by GNS. More accurate mapping of the fault zone is recommended.
- Slope instability of cut faces, particularly along Tirohanga Road and the properties above.
- Proximity to aquifers during pile installation with positive head of +5 m may require specialist piling techniques to minimise the potential negative effects (contamination) on the aquifer.
- Pile installation in river.
- Connecting the bridge structure with the stopbank and/or additional pipes to convey stormwater through the stopbanks could interfere with the integrity of the stopbanks.
- River contamination during construction.
- Flood/collision/debris raft loading on piers.
- Traffic delays during construction.
- Reputational risk due to delays.
- Business claims for loss of profit due to delays.
- Inclement weather and flooding of the river site.
- Rupture of the Wellington Fault.

7 Stormwater

7.1 Overview

The Transport Agency Stormwater Treatment Standard for Road Infrastructure sets the framework for stormwater management and aims to "*provide the best practice for both stormwater quantity and quality control in the absence of local requirements or where local requirements are limited, Transport Agency will undertake to demonstrate environmental responsibility*"

The following stormwater aspects will be considered for the project in order to provide sufficient information to enable the processing of resource consent applications.

This section outlines the main aims and objectives of various national standards which support a stormwater strategy for the Melling Interchange.

The key reference sources used in this assessment are:

- Wellington City Council Water Sensitive Urban Design (WSUD);
- NZ Transport Agency P46: April 2016 – State Highway Stormwater Specification;
- NZ Transport Agency Stormwater Treatment for State Highway Infrastructure (May 2010);
- Regional Standards for Water Services - Wellington Region (November 2012);
- Water Sensitive Design for Stormwater - Auckland (March 2015).

Common terms used to describe stormwater treatment in the reference sources are:

- SUD – Sustainable Urban Drainage;
- LID – Low Impact Design;
- WSUD – Water Sensitive Urban Design.

The principles or LID and WSUD are similar, both focus on the introduction of systems which reflect natural treatment systems and at source control and treatment. Stormwater management has evolved over the last two decades from the application of individual SUD systems through into more holistic LID and WSUD approaches. The latest guidelines on WSUD being promoted both by Wellington City and Auckland City.

The Transport Agency has requirements for stormwater conveyance, treatment and fish passage. Their policy both relates to cross drainage (drainage from outside the immediate project area) and the collection and treatment of stormwater from within the project area.

The design philosophy is to separate between contaminated stormwater flows and clean stormwater to minimise the volume for treatment, which ultimately makes treatment more effective, and also to apply a treatment train approach that considers both source control and treatment.

Additionally, the fundamental requirement for stormwater collection is to mitigate the impact on increasing stormwater volumes on the downstream receiving environment by either mitigation storage or by increasing the downstream system conveyance capacity.

The best control measure to apply in this regard is to look to introduce a range of surface treatment options to reduce the post development runoff potential down towards pre-development levels. i.e. by introducing permeable surface paving, tree pits, and or rain gardens or wetlands that remove peak flow runoff in part or in whole by varying degrees of ground soakage.

Table 7-1: Consent Considerations

Stormwater aspect	Significance
Pavement drainage quantity and quality	Development of stormwater treatment concepts and their impact on off-road land requirements.
Off-road stormwater quantity	Check upgrade and design requirements for transverse drainage structures.
Wider catchment issues	Flooding impacts

In addition to interacting with sensitive receiving environments, the proposed interchange will interact with the existing infrastructure including local roads, property accesses, drainage infrastructure etc.

7.2 Reference Documents and Standards

The following documents contain information relevant to the project area:

- Bridge Manual SP/M/022, Transport Agency
- Draft P46 State Highway Stormwater Specification, Transport Agency, 2015
- Stormwater Management Issues and Options for Wellington Region, GWRC
- Stormwater Treatment Standard for State Highway Infrastructure, Transport Agency, 2010
- Wellington City Council Water Sensitive Urban Design, Current
- Wellington Land Development Manual, 2012
- Regional Standards for Water Services – Wellington, 2012
- Tools for Estimating the effects of Climate Change on Flood Flow, Ministry for the Environment, 2010
- TP10 Stormwater Management Practice, Auckland Regional Council
- Water Sensitive Design for Stormwater - Auckland (March 2015)

7.3 Historical Flooding

The Hutt River and sections of SH2 in the vicinity of Melling bridge do flood. This includes sections of local roads (e.g. Block Road) which become impassable in high rainfall events.

Image from Stuff.co.nz

Figure 7-1: Flooding on Block Road under Melling Bridge

7.4 Design Constraints

7.4.1 Summary of design constraints

The following design constraints are recognised.

- Sensitive receiving environment (Hutt River)
- Land constraints
- Proximity to stopbanks, reserves and houses
- Existing road infrastructure
- Existing flood levels, flow routes etc.
- Stakeholder requirements
- Contaminated land
- Property

7.5 Design Approach

The following design approach was undertaken:

Table 7-2: Design Approach

Aspect	Approach
Infrastructure	• Site walkover • Review of LIDAR, RAMM data and bridge drawings
Planning	• Discussions with GWRC regarding the RiverLink Stopbank project • Review of Hutt City Council contaminated land data base • Review of the proposed Wellington Regional Council – Proposed natural Resources Plan • Review of Hutt City District Plan
Peak flows	• Rational method for culverts • HEC-HMS/HEC-RAS model for the larger catchments.
Treatment	• Determined the extent of the highway where treatment is necessary based on environmental constraints

The western side of SH2 is mountainous, and between Dowse Drive (Maungaraki) and Wairere Road (SH2 north of Melling Bridge) there are a number of culverts already under SH2. Some take significant hill catchments and some have concrete wall surrounds at the SH2 road edge.

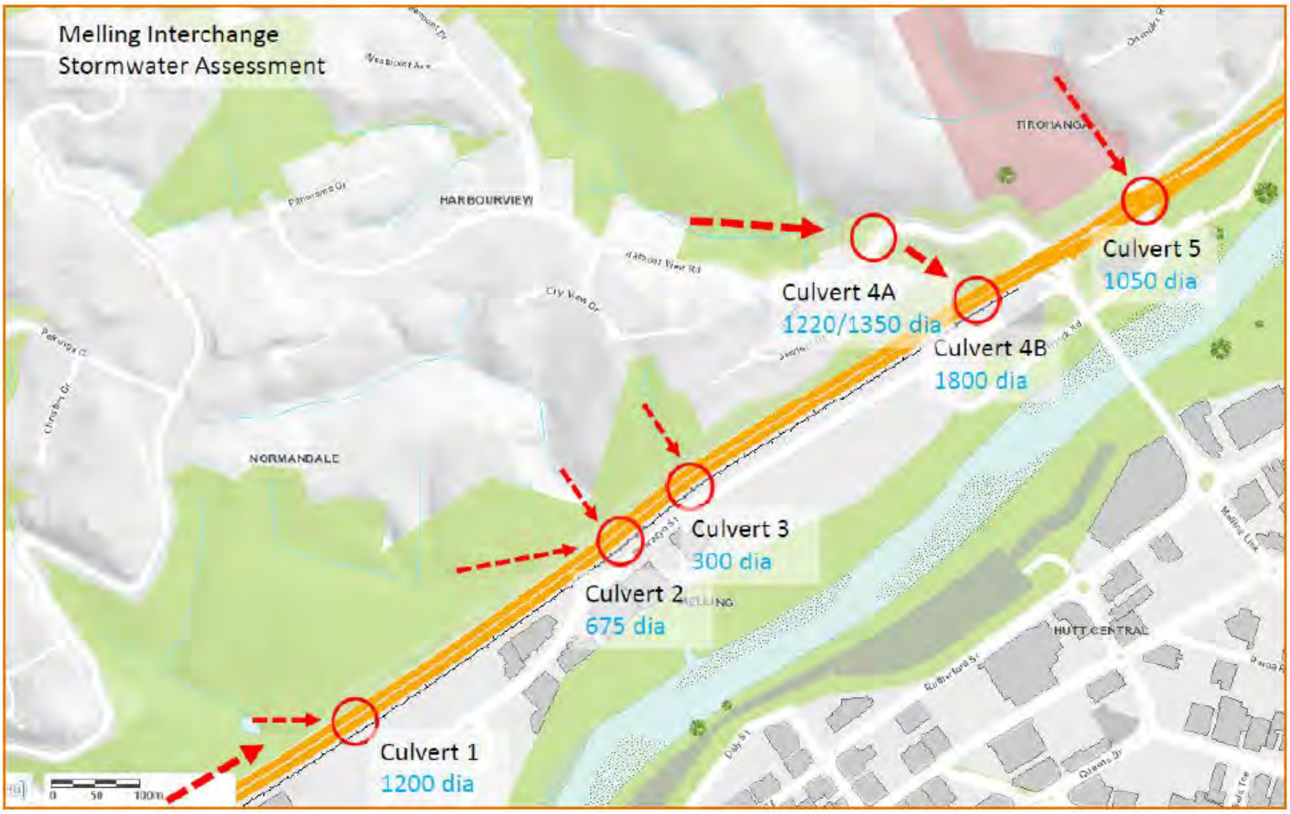

Figure 7-2: Cross drainage culverts

The initial high-level assessment (based on an assessment of RAMM, a site walkover and a hydrological calculation) indicates several of the cross-drainage culverts are undersized with a level of service between a 5 and 10-year storm event ARI (average return interval). These are likely to be at risk of local flooding which may or may not impede traffic flow on SH2 and may not comply with current Transport Agency requirements.

The catchment with the largest flow drains the Harbour View Road gully and is in the direct location of the proposed Melling Interchange. Peak storm flows from this catchment are anticipated to be 10 m3/s for a 100-year storm event. The stormwater intake into the head of the culvert is located within a steep sided gully, crossed on the downward side by the Harbour View Road embankment. This culvert has a 1350 mm internal diameter pipe and directs stormwater on a 4 % grade under Harbour View Road and discharges about 20 m upstream of SH2 into an open channel. This pipe has a full flow capacity of 10.7 m3/s.

The stormwater discharged from the Harbour View Road gully into an open channel then enters a box culvert approximately 1.5 m wide by 1.2 m high before discharging into the Hutt River.

The works associated with the proposed new bridge crossing and approach into Harbour View Road, will impact on the 1350 mm pipe, open channel and entry point into the box culvert and require a new stormwater pipe to avoid the bridge piles and new earthworks.

The hydraulic capacity shortfall at several other cross highway culverts may be resolved through the creation of a secondary overland flow path between those culverts and the installation of the new stormwater culvert from the Harbour View Road Gully.

A new stormwater collection system will be required to collect stormwater from the new Melling Interchange – the system should be designed to meet performance limits outlined in NZ Transport Agency standards, namely, providing a collection system capacity to meet a future 10 year ARI storm event (with climate change), and passing stormwater through a stormwater quality treatment device, either at source or located in downstream locations, prior to discharge into the Hutt River.

7.6 Treatment

Treatment needs to be incorporated where practicable. Liaison with GWRC around risk reduction, use of existing culvert locations, maintaining fish passage, provision of a maintainable drainage solution, and minimisation of drainage structures are all considerations.

Assuming treatment is needed, available space is an issue. Swale treatment is a consideration for the western side of SH2 (within vegetation) or use of the fill batters (with planting and concrete strip vanes to disperse road runoff). Alternatively, the use of proprietary devices such as online filters like ‘downstream defenders’ could be placed in maintainable areas such as the carpark next to the current Melling Link Bridge.

There may be potential to locate stormwater treatment facilities such as wetlands on the upper berm of the river (within the Hutt River corridor), incorporated into the overall biodiversity improvements of RiverLink.

If there is a consent condition that requires not increasing stormwater discharge, then detention may be required. This could be accommodated by the use of oversized culverts placed longitudinally e.g. 2 m diameter culverts holding water around the low points.

The recommended design approach is to minimise the volume of stormwater runoff needing conveyance and treatment by maximising the use of ground soakage and or mitigation storage through the use of raingardens, swales, tree pits and wetlands to reduce the peak runoff flow and to remove contaminants, sediments and silts.

There is the potential to neutralise an increase in stormwater runoff flows from the additional seal area by providing permeable paving for surface treatment and through the use of SUD stormwater treatment devices including a wetland treatment zone.

7.7 GWRC RiverLink Flood Protection Project

Consultation with GWRC will be continued regarding their proposed river training works over the next 10 years as this could affect the way the river is trained and therefore affect pile and abutment design in relation to attraction of scour. In addition, the location of the bridge needs to consider culvert location.

8 Pedestrian and Cycling Infrastructure

The Wellington RLTP states that 'providing separated cycling facilities on or adjacent to high volume, high speed highways and roads' is a priority. It also highlights that, as well as providing options for less experienced riders, 'these corridors must also provide options for more experienced cyclists who may wish to travel at greater speeds.' Accordingly, the design approach for cycling is that facilities separated from general traffic (i.e. dedicated cycle lanes and/or off-road shared use paths and/or separated paths such as Copenhagen style cycle paths) will be provided for cyclists passing though the SH2 Melling interchange and across the Hutt River. On local roads, on-road facilities (e.g. wider traffic lanes or shoulders) will be provided for experienced riders. Generally, pedestrians will be accommodated on a network of shared use paths and footpaths tying into and matching existing footpaths. In general, crossings will be toucan style signalised crossings or subways for both pedestrians and cyclists.

A minimum width of 4.0 m for the shared use path has been adopted. This allows a number of shared or separated arrangements to be considered during the detail design phase. It is proposed that the shared use path be grade separated through the interchange to provide an equivalent level of service for cyclists and pedestrians as that provided to road-based traffic.

A high level of service cycling network with complete connectivity has been designed so that it can be expanded beyond the limits of the scheme to tie in with any future walking and cycling facilities, especially on the Hutt River side of SH2.

8.1 SH2

There are currently no specific expressway cycling facilities on SH2 in the vicinity of the existing Melling Link intersection. Confident cyclists tend to cycle in the left-hand traffic lane. Less confident cyclists are not catered for. The narrow footpath adjacent to the traffic lane has a relatively poor riding surface and is unlikely to be suitable for use as a shared use path in its present configuration. There is no road shoulder. Refer to Figure 8-1.

Figure 8-1: Current lane arrangements on SH2 where cyclists share the lane with general traffic

The design philosophy for SH2 is to provide a safer alternative to crossing the exit and entrance ramp gore areas in both north and southbound directions. The ramps will have generous road shoulders that can be utilised by cyclists. In both northbound and southbound directions, cyclists will be able to cycle on the ramp shoulder up to the ramp terminal intersections where they can join the off-road shared use path facilities and cross the intersections by means of signalised toucan crossings. They will be able then to re-join the entrance ramp shoulder on the far side of the intersections and continue down to the expressway.

Any large scale widening of the existing expressway shoulder, as shown in Figure 8-1 above, would be beyond the scope of this project, although a short length of widened shoulder will be provided in the immediate vicinity of the exit and entrance ramps before the new alignment ties into the existing expressway alignment and cross-section width.

In addition, southbound cyclists have the option of leaving the ramps just past the nose and using a network of two-way shared use paths and subways instead of continuing up to the ramp terminal intersections and crossing at the toucan crossings. These shared use facilities, which are separated from road traffic, connect with existing cycle trail/lanes in the Hutt River corridor so that cyclists can leave or join the SH2 expressway route at the Melling interchange if desired.

8.2 Local Roads

On local roads minimum 1.5 m wide footpaths have been provided. Footpaths are provided on both sides of the road, where possible. On Harbour View Road and Tirohanga Road, for example, the footpaths are designed to be on only one side of the road to tie into and match the narrow widths of the existing footpaths (approximately 1.2 m wide).

In the HCC CBD area footpaths are a minimum of 2.4 m wide as agreed with HCC.

Pedestrian facilities have been designed in consideration of the Transport Agency's Pedestrian Planning Guide.

Cyclists on local roads are catered for through a combination of:

- 1.5 m wide sealed road shoulders (where the road has shoulders),
- appropriate width (wide) general traffic lanes
- marked cycle lanes,
- advance stop boxes,
- shared use paths, and
- connections to existing and proposed cycle paths (including the Hutt River Trail).

The new bridge and interchange joins Harbour View Road about 10 m above the existing SH2 level and about halfway along the existing climbing lane. The climbing lane will, therefore, become too short, and since the height difference will be reduced, the climbing lane has not been retained in the proposed layout. The existing road width of Harbour View Road has been put to better use by re-marking it as only two lanes but with 1.75 m shoulders for cyclists. This should improve safety for cyclists and improve sight distance in the left-hand curve past the existing cut face in the downhill direction opposite Gaskill Grove.

9 Utility Services

Given the scale of the project and the significant earthworks and underground excavations proposed, it is expected that all utility services within the SH2 area of the project will need to be replaced (i.e. renewed and in most cases realigned). Utility services in the Hutt City CBD area are less likely to be impacted given construction in that area is predominantly surface works.

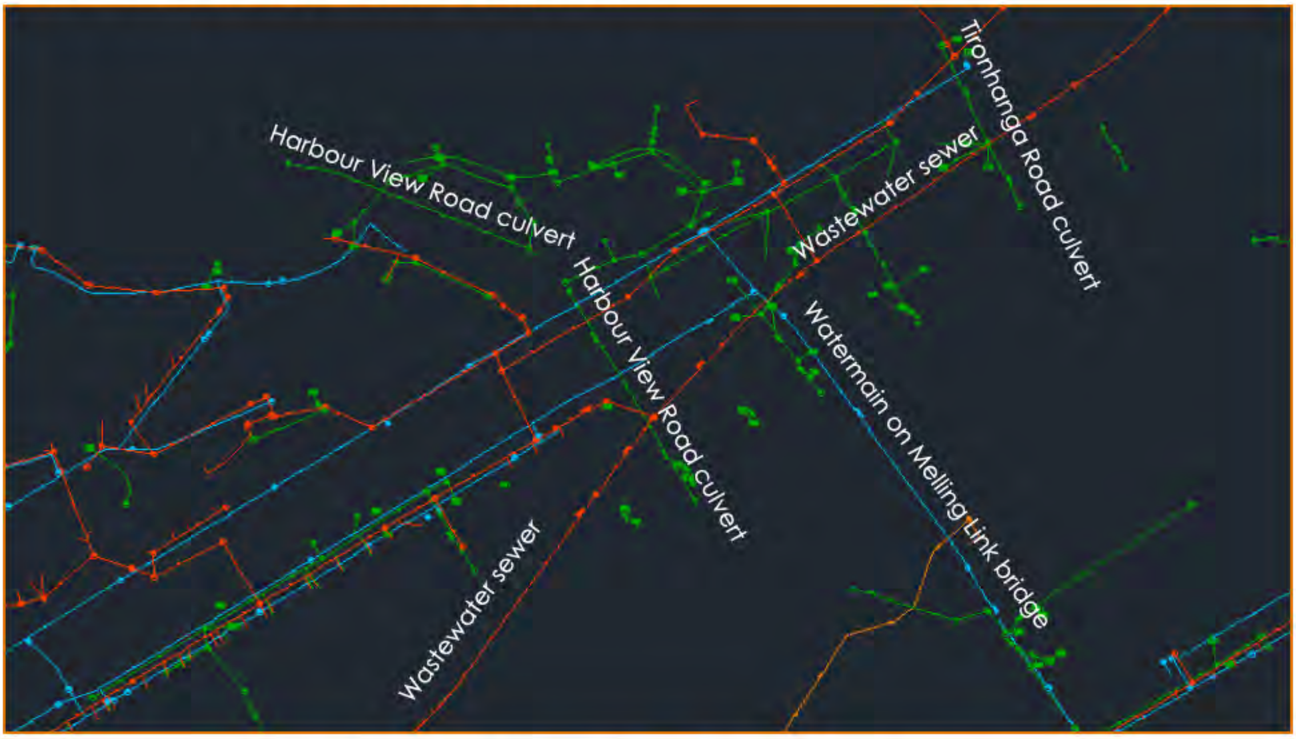

Figure 9-1: Underground utility services information

Most of the underground services impacted are uncomplicated and will be straightforward to renew. However, the following utility services are complex and will require specific consideration (e.g. design, programming, staging, etc) during the final design phase.

- Cross culvert that drains the Harbour View Road gully (refer to stormwater section above) – shown in green in the figure above.
- Watermain that crosses the river on the current Melling Link bridge and will, presumably, need to be re-routed onto the new river bridge – shown in blue in the figure above.
- Wastewater (pressure sewer line) that follows the alignment of the stop bank - shown in red in the figure above.
- Two electrical transformers, one associated with the Melling Rail line and one adjacent to Queens Drive, which will require relocation.

While it is expected that the RiverLink stopbank project will precede the Melling project and may relocate some of the above services (e.g. sections of the pressure sewer line), significant service relocation work will need to be undertaken as part of the interchange works, possibly as enabling works.

10 Project Staging

As part of the design philosophy process consideration was given to how the project might be staged and whether there is an opportunity to build the new Hutt River Bridge and stop banks first and build the interchange later. The following sketch illustrates a potential interim road connection.

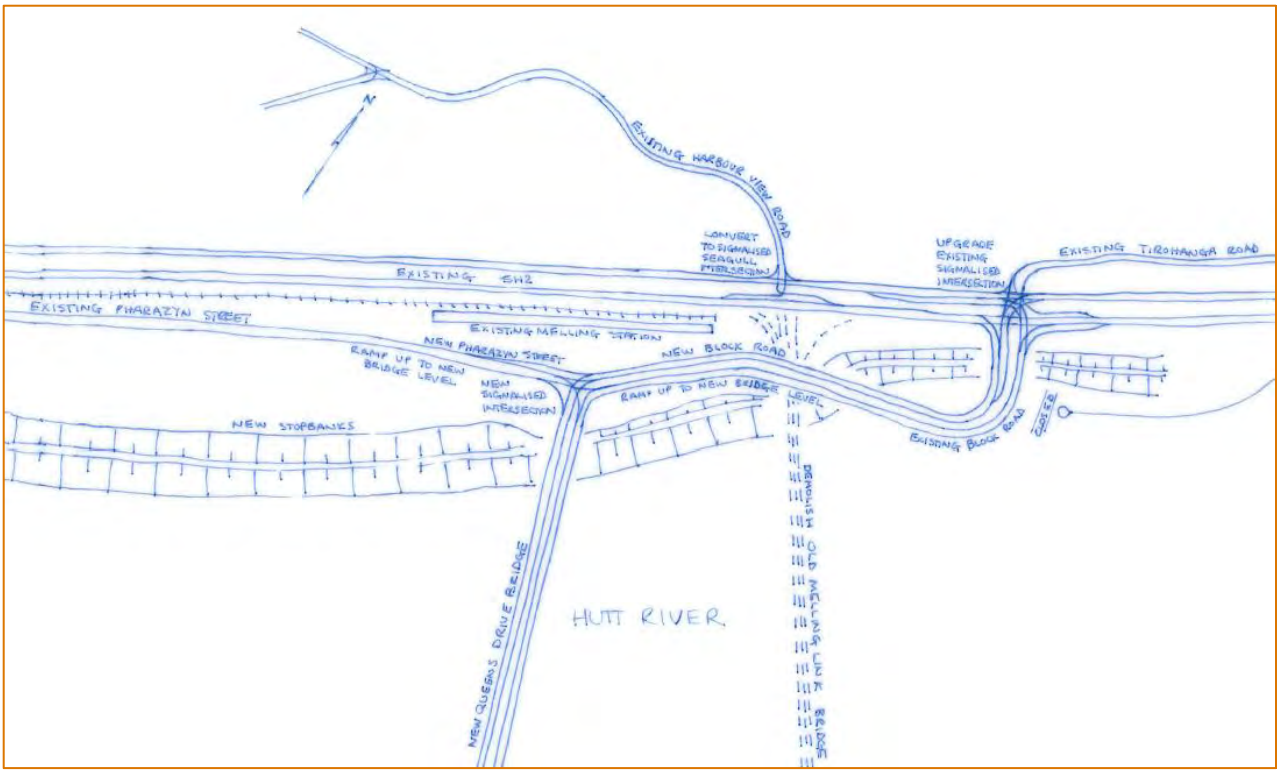

Figure 10-1: Potential Staging

The interim layout includes a common layout for the SH2/Block/Tirohanga intersection which combines Melling Link and Block Road traffic into one intersection with SH2. As such a significant number of additional vehicles are passing through the combined intersection, two main areas of concern result.

1. The present provision for the exclusive right-turn lane from SH2 into Melling Link is such that there is about 200 m available for stacking before the right-turn queue impacts on the adjacent through lane. With the interim layout as shown in Figure 10-1, which assumes the minimum amount of redundant work, the right-turn movement from SH2 into Block Road would have only a short length of exclusive right-turn lane due to the need to provide a right turn into Harbour View Road. Given the high demand for this movement in the PM peak in particular, it would not take much for the queue to extend into the adjacent through lane effectively reducing this to a single northbound through lane on SH2. Therefore, an alternative layout that carries three northbound lanes through the Harbour View Road intersection should be considered. This would require some widening and a slight realignment of SH2

2. The left- and right-turn movements out of Block Road would increase significantly in both peaks. In the PM peak in particular, it is unlikely that there would be sufficient capacity on this approach to cater for the increase in demand, as this approach is already close or at capacity in this period. Of course, the need to provide more time for this approach impacts on the other intersection approaches.

11 Health and Safety in Design

A health and safety in design workshop was held during the development of the proposed design. The workshop considered the impacts of the proposed design and the potential hazards and risks that might require mitigation strategies to be documented in future project phases. The workshop identified the following extreme or high-risk areas associated with the construction, maintenance, operation, and/or demolition of this project.

Risk Area	Risk Description
Steep / Unstable slopes	Slips, falls, rolling equipment
Artesian conditions	Known high-pressure underground aquifer in the area. Could result in unexpected high-pressure water 'explosion'
Bank/Slope Instability	Piling and heavy lifting (craning) may be required in the vicinity of the riverbank.
Underground - Watermain	Known high-pressure underground watermain in the area. Could result in unexpected high-pressure water 'explosion'.
Separation between adjacent moving plant/machinery	Tight site and benching will limit available space to undertake work and puts workers near moving plant.
Confined spaces	Stormwater works require the installation of a long, large diameter culvert at a relatively deep level - this could create a confined space and may lead to high velocity, high volume flows resulting in scour failures.
Post tensioned reinforced concrete	Risk of strand failure.
Falling from height and/or falling objects	Building of bridges and walls will require working at height and could result in falls and or falling objects.
Lifting / Cranes / Working under suspended loads	Bridge and wall construction will require lifting of large prefabricated elements.
Live Public Traffic (Highway/ Pedestrian/Cycleway)	Site is very tight and may necessitate complicated temporary traffic arrangements during construction.
Maintenance Access (e.g. for cleaning, removal / replacement of plant)	Site is very tight and may restrict access or necessitate difficult/unexpected access and egress points.
Maintenance of landscaping	Maintenance of landscaping may necessitate working at height in difficult to access areas (e.g. above retaining walls).
Existing Hazards	The construction phase will require the demolition of the existing Melling Bridge across Hutt River (which is a concrete structure with piles that terminate in an aquifer).
Complex construction	If a single span 220m arch bridge option is chosen for the main river bridge this would require specialist design and construction expertise.
Maintenance Traffic Management requirements	Maintenance repairs to damaged flexible barrier requires maintenance personnel to work near live traffic.

Figure 11-1: Identified Safety in Design risks with an extreme or high rating

It is recommended that any subsequent design phase:

- Review and confirm the above SiD factors identified as part of the Detailed Business Case phase.
- Identify other risk factors that may have arisen as a consequence of:
  - Further refinement of project
  - Changes to the scope of the project
  - Discussions/negotiations with stakeholders, etc.
- Assess the probability of occurrence of each of the risk factors now identified
- Delete previously identified risk factors which are no longer relevant. This may occur as a result of an event happening which makes the risk factor a constraint, or as a result of events being overcome by the passage of time, or as a result of the refined design eliminating the risk.
- Assign a likelihood of occurrence against each risk factor.

Appendix A Structures Report

SH2 MELLING INTERSECTION IMPROVEMENTS DETAILED BUSINESS CASE

PRELIMINARY STRUCTURE OPTIONS REPORT

PREPARED FOR NZ TRANSPORT AGENCY

31 May 2019

Stantec

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QUALITY STATEMENT

PROJECT MANAGER	PROJECT TECHNICAL LEAD
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PREPARED BY		
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REVIEWED BY		
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REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
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1	17/07/19	Draft for Comment Rev 1				
2	13/09/19	Draft for Comment, Appendix C added				

NZ Transport Agency

Preliminary Structure Options Report

CONTENTS

1. Introduction

1.1 Project background

The Melling intersection project was borne out of two separate programmes; the SH2: Ngauranga to Te Marua Programme Business Case (N2TM PBC), and the Melling Gateway (RiverLink) Programme Business Case (RiverLink PBC).

The N2TM PBC focussed on multi-modal inter-regional connections, to increase rail patronage and reduce commuter traffic on SH2 by improving rail services on the Hutt Valley and Wairarapa lines. However, Melling intersection improvements were identified as being required in the early/short term phases of programme delivery to address the safety and access problems to the Hutt City Central Business District (CBD).

The RiverLink PBC is a multi-agency programme involving the NZ Transport Agency, Greater Wellington Regional Council (GWRC) and Hutt City Council (HCC) that seeks to deliver:

- Improved protection from Hutt River flood events
- Better access to Hutt City CBD and the railway station by all modes
- Improved liveability and quality of life for people working and living in Hutt City CBD.

Since the confirmation of these programmes, the Melling Intersection Improvement project has progressed through an Indicative Business Case. The preferred option is a grade separated interchange and new bridge over the Hutt River to connect into Queens Drive.

1.2 Reasons for the construction of the structures

This project requires the construction of two bridges; an interchange bridge and a river bridge. The former structure grade separates SH2 through traffic from turning traffic entering or exiting the state highway, and a second structure crosses the Te Awa Kairangi/Hutt River. There are also two pedestrian underpasses (not detailed in this report as they are Category 3 structures) and numerous high (5m+) retaining structures supporting the proposed on- and off-ramps along the SH2 main alignment, along Harbour View Road and Tirohanga Road.

The current traffic signals on SH2 are located within a high-speed environment (100 km/h) which is highly undesirable and does not fit within the Safe System philosophy. These traffic signals are the first impediment to the free flow of vehicles on the expressway environment travelling north from Wellington and are out of context with that route. Capacity constraints at this intersection result in significant queuing during peak hours, which contributes to rear-end crashes equating to more than 50% of crashes in the project area. The capacity problem also has a significant adverse impact to the productivity, and hence economic efficiency, of businesses trading in Hutt City.

The existing Melling Link Bridge is a significant constriction on the Hutt River, as it constrains the volume of water that can flow through the river channel during a flood event. It restricts the flow of floodwaters to a 1 in 200 year flood event, with the height of the bridge contributing to the flood risk for the surrounding area which includes the local road network. Raising any proposed bridge is an integral part of the proposed GWRC flood defence upgrade for RiverLink.

1.3 General Site Description

The existing Melling Link intersection located at a very constricted section of SH2 along the Hutt River corridor. On the north-eastern side of SH2 is the very steep hill suburbs of Harbour View and Tirohanga (near vertical hill face in places at SH2 level) and to the southeast runs both the Hutt River and the Melling railway line/train station.

The Hutt River itself is slightly narrower through this area than other upstream or downstream sections, which is part of the problem that the RiverLink project would like to address as it reclaims some of the land (including Daly Street) on the CBD side for the eastern stopbank.

2. Factors Influencing Design

2.1 Service requirements (function)

Both structures would cater for low speed environments (40-60km/h), with SH2 passing under the interchange structure at 100 km/h. Based on existing traffic volumes (2017) approx. 23,500 vehicles per day (vpd) would use each structure, however as the traffic congestion is very bad during the morning and evening peak hours, there could be a latent demand for the Melling Link corridor (and hence access to SH2), whereby trips are either diverted, deferred or do not occur. With SH1 Transmission Gully set to open in 2020, the traffic volumes through the project area could increase further, with a spike in traffic growth greater than the traffic growth of the past 5-10 years.

While no project specific walking and cycling plans have been developed to date, catering for these modes has been a key focus for stakeholders. The new structures are planned to provide much better connectivity between Hutt CBD and the Melling train station, as well as better connectivity for those locations and the hill suburbs of Tirohanga and Harbour View. With the advent of electric bicycles, cycling has become a much more viable mode of transport for those hill suburb residents.

Consideration of utilities was performed under the RiverLink project. For the purposes of this report it has been assumed that all existing utilities would be appropriately catered for by the new structures and that capacity for future utilities would be provided for as per NZ Bridge Manual requirements.

2.2 Foundation (subsurface) conditions

The Melling site is adjacent to the Hutt River and comprises an area of complex geology and large topographic changes.

The Preliminary Geotechnical Appraisal (MWH, 2017) covers the principal geotechnical (subsurface conditions) risks and constraints as follows:

1. The potential for soft and weak materials across site
2. The potential for low quality rock for cut slope batters and slope stability
3. The presence of the sensitive shallow and deep aquifers within the potential piling zone and the possibility of artesian conditions
4. The position of the Wellington Fault is inferred and remains undefined for bridge design purposes. As currently mapped it passes roughly parallel to the existing stop bank beneath the proposed River bridge location.
5. Contrasting variable ground conditions in the proposed foundation locations of the proposed bridges.
6. The potential for contaminated soil.

A site walkover (MWH, 2017) also identified localised slope instabilities in both the bedrock (greywacke) and in the colluvium materials superimposing the bedrock.

The presence of the aquifer presents significant challenges when proposing piled foundations. It is proposed to adopt similar sleeving and bored piling techniques to that used on the Ewen Bridge downstream of the Melling site. Specific piling details will be developed at the preliminary design stage but will likely utilise inner and outer steel casings and concrete annulus plugs to prevent contamination of the aquifer.

2.3 Urban design considerations

All bridge and retaining structures will be highly visible to the public and road users and any specific urban design features such as structural form, pier shape, external barrier profile, wall texture, colour, lighting etc will be developed further alongside RiverLink and NZTA urban designers taking into account stakeholder desires at the preliminary design stage.

Typically, the approach (for the preferred structural options) has been to adopt uncluttered and contemporary designs with clean structural lines and a simple but elegant appearance with good integration with the local environs. The positive appearance of the structures will be achieved through a good selection of structural form and function.

Based on the preferred options mentioned later in this report the road bridges are not intended to be developed as iconic structures. It is considered that the footbridge is more suited to this purpose.

At this concept stage, it is anticipated that the urban design, landscape and ecology project objectives adopted for the RiverLink project will also be extended to the Melling River Bridge project. The objectives, which are discussed in detail in Boffa Miskell's Technical Report T-17/16, "RiverLink Preliminary Design", dated 30 April 2018, are summarised as follows:

- Flood risk – improve Hutt Valley flood resilience
- Linking and development - improve walking, cycling and other active modes to and along the river corridor and facilitate development opportunities
- Traffic development – identify and provide modifications for the wider network and improve function, safety and accessibility between SH2 and the local road network
- Amenity and ecology – Improve ecological performance, provide amenity for the public and private properties along the river corridor, generate spaces and places reflective of user's needs, cultural and landscape values
- Implementation, strategic and economic sustainability - enable staged implementation, ensure the design outcome is affordable, engage with communities regarding design options and consider existing statues, strategies and plans during option development

The urban design aspects for all structures will be developed in accordance with the following guidance:

- NZ Bridge Manual
- NZTA's Bridging the Gap: NZ Transport Agency urban design guidelines, incorporating Appendix 5 Urban Design Considerations in Bridge Design matrix
- Bridge Aesthetic design guidance set out by Roads and Maritime Services.

Full consideration will be given to the above objectives, guidance and any others as deemed appropriate, during the preliminary design stage and entered into the Design Statement for each structure as required by the Bridging the Gap Appendix 5 design matrix guidance.

2.4 Geometrics (vertical and horizontal alignment)

The vertical and horizontal alignments are primarily governed by the following:

- The need to tie into the existing alignments of Harbour View Road, Queens Drive and Rutherford Street
- The required clearance over the stop banks, all of which are in very close proximity of the two proposed bridges
- The limited width available for the interchange between the stop banks and the hillside
- Clearance envelopes for the motorway and possible future extension of the railway line
- Clearance envelopes for the cycleway underpasses
- Clearance envelopes in the RiverLink car park to allow future pedestrian and vehicular use.
- Not affecting the levels or lateral positions of the new stop banks
- Meeting safe intersection and stopping sight distance requirements, and maximum gradients for motorway ramps, and cycleways and footpaths
- Draining the surface of stormwater adequately.

A maximum typical bridge width is shown in the figure below, actual deck widths will vary between 24.6m and 29m depending on where the section is taken and the number of traffic lanes. The sketch assumes a Super-T superstructure arrangement and is typical for both the interchange bridge and the river bridge.

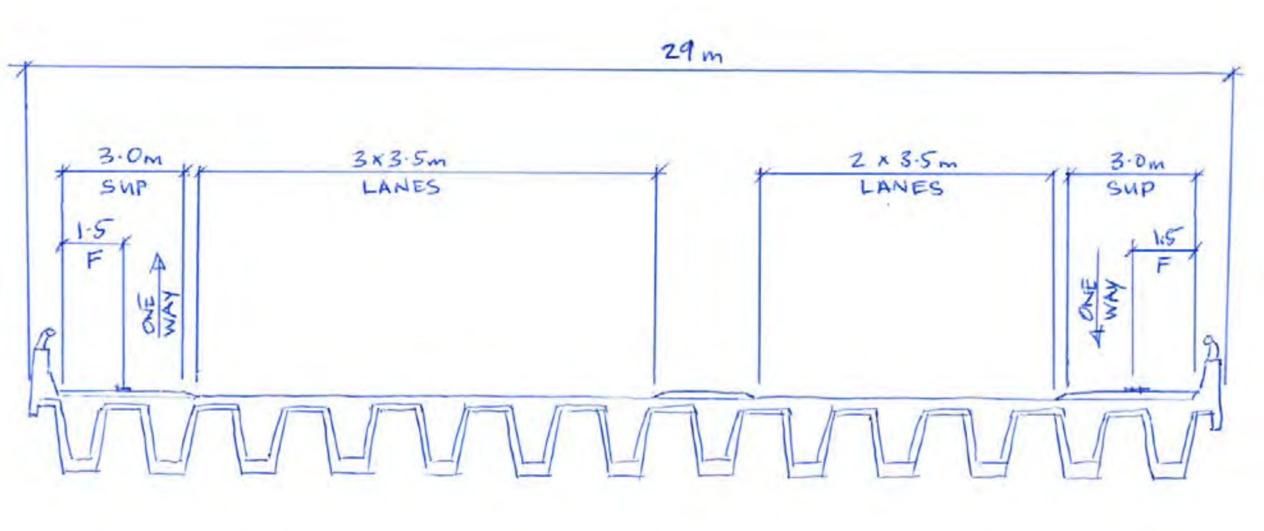


Figure 2-1: Typical bridge cross-section

2.5 Hydrology

2.5.1 Flood hydrology

Greater Wellington Regional Council (GWRC) have developed extensive hydraulic models and flood hydrology for the Hutt River. Two principal GWRC documents have driven improvements along the river over the past 18 years, the Hutt River Floodplain Management Plan 2001 (HRFMP) and the Hutt River Environmental Strategy 2001 (HRES).

The flood protection outcomes, delivering on providing regional resilience, are set out in the HRFMP. The plan establishes a safe and agreed flood conveyance protection level (including predicted climate change effects) of 0.23% Annual Exceedance Probability (1 in 440 year return period flood). This translates to a flood conveyance capacity of 2800 cumecs (cubic metres per second) which allows for uncertainties associated with flood risk, and thereby sets the design flood for development of the flood protection designs. An indicative maximum velocity (not effective velocity) during an event of this magnitude is in the order of 3.5m/s.

Along with the HRFMP, the HRES sets the strategic direction for managing the Hutt River environment. It is understood that this strategy is currently under review to update and provide more specific environmental outcomes for the Hutt River. The review reflects recreational and environmental challenges with growing and competing demands on the river. The strategy will set new objectives and directions for the whole river environment.

The existing Melling Bridge is identified as a key constriction point on the Hutt River, and without replacement only a 0.5% annual exceedance probability (1-in-200 year return period) level of service can be achieved and therefore does not meet the intent of the HRFMP or the HRES. The existing bridge is owned by the Hutt City Council.

The waterway design of the proposed river bridge, with respect to design floods, debris loading on piers and freeboard, shall comply with the requirements of the NZ Bridge Manual. For the purposes of this report, it is proposed that the freeboard allowance will be "top of stop bank + 600mm". This should provide sufficient clearance for flood debris to pass under the bridge when the river is in spate, whilst minimising the impact on the highly constrained approach tie-ins at either end of the bridge.

2.5.2 Scour

In 1999 Opus completed a report entitled 'Melling Bridge Assessment of Vulnerability Supplementary Scour Investigations' and determined that scour in a large flood event could extend down to -5.5m below Mean Sea Level (MSL). Such scour depths pose a risk of breaching the aquiclude. This breach would have a severe impact on the aquifer system, which is an important water supply for the region. The erosion associated with the breach of the aquifer also has the potential to severely undermine any proposed bridge pier foundations.

Opus's report also states that the Hutt River through the existing Melling Bridge reach is aggrading at an annual average rate of 50mm to 70mm. The aggradation is reduced to about 30mm annually through the bridge portal itself, probably due to the increased velocity of the slightly constricted channel cross-section. This suggests overall that the river bed material during normal flows and low return period flood events is relatively stable.

General, contraction and local scour depths for the proposed river bridge piers and abutments will be determined in accordance with the requirements of the NZ Bridge Manual and scour preventative measures, such as rock armouring, incorporated as deemed necessary.

Further localised site investigations to assess the lower bed materials, aquiclude properties and aquifer levels is recommended given the potential risk of an aquifer breach.

2.6 Constraints on span and clearances

2.6.1 River Bridge

The proposed Melling River Bridge will extend from stop bank to stop bank.

There are two options available for how the bridge abutments connect into the existing roading network at each end of the bridge, these are:

- Remove all stop bank interaction by spanning them with additional land span structures
- Build the bridge abutments into the stop banks and design accordingly using current best practice

It is understood that GWRC's preferred approach is to not to have 'hard' abutment structures within 'soft' stop banks due to the potential erosion issues that may develop during flood events and may jeopardise stop bank performance. If this approach is adopted is adds significant design complexity and cost to both ends of the structure, but more so to the city end tie-in due to the angle of the stop bank on this side. For a more detailed discussion on this topic refer to Appendix A of this report.

Where practicable all bridge piers will be located outside of the main (normal flow) river channel, but for the multi-span option the shorter spans will inevitably result in a pier (or two) within the main river channel.

2.6.2 Interchange Bridge

The clearances provided for this structure will meet or exceed the requirements of the NZ Transport Agency's Bridge Manual. In addition to spanning SH2 this bridge will also span a 4m wide combined cycleway/walkway.

2.7 Constraints on construction methods

Four key constraints have been identified regarding the construction methods for the bridges:

- Interaction with the new alignment of the stop banks (this is discussed further in Appendix A)
- Interaction with the Hutt River
- Ground conditions
- General site constraints – proximity of train station, river, local roading network, accesses to local businesses, slope stability constraints around the Tirohanga Road alignment etc.

2.8 Constraints on construction materials

Rivers are a particularly sensitive receiving environment and are very susceptible to potential contamination during both construction and any maintenance works carried out throughout the design working life of the structure. These constraints impact on the type of construction material adopted.

The durability requirements imposed by the NZ Bridge Manual and the practical span lengths required to cross the Hutt River preclude all but prestressed or post-tensioned reinforced concrete and structural steelwork as viable construction material options. The proximity of the bridge site to the coast (approximately 3.3km) rules out weathering steel as a viable material option in this instance.

Both structural steelwork and reinforced concrete superstructure options will undoubtedly require 'wet' concrete elements during construction (such as piles, pile caps, piers, pier caps etc) and the construction of these in the river will have to be managed appropriately during construction using well-established construction techniques.

Whilst protective coating systems for structural steelwork are continuously improving, the long-term maintenance of structural steelwork across rivers is problematic and expensive due to the inherent access issues and the full encapsulation and capture required during the removal and recoating of the protective coatings. This cost would be significant on a bridge of this length.

On the above basis, reinforced concrete is considered to provide the least environmental impact of all construction material options via the use of precast/prefabricated elements where possible. Reinforced concrete is also considered to provide the best long-term durability option in this river environment.

2.9 Interaction of construction with traffic flows

The Queens Drive connection is expected to have a relatively low degree of disturbance for traffic, as the bridge can be largely built offline and the heavy traffic volumes crossing the Hutt River are otherwise unaffected as they would use the existing Melling Link Bridge. A combination of shoulder and possible temporary road closures at the Queens Drive / Rutherford Street intersection would be expected at the CBD end during construction of the new road tie-ins, while Block Road and Pharazyn Street would be closed off permanently on the SH2 side, consequently some traffic re-routing would be necessary during construction.

2.10 Site seismic hazard

The site seismic hazards identified include:

- Strong ground shaking
- Fault rupture
- Tectonic (uplift/subsidence/tilting)
- Liquefaction
- Lateral spreading and/or cyclic softening and strength losses
- Landslide
- Tsunami
- Poor and/or variable ground

Considering the significant geotechnical hazards identified above, the close proximity of the proposed structures to these hazards, the length of the proposed river bridge and based on the high likelihood of this site being outside of the design ground motion parameters specified by NZS1170.5 (Structural Design Actions: Earthquake Actions – New Zealand) a site specific seismic hazard study is strongly recommended prior to commencement of detailed design.

Best practice for bridge design is to avoid constructing structures that span known faults altogether, particularly faults as significantly active as the Wellington Fault. Based on current geotechnical information, it is considered highly probable that the river bridge will span the Wellington Fault and is therefore susceptible to sudden and significant lateral, longitudinal and/or vertical movements should a fault rupture occur. To accommodate movements of such magnitude into the design of a bridge (movements which may in themselves be well beyond those considered acceptable under Bridge Manual displacement limits) can be extremely costly. A common approach to minimise these costs is to seek departures from standards from the Road Controlling Authorities (RCAs) and accept that some controlled excessive movement may occur during larger events resulting in sacrificial and/or repairable structural damage.

The departures from standard required for this project (if any) will be developed during the preliminary and detailed design phases. This proposed approach is not uncommon, particularly for seismic design parameters, but the design approach and associated costs will need to be optimized, discussed and agreed early on with the necessary RCAs.

It is considered reasonable at this stage to assume that in order to provide cost-effective river or interchange bridge solutions some departures from the seismic design requirements may be justifiable.

2.11 Environmental considerations and constraints

A key consideration for the ecology of the site is the maintenance of the river, its bed and its banks during construction. Therefore, any vegetation clearance and management of the river during construction and as a result of the construction, including proposed management and remediation of any contaminated land encountered, need to be clearly communicated to ensure compliance with any consenting requirements. That said, the RiverLink project will have a significant effect on the riverbed, riverbanks and the stopbanks, and therefore, depending on timing, the additional effect of the bridge construction may be minimal. It is expected this will be detailed more comprehensively in the Assessment of Environmental Effects (AEE) during the next phase of consenting, and subsequently in the supplier's Environmental Management Plan during construction.

The installation of the bridge abutments and piers and their respective foundations in the river channel will need careful consideration. Temporary access will be required over and adjacent to the river to install the bridge foundations and substructure elements. At this early stage it is difficult to state with complete accuracy the precise relationship between the substructure elements and the river as the level of topographical information currently available is limited.

Extreme care will also need to be exercised whilst installing the bridge piles to ensure that the aquifer is not contaminated.

The existing Melling Link bridge currently creates a significant constriction to the existing river channel and will require demolition following completion of the proposed structures. Utilities crossing the existing bridge will need to be decommissioned and re-routed over the new bridge prior to the commencement of demolition. The prestressed nature of the 90 feet (27.45m) long existing bridge beams of each of the five spans will require careful planning and execution to ensure that removal is completed safely and with minimal impact on the river. The existing bridge piers and abutments will also need to be removed to below riverbed level.

2.12 Bridge Barriers

The performance level of all bridge barriers will be determined in accordance with Appendix B of the NZ Bridge Manual but are likely to be Test Level 5 (TL-5). The on-structure TL-5 barriers will include Texas HT rails.

3. Design Options (for each option)

3.1 River Bridge Options

3.1.1 Multi-span Super-T bridge

Refer to River Bridge Option 1 in Section 5 for a 3D visualisation of this bridge.

3.1.1.1 Structural forms and modes of behaviour

The multi-span Super-T river bridge option comprises seven 31.4m spans of precast prestressed Super-T girders with an in situ concrete deck supported on reinforced concrete substructure elements with piled foundations. The total overall length is approximately 220m between stop banks. The bridge has an overall width of 28m and comprises up to five 3.5m traffic lanes, two 3m combined walkway/cycleways and a 1.8m central median. The Super-T beams are 1525mm deep and the beams are integral with the piers and abutments.

The abutments comprise reinforced concrete bank seats on MSEW abutments. MSEW walls are provided as they are particularly tolerant of seismic movements expected at this site.

Provision for expansion and contraction is provided by an expansion joint at the ends of the surface-level approach slabs.

3.1.1.2 How the design addresses the factors influencing the design

This form of bridge is used throughout New Zealand, it is cost-effective, and its integral arrangement has proven seismic performance. It is also familiar to the key players in the New Zealand contracting industry so is likely to result in a more competitive tender price.

The shorter multi-span nature of the bridge allows for smaller foundations. All piled foundations shall be constructed similar to that used on the Ewen Bridge approximately 500m downstream i.e. double sleeved and plugged to ensure the aquifer is not contaminated.

Vertical load resistance is provided by the piled foundations, with all other structural elements spanning back to the piles. Similarly, lateral loading is transferred into the piled foundations with resistance ultimately being provided by the soil over the length of the pile and at the bridge abutments.

Seismic design will be in accordance with the NZ Bridge Manual (refer Section 2.10). Resistance to seismic loading at the ultimate limit state is assumed to be provided by the lateral and vertical capacity of the pier and abutment piles, with some contribution from the soil passive pressure behind the abutments. The bridge has been designed to dissipate energy in a ULS seismic event by forming plastic hinges within the piers and piles.

Considering the proximity of the bridge to the Wellington fault, low damage technology, such as dissipative controlled rocking on bridge piers, could also be investigated to minimise bridge damage and provide quicker reinstatement following a seismic event.

The proposed multi-span Super-T option arrangement utilises seven 35m spans and therefore has six piers in the river. The overall width of the proposed bridge deck is significant at greater than 28m and therefore a single column 'hammerhead' style pier is considered unlikely. It is more likely to comprise solid 'slab' piers rather than two or three individual columns per pier thus minimising in-stream turbulence and reducing associated scour effects.

During flood flows the increased number of piers associated with this option does present an increased risk of debris capture and restriction of flood flows when compared to the other two options even with the proposed increased freeboard, but it is still considered a far better situation than the current Melling Link arrangement. The increased number of piers also increases the risk of scour at the piers, but this arrangement is considered no different to countless other multi-span bridges across wide rivers in New Zealand, and can be easily managed with appropriate riverbed protection. The effects of this bridge arrangement shall be determined via appropriate hydraulic modelling using the Greater Wellington Regional Council's previous hydraulic model of the river to assess the impact of the preferred option.

The increased number of piles required to accommodate the increased number of piers also increases the likelihood of aquifer contamination.

3.1.1.3 Likely methods of construction

The proposed river bridge is located across the Hutt River approximately 150m south of the existing Melling Link Bridge. The construction site is relatively accessible from the city side via the car park located within the river's flood plain. The site is considerably more constrained from the SH2 side, primarily due to the proximity of the State Highway and the Melling railway station. It is expected that access for all pier construction and the eastern abutment will be from the city side. The western abutment will likely require careful consideration and traffic management to prevent impact on an already heavily used intersection and train station.

The assumed construction methodology can be summarised as follows:

- The pier pile sleeves installed
- The pier columns are formed above ground level up to the underside of the pier heads
- The MSE walls will be built up above existing ground level to the required height and the lower half of the abutment beams and pier crossheads will be constructed.
- The precast beams will be lifted into position and placed on the partially completed abutments and piers. The beams shall be placed from the centre of the deck first, working outwards.
- The deck and remainder of the pier heads and abutment beams will be poured in accordance with the deck pour sequence determined during detailed design.
- The remainder of the structure including approach slabs, barriers, expansion joints and surfacing will be completed.

3.1.1.4 Construction materials and durability

Durability of reinforced and prestressed concrete members shall be achieved with adequate cover of dense concrete. Cover shall be as per the Concrete Structures Standard (NZS 3101) for a 100 year design life.

3.1.1.5 Cost Estimates

The preliminary cost estimate for this option is based on a typical rate for this type of bridge of $4,500 per square metre.

Total base estimate is $27.7M.

If no interaction is allowed with the existing stop banks (as per GWRC's preference) this would add two additional land spans to either end of the bridge (to span the stop banks) at a further cost of approximately $5M.

Total combined cost is $32.7M.

This excludes GST, main Contractor's P&G, overhead and profit and estimating contingency.

3.1.2 Post-tensioned Twin Box Girder

Refer to River Bridge Option 2 in Section 5 for a 3D visualisation of this bridge.

3.1.2.1 Structural forms and modes of behaviour

The post-tensioned variable depth twin box girder option comprises three spans (60m+100m+60m), a total length of 220m between stop banks. It is expected that the bridge would be built as a balanced cantilever from the two piers constructed on each side of the normal flow river channel. The box girders could be cast-insitu or precast glued segmental. For this report, and based on the span lengths, the depth of the superstructure has been sized at 5m at the piers to 2.5m at the midspan/abutments. The deck profile is parabolic.

The bridge has an overall width of 28m and comprises up to five 3.5m traffic lanes, two 3m combined walkway/cycleway and a 1.8m central median. The deck is integral with the piers and supported on elastomeric bearings at the abutments.

The abutments and piers are supported on reinforced concrete bored piles.

Provision for expansion and contraction is provided by an expansion joint at each abutment.

3.1.2.2 How the design addresses the factors influencing the design

The continuous nature of bridge, limited number of spans and variable depth deck results in an elegant bridge form.

The bridge arrangement results in the bridge piers being located on the banks of the river either side of the normal flow river channel and therefore causes minimal disruption to the river during construction. The balanced cantilever method of construction also results in a large proportion of the construction work being carried out at bridge deck level, further reducing any impact on the river.

This form of construction is considered somewhat specialist and would require a Contractor with previous experience in this form of bridge construction. That said, this form of bridging has been used in New Zealand since the 1960s, so is not new.

All piled foundations shall be constructed similar to that used on the Ewen Bridge approximately 500m downstream i.e. double sleeved and plugged to ensure the aquifer is not contaminated.

Vertical load resistance is provided by the piled foundations, with all other structural elements spanning back to the piles. Similarly, lateral loading is transferred into the piled foundations with resistance ultimately being provided by the soil over the length of the pile and at the bridge abutments.

Seismic design will be in accordance with the NZ Bridge Manual (refer Section 2.10). Resistance to seismic loading at the ultimate limit state is assumed to be provided by the lateral and vertical capacity of the pier and abutment piles, with some contribution from the soil passive pressure behind the abutments. The bridge has been designed to dissipate energy in a ULS seismic event by forming plastic hinges within the piers and piles.

Considering the proximity of the bridge to the Wellington fault, low damage technology, such as dissipative controlled rocking on bridge piers, could also be investigated to minimise bridge damage and provide quicker reinstatement following a seismic event.

3.1.2.3 Likely methods of construction

The proposed river bridge is located across the Hutt River approximately 150m south of the existing Melling Link Bridge. The construction site is relatively accessible from the city side via the car park located within the river's flood plain. The site is considerably more constrained from the SH2 side, primarily due to the proximity of the State Highway and the Melling railway station. It is expected that access for all pier construction and the eastern abutment will be from the city side. The western abutment will likely require careful consideration and traffic management to prevent impact on an already heavily used intersection and train station.

The assumed construction methodology can be summarised as follows:

- The pier pile sleeves installed
- The pier columns and abutments are formed above ground level up to the underside of the pier heads
- Construct a 6m section above both piers and assemble the land span cantilever carriage.

- Construct a 4m section on the land span and then shift cantilever carriage
- Assemble centre span cantilever carriage and construct 4m of the centre span
- When concrete is at least 3 days old stress cantilever tendons
- Repeat the above stages until centre spans are within 2m of closing
- Construct final 6m of land spans
- Prior to placing concrete in the closing pour jack bridge halves
- Construct the centre span closing pour
- When centre span closing pour is at least 7 days old stress continuity cables and local cables.
- Remove all falsework and construct backwalls
- The remainder of the structure including approach slabs, barriers, expansion joints and surfacing will be completed.

3.1.2.4 Construction materials and durability

Durability of reinforced and post-tensioned concrete members shall be achieved with adequate cover of dense concrete. Cover shall be as per the Concrete Structures Standard (NZS 3101) for a 100 year design life.

3.1.2.5 Cost Estimates

The preliminary cost estimate for this option is based on a typical rate for this type of bridge of $7,000 per square metre.

Total base estimate is $43.1M.

If no interaction is allowed with the existing stop banks (as per GWRC's preference) this would add two additional land spans to the length of the bridge (to span the stop banks) at a further cost of approximately $5M.

Total combined base estimate is $48.1M.

This excludes GST, main Contractor's P&G, overhead and profit and estimating contingency.

3.1.3 Network Tied Arch

Refer to River Bridge Option 3 in Section 5 for a 3D visualisation of this bridge.

3.1.3.1 Structural forms and modes of behaviour

The network tied arch option comprises a single 220m span between stop banks.

If it were to be constructed it would become the longest network arch in New Zealand by some margin. The current longest being the 100m long Waikato River Bridge on the East Taupo Arterial Road, built in 2010. The longest span network arch in the world at the time of writing this report is reputed to be the Bugrinsky Bridge across the Ob River in Russia at 380m long. Therefore, the 220m span be promoted here is well within current span limits.

The network arch is essentially a simply supported truss with only axial compressive and tensile forces. The arch is the top chord, the deck is the bottom chord, with the hangers acting as the diagonal elements. Bending moments and shear forces are very small in network arches resulting in smaller sections and lighter structures.

The axial forces in the tension and compression chords are inversely proportional to the distance between them. The rise of the arch adopted for this option follows current best practice at approximately span/6.

The hanger nodes are commonly placed equidistantly along the arch and typically cross other hangers at least twice.

The bridge has an overall width of 28m and comprises up to five 3.5m traffic lanes, two 3m combined walkway/cycleway and a 1.8m central median.

The abutments are supported on reinforced concrete bored piles.

Provision for expansion and contraction is provided by an expansion joint at each abutment.

3.1.3.2 How the design addresses the factors influencing the design

This form of bridge is relatively new to New Zealand, with only two in existence, both built in the last 10 years. It is understood that the two that have been constructed have been chosen as alternative designs over more traditional bridge forms based on their proven cost savings.

They are structurally efficient and therefore section sizes required are smaller. This results in less material and less weight, which in turn results in less substantial foundations. Their light weight also proves to be a significant advantage on a site that is seismically susceptible due to their lower seismic mass.

All piled foundations shall be constructed similar to that used on the Ewen Bridge approximately 500m downstream i.e. double sleeved and plugged to ensure the aquifer is not contaminated.

Vertical load resistance is provided by the piled foundations, with all other structural elements spanning back to the piles. Similarly, lateral loading is transferred into the piled foundations with resistance ultimately being provided by the soil over the length of the piles.

Seismic design will be in accordance with the NZ Bridge Manual (refer Section 2.10). Resistance to seismic loading at the ultimate limit state is assumed to be provided by the lateral and vertical capacity of the abutment piles, with some contribution from the soil passive pressure behind the abutments. The bridge has been designed to dissipate energy in a ULS seismic event by forming plastic hinges within the piles.

If this option is developed further an MSE abutment option will also be looked at to determine if a bankseat abutment solution is viable.

3.1.3.3 Likely methods of construction

The car park on the eastern side of the river appears to have adequate space to be used as a temporary laydown area for the arch bridge components and could also be used to locate the crane required to lift the bridge's component parts into place over the river. Depending on crane availability and space it may be possible to lift the entire bridge onto its abutments in one lift. A feasibility assessment of this will be developed at preliminary design should this bridge become the preferred option.

The piled bridge foundations will be constructed whilst the arch sections are being fabricated.

3.1.3.4 Construction materials and durability

Durability of reinforced concrete members shall be achieved with adequate cover of dense concrete. Cover shall be as per the Concrete Structures Standard (NZS 3101) for a 100 year design life.

Exterior surfaces of structural steelwork arch chords and hangers will be coated using a thermal metal spray system with a sealer coat or similar. Interior surfaces will be coated using the same system but with a thinner coating thickness.

3.1.3.5 Cost Estimates

Despite an extensive internet search, determining actual bridge costs for the two tied network arch bridges already constructed in New Zealand has proven elusive.

Some assistance from the NZTA in obtaining actual costs for these structures would be much appreciated.

3.2 Interchange Bridge Options

3.2.1 Single Span Super-T

3.2.1.1 Structural forms and modes of behaviour

The single span Super-T interchange bridge option comprises a 30.9m clear span precast prestressed Super-T girders with an in situ concrete deck supported on reinforced concrete bankseats on MSEW abutments. The bridge has an overall width of 28m and comprises up to five 3.5m traffic lanes, two 3m combined walkway/cycleway and a 1.8m central median.

The Super-T beams are 1225mm deep and are integral with the abutments, thereby eliminating the need for bearings or expansion joints.

3.2.1.2 How the design addresses the factors influencing the design

Longitudinal seismic actions will be resisted by a combination of friction beneath the abutment beam and passive resistance behind the abutment. Transverse seismic actions will be resisted largely by friction beneath the abutment beam, although some passive resistance will be provided by the reinforced concrete wingwalls. Where the longitudinal and transverse seismic actions exceed the friction and passive resistance in a ULS or MCE event, it is intended that the bridge moves on top of the RE wall.

MSEW walls perform well during seismic events and can accommodate relatively large displacements with little to no detrimental effect.

3.2.1.3 Likely methods of construction

The proposed interchange bridge is located across SH2. The site is constrained due to the local topography, the proximity of the State Highway and the Melling railway station.

The assumed construction methodology can be summarised as follows:

- RE walls will be built up above founding level to the required height. The fill will be either suitable excavated material or imported;
- Settlements will be monitored during construction
- The abutment beams excluding headwalls are constructed
- The precast beams are lifted into position and placed on the partially completed abutment
- The abutment headwalls and 6.0m of the deck slab at each end of the bridge are poured
- The remaining deck slab is poured
- The remainder of the structure including approach slabs, barriers and surfacing will be completed.

3.2.1.4 Construction materials and durability

Durability of reinforced and prestressed concrete members shall be achieved with adequate cover of dense concrete. Cover shall be as per the Concrete Structures Standard (NZS 3101) for a 100 year design life.

3.2.1.5 Cost Estimates

The preliminary cost estimate for this option is based on a typical rate for this type of bridge of $4,000 per square metre.

Total base estimate of $3.6M.

This excludes GST, main Contractor's P&G, overhead and profit and estimating contingency.

3.2.2 Twin-Span Single Hollow Core

3.2.2.1 Structural forms and modes of behaviour

The twin-span single hollow core interchange bridge option comprises 2 x 15.5m span precast prestressed single hollow core beams supported on reinforced concrete bankseats on MSEW abutments. The bridge has an overall width of 28m and comprises four 3.5m traffic lanes, two 3m combined walkway/cycleway and a 1.8m central median. The central pier would be piled and located in the median.

The single hollow core beams are 750mm deep and are semi-integral with the abutments, thereby only requiring very simple strip bearings and expansion joints.

3.2.2.2 How the design addresses the factors influencing the design

Longitudinal seismic actions will be resisted by a combination of friction beneath the abutment beam and passive resistance behind the abutment. Transverse seismic actions will be resisted largely by friction beneath the abutment beam, although some passive resistance will be provided by the reinforced concrete wingwalls. Where the longitudinal and transverse seismic actions exceed the friction and passive resistance in a ULS or MCE event, it is intended that the bridge moves on top of the RE wall.

MSEW walls perform well during seismic events and can accommodate relatively large displacements with little to no detrimental effect.

3.2.2.3 Likely methods of construction

The proposed interchange bridge is located across SH2. The site is constrained due to the local topography, the proximity of the State Highway and the Melling railway station.

The assumed construction methodology can be summarised as follows:

- RE walls will be built up above founding level to the required height. The fill will be either suitable excavated material or imported;
- Settlements will be monitored during construction
- Central pier piles installed
- Central pier constructed to deck level
- The abutment beams excluding headwalls are constructed
- The precast beams are lifted into position and the insitu concrete infill installed
- Transverse post-tensioning installed
- The abutment headwalls and pier shear key poured
- The remainder of the structure including approach slabs, barriers and surfacing will be completed.

3.2.2.4 Construction materials and durability

Durability of reinforced and prestressed concrete members shall be achieved with adequate cover of dense concrete. Cover shall be as per the Concrete Structures Standard (NZS 3101) for a 100 year design life.

3.2.2.5 Cost Estimates

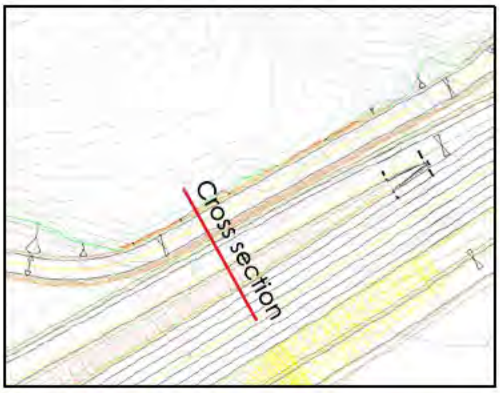
The preliminary cost estimate for this option is based on a typical rate for this type of bridge of $4,250 per square metre.

Total base estimate is estimated at $3.8M.

This excludes GST, main Contractor's P&G, overhead and profit and estimating contingency.

3.3 Retaining Structure Options

The options for retaining structures designed to support the current geometric configuration of the Melling Interchange roading project have been assessed in relation to how they are expected to perform under the factors influencing the design in Section 2, and especially under the seismic hazard considerations discussed in Section 2.10. Furthermore, because a terraced form is inevitably adopted in the northern half of the interchange (Figure 1), a more rigorous design is required for the lower walls (essentially the northbound on-ramp) due to the expected development of an additional horizontal thrust.



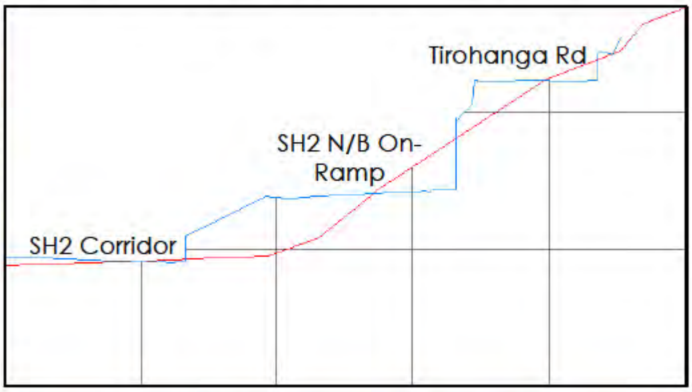


Figure 3-2 Cascading walls layout and section – northern on-ramp area (grid size is 10m x 10m)

Three alternative options have been considered and are discussed below. These are:

1. Mechanically stabilized earth walls (MSEW);
2. Anchored reinforced concrete cantilevered (L-shaped) walls;
3. Hybrid anchored soldier pile walls.

Any of these options may be combined with low height modular retaining walls like gabion walls, precast reinforced concrete stem walls, etc.

The cost estimates per square metre for the various types of retaining structures presented below are of a similar order and effectively cancel each other out. On this basis they have been omitted from this comparison.

3.3.1 Option 1: Mechanically stabilised earth walls

Refer to Retaining Wall Option 1 in Section 5 for a typical cross-section of this wall type.

3.3.1.1 Structural form and modes of behaviour

A mechanically stabilized earth wall (MSEW) comprising:

- AP65 engineered fill which is reinforced with geogrids;
- Layers of extensible geogrid (HDPE or polyester) at vertical centres and lengths that are determined during the design process;
- AP65 engineered backfill, to fill the space between the MSE part and the existing slope where required;
- Granular filter between the MSEW mass and the natural ground; and
- Flexible (welded wire mesh, geosynthetic facing) or rigid facing (segmental precast concrete panels, precast modular concrete blocks), which is connected to the MSE mass through geogrids. The type of facing, and the connection types and strength are determined during the design process.

The MSEW option can easily reach over 10 m in height and can have a steep batter angle (>70°) or even vertical. MSEW systems can absorb much of the earthquake forces through internal deformation that may result in non-detrimental horizontal deflections of the face, whilst maintaining the functionality of the road corridor they support. Deformations may be reduced to the target acceptable levels by appropriate design of its internal reinforcement (geogrids and binders).

3.3.1.2 How the design addresses the factors influencing the design

The MSEW is a flexible structure. Its flexibility allows it to absorb much of the earthquake actions (including fault rupture) through internal deformation without detrimental effects in its internal strength and stability. It is relatively simple to construct by selecting from the already available materials the appropriate reinforcement geometry, stress transfer mechanism, reinforcement material, extensibility of the reinforcement material, and type of facing and connections.

The MSEW can be designed in such a way that the mode of deformation is as much controlled as possible, avoiding for example rotation and tilting, and allowing for base sliding primarily. The footprint required for adequate performance may be adjusted by altering the batter angle and/ or adding binder to stabilize the engineered fill (cement and/ or lime stabilization). The selection between flexible and rigid facing depends mostly on the aesthetics requirements of the project.

For the special case of bridge abutments, the stiffness of the MSEW structure may be controlled by using inextensible steel straps instead of binder additive.

3.3.1.3 Likely methods of construction

The construction involves a slightly different sequence of steps in case of flexible or rigid facing.

Flexible facing

- Preparation of subgrade. Removal of unsuitable materials from the area to be occupied by the retaining structure. All organic matter, vegetation, slide debris and other unstable materials should be stripped off and the subgrade compacted.
- Construction of subsurface drainage features.
- Placement and compaction of engineered fill on the subgrade to the level of the first layer of reinforcement and its compaction.
- Placement of first reinforcing layer.
- Placement and compaction of engineered fill on reinforcement.
- Placement of the granular filter between the MSEW and the natural ground.
- Construction of face and behind the face drainage features.
- Placement of additional reinforcement and engineered fill.
- Construction of surface drainage features.

Rigid facing

- Preparation of subgrade. Removal of unsuitable materials from the area to be occupied by the retaining structure. All organic matter, vegetation, slide debris and other unstable materials should be stripped off and the subgrade compacted.
- Construction of subsurface drainage features.
- Placement of a leveling concrete pad for the erection of the facing elements.

- Erection of the first row of facing panels on the prepared leveling pad.
- Placement and compaction of engineered fill on the subgrade to the level of the first layer of reinforcement and its compaction.
- Placement of first reinforcing layer.
- Placement and compaction of engineered fill on reinforcement.
- Placement of the granular filter between the MSEW and the natural ground.
- Construction of face and behind the face drainage features.
- Placement of additional reinforcement and engineered fill.
- Construction of surface drainage features.

3.3.1.4 Construction materials and durability

The construction materials are AP65, welded wire mesh or precast concrete elements, HDPE or polyester geogrid, steel straps for the case of bridge abutments, granular filter and prefabricated drainage systems. All elements are inert, easy to procure even in a prefabricated form, and should satisfy the design life and durability requirements of the project. All geosynthetic elements should be sourced from pre-approved providers by NZTA.

3.3.1.5 Cost estimates

Refer to the concluding paragraph in Section 3.3 above.

3.3.2 Option 2: Anchored reinforced concrete cantilevered (L-shaped) walls

Refer to Retaining Wall Option 2 in Section 5 for a typical cross-section of this wall type.

3.3.2.1 Structural form and modes of behaviour

An anchored reinforced concrete cantilevered (L-shaped) wall comprising:

- Reinforced footing and stem;
- AP65 engineered backfill;
- Granular of prefabricated filter that is placed between the stem and the backfill;
- Class I corrosion protection permanent anchor(s)with appropriate pretention (tie backs) or soil nails (no pretention) that connect to the stem;
- Weep holes and sub horizontal drains.

The anchored reinforced concrete cantilevered wall option can reach over 8 m in height with appropriate anchor and or soil nail design. It is a rigid retaining system. The footprint required for construction is much less than that of the MSEW. The anchoring system minimizes any rotational behaviour, and by mobilizing a large ground mass minimizes base sliding as well.

3.3.2.2 How the design addresses the factors influencing the design

A reinforced concrete cantilevered (L-shaped) retaining wall resists bending due to earth pressures from the backfill, which provides part of the stabilizing weight by resting on the base slab and thereby acts together with the wall as a semi-gravity structure. The addition of an anchored system strengthens a large ground mass holding it together with a robust stress transfer mechanism. However, if it is built as a continuous linear element, being a rigid system may by unforgiving under severe earthquake shaking and especially if fault rupture affects it. To counteract this behaviour, this type of retaining system should be segmented by a careful design and construction of vertical joints that allow for discrete blocks to move independently if needed.

3.3.2.3 Likely methods of construction

The construction involves:

- Preparation of subgrade. Removal of unsuitable materials from the area to be occupied by the retaining structure. All organic matter, vegetation, slide debris and other unstable materials should be stripped off and the subgrade compacted.
- Construction of subsurface drainage features.
- Construction of the foundation.
- Construction of the stem either by pouring in situ or by using precast panels. The stem includes preformed holes for the anchoring and the drainage systems.
- Careful placement of the granular or prefabricated filter between the stem and the backfill.
- Careful placement and compaction of engineered backfill.

- Construction of the anchoring system. When anchors are used, they should be extended beyond the failure plane.
- Construction of the sub horizontal drains.
- Construction of surface drainage features.

3.3.2.4 Construction materials and durability

The construction materials are AP65, poured in situ or precast concrete elements, steel, prefabricated anchors and/ or soil nails that comply with Class I corrosion protection, and granular or prefabricated drainage systems. All elements are inert, easy to procure even in a prefabricated form, and should satisfy the design life and durability requirements of the project. All geosynthetic elements should be sourced from pre-approved providers by NZTA.

3.3.2.5 Cost estimates

Refer to the concluding paragraph in Section 3.3 above.

3.3.3 Option 3: Hybrid anchored soldier pile walls

Refer to Retaining Wall Option 3 in Section 5 for a typical cross-section of this wall type.

3.3.3.1 Structural form and modes of behaviour

A hybrid anchored soldier pile wall comprising:

- AP65 engineered backfill where necessary;
- Bored or driven piles that ideally should be socketed to bedrock;
- Granular filter that is placed behand the precast panels;
- Precast panels that fit in between the piles;
- Class I corrosion protection permanent anchor with appropriate pretention (tie backs) that connect to the piles;
- Weep holes and sub horizontal drains.

The hybrid anchored soldier pile wall option can reach over 8 m in height with appropriate anchor design. It is a stiff retaining system. The footprint required for construction is even less. The combination of piles and the anchoring system minimizes any rotational behaviour but may allow for localized horizontal deflections that are not detrimental.

3.3.3.2 How the design addresses the factors influencing the design

A hybrid anchored soldier pile retaining wall resists bending via the combination of piles and pre-tensioned anchors. Passive resistance is mobilized through the pile socket. The addition of an anchored system strengthens a large ground mass holding it together with a robust stress transfer mechanism. However, if it is built as a continuous linear element, being a stiff system may by unforgiving under severe earthquake shaking and especially if fault rupture affects it. To counteract this behaviour, this type of retaining system should include flexible connections between the precast panels and the piles at carefully design and selected locations that would allow for discrete blocks to move independently if needed. Furthermore, the effects of dynamic soil-structure interaction should be considered when P-δ effects are important (i.e. the bending moment caused by axial force times column deflection).

3.3.3.3 Likely methods of construction

The construction involves:

- Preparation of subgrade. Removal of unsuitable materials from the area to be occupied by the retaining structure. All organic matter, vegetation, slide debris and other unstable materials should be stripped off and the subgrade compacted.
- Construction of subsurface drainage features.
- Construction of the piles.
- Construction of the facing using precast panels. They include preformed holes for the drainage system.
- Careful placement of the granular or prefabricated filter between the precast panel and the ground face/ backfill.
- Careful placement and compaction of engineered backfill where required.
- Construction of the anchoring system connected with the piles. They should be extended beyond the failure plane.
- Construction of the sub horizontal drains in between the piles.
- Construction of surface drainage features.

3.3.3.4 Construction materials and durability

The construction materials are AP65, poured in situ or precast concrete elements, steel, prefabricated anchors that comply with Class I corrosion protection, and granular or prefabricated drainage systems. All elements are inert, easy to procure even in a prefabricated form, and should satisfy the design life and durability requirements of the project. All geosynthetic elements should be sourced from pre-approved providers by NZTA.

3.3.3.5 Cost estimates

Refer to the concluding paragraph in Section 3.3 above.

4. Description of Preferred Structural Options (Preliminary)

Refer to Appendix B for a table comparing the benefits and disbenefits of the different river bridge and retaining wall options.

4.1 River Bridge

4.1.1 Description of structure option

The preferred river bridge option is described in 3.1.1 of this report and comprises a multi-span Super-T bridge on piled foundations. A rendered image of the bridge can be found in Section 5 of this report.

From an engineering perspective, this is the preferred option for the following reasons:

- Cost-effective
- Well proven technology
- Resilient
- Durable
- Urban design elements can be easily incorporated
- Larger number of piers resulting in lower foundation loads per pier.
- Uncluttered contemporary design with clean structural lines and a simple but elegant appearance

The bridge and its associated structures provide a complementary system that allows for incorporation of urban design elements such as patterning on the abutments, piers and external faces of traffic barriers.

4.1.2 Structural type

The preferred structural type consists of precast prestressed Super-T girders with an insitu deck supported on reinforced concrete substructure elements with piled foundations. Abutments and piers will be orientated parallel to the river which results in an approximate 15° skew. Vertical load resistance is provided by the piled foundations with all other structural elements spanning back to the piles. Similarly, lateral loading is transferred into the piled foundations with resistance ultimately being provided by the soil over the length of the pile. The integral nature of the bridge minimises the need for expansion joints and bearings. As the overall length of the bridge exceeds the limits set by the NZ Bridge Manual for the maximum length of integral or semi-integral bridges expansion joints will be provided as required.

4.1.3 Span arrangements

The bridge comprises a 220m long bridge between stop banks with seven equal spans of approximately 31.4m. It was selected as the preferred river bridge option due to its open experience for bridge users, its thin structural depth which reduces its impact on the flood levels, its low cost compared to other options and its appropriateness for its location and required function. The Super-T beams are integral with the piers and abutments.

4.1.4 Foundation type

The foundations will comprise bored piles using a plugged double sleeve arrangement to prevent contamination of the aquifer, similar to that used on the Ewen Bridge 500m downstream.

4.1.5 Proposed arrangements for construction

The assumed construction methodology can be summarised as follows:

- The pier pile sleeves installed
- The pier columns are formed above ground level up to the underside of the pier heads
- The MSE walls will be built up above existing ground level to the required height and the lower half of the abutment beams and pier crossheads will be constructed.
- The precast beams will be lifted into position and placed on the partially completed abutments and piers. The beams shall be placed from the centre of the deck first, working outwards.
- The deck and remainder of the pier heads and abutment beams will be poured in accordance with the deck pour sequence determined during detailed design.
- The remainder of the structure including approach slabs, barriers, expansion joints and surfacing will be completed.

4.1.6 Risks and hazards considered

The key risks are as follows:

1. The potential for soft and weak materials across site
2. The potential for low quality rock for cut slope batters and slope stability
3. The presence of the sensitive shallow and deep aquifers within the potential piling zone and the possibility of artesian conditions
4. The position of the Wellington Fault is inferred and remains undefined for bridge design purposes. As currently mapped it passes roughly parallel to the existing stop bank beneath the proposed River bridge location.
5. Contrasting variable ground conditions in the proposed foundation locations of the proposed bridges.
6. Number and type of piers in the waterway creates a potential flood debris and scour risk. To date, GWRC have not indicated a maximum number of piers or their preferred type. They have indicated that the Ewen Bridge design works well.

A site walkover (MWH, 2017) also identified localised slope instabilities in both the bedrock (greywacke) and in the colluvium materials superimposing the bedrock.

The presence of the aquifer presents significant challenges when proposing piled foundations. It is proposed to adopt similar sleeving and bored piling techniques to that used on the Ewen Bridge 500m downstream of the Melling site. Specific piling details will be developed at the preliminary design stage but will likely utilise inner and outer steel casings and concrete annulus plugs to prevent contamination of the aquifer.

4.1.7 Estimated costs of proposed structure option

The preliminary cost estimate for this option is based on a typical rate for this type of bridge of $4,500 per square metre.

Total base estimate is $27.7M.

If no interaction is allowed with the existing stop banks (as per GWRC's preference) this would add two additional land spans to either end of the bridge (to span the stop banks) adding a further $5M to the overall cost.

Total combined cost is $32.7M.

This excludes GST, main Contractor's P&G, overhead and profit and estimating contingency.

4.1.8 Recommended design requirements and standards

The cost of this bridge easily exceeds the $16M threshold specified in the NZ Bridge Manual therefore the bridge should be categorised as an Importance Level (IL) 4 structure. It is recommended that this categorisation be revisited at the preliminary design stage to see if it is possible to reduce this to an IL3+ or even an IL3 structure. This re-categorisation will significantly reduce the seismic demand on the proposed bridge and associated structures.

Consideration also needs to be given to the possibility of a rupture of the Wellington fault. Its current location is only indicative, and it is highly likely that this river bridge structure will span it. Designing to accommodate the expected lateral or vertical movements could prove economically unviable. The level of resilience will therefore need to be established prior to proceeding to the preliminary design stage.

The below design requirements and standards are recommended:

- NZTA Bridge Manual SP/M/022, Third Edition, Amendment 3, 2018.
- AASHTO LRFD Bridge design specifications, 2014.
- BS EN 1998-5 Eurocode 8 Design of structures for earthquake resistance part 5, Foundations, retaining structures and geotechnical aspects, 2004.
- Wood J.H, Elms D.G. (1990). Seismic Design of Bridge Abutments and Retaining Walls. Road Research Unit Bulletin 84 Volume 2.
- Murashev A.K. (2003) Guidelines for design & construction of geosynthetic reinforced soil structures in New Zealand. Research report 239, NZ Transport Agency, Wellington.
- NZS 3101:2006 Concrete Structures Standard;
- NZS 3404:1997 Steel Structures Standard;
- AS 5100:2004 Bridge Design (where not covered by NZ standards);
- NZS 1170.5:2004 Structural Design Actions Part 5: Earthquake Actions – New Zealand;
- The New Zealand Building Code;
- Department of Building and Housing amendments to the New Zealand Building Code, Clause B1/VM1 Structure following the Canterbury earthquakes; and
- AASHTO LRFD Bridge Design Specifications, Seventh Edition (for design of the pile-column splices).

4.2 Interchange Bridge

4.2.1 Description of structure option

The preferred interchange bridge option is described in 3.2.1 of this report and comprises a single span Super-T bridge on reinforced concrete bankseats on MSEW abutments.

From an engineering perspective, this is the preferred option for the following reasons:

- Cost-effective
- Well proven technology
- Resilient
- Durable
- Urban design elements can be easily incorporated
- Uncluttered contemporary design with clean structural lines and a simple but elegant appearance

The bridge and its associated structures provide a complementary system that allows for incorporation of urban design elements such as patterning on the abutments, piers and external faces of traffic barriers.

4.2.2 Structural type

The preferred structural type consists of precast prestressed Super-T girders with an insitu deck supported on reinforced concrete substructure elements on MSEW abutments.

Longitudinal seismic actions will be resisted by a combination of friction beneath the abutment beam and passive resistance behind the abutment. Transverse seismic actions will be resisted largely by friction beneath the abutment beam, although some passive resistance will be provided by the reinforced concrete wingwalls. Where the longitudinal and transverse seismic actions exceed the friction and passive resistance in a ULS or MCE event, it is intended that the bridge moves on top of the RE wall.

4.2.3 Span arrangements

The bridge comprises a 31.9m long single span bridge. It was selected as the preferred interchange bridge option due to its open experience for bridge users, its thin structural depth, its low cost compared to other options and its appropriateness for its location and required function. The Super-T beams are integral with the bankseats.

4.2.4 Foundation type

MSEW are spread foundation walls that perform well during seismic events and can accommodate relatively large displacements with little to no detrimental effect so are well suited to this location.

4.2.5 Proposed arrangements for construction

The assumed construction methodology can be summarised as follows:

- RE walls will be built up above founding level to the required height. The fill will be either suitable excavated material or imported;
- Settlements will be monitored during construction
- The abutment beams excluding headwalls are constructed
- The precast beams are lifted into position and placed on the partially completed abutment
- The abutment headwalls and 6.0m of the deck slab at each end of the bridge are poured
- The remaining deck slab is poured
- The remainder of the structure including approach slabs, barriers and surfacing will be completed.

4.2.6 Risks and hazards considered

The key risks are considered to be geotechnical as follows:

1. The potential for soft and weak materials across site
2. The potential for low quality rock for cut slope batters and slope stability
3. The presence of the sensitive shallow and deep aquifers within the potential piling zone and the possibility of artesian conditions
4. The position of the Wellington Fault is inferred and remains undefined for bridge design purposes. As currently mapped it passes roughly parallel to the existing stop bank beneath the proposed River bridge location.
5. Contrasting variable ground conditions in the proposed foundation locations of the proposed bridges.

A site walkover (MWH, 2017) also identified localised slope instabilities in both the bedrock (greywacke) and in the colluvium materials superimposing the bedrock.

The presence of the aquifer presents significant challenges when proposing piled foundations. It is proposed to adopt similar sleeving and bored piling techniques to that used on the Ewen Bridge 500m downstream of the Melling site. Specific piling details will be developed at the preliminary design stage but will likely utilise inner and outer steel casings and concrete annulus plugs to prevent contamination of the aquifer.

4.2.7 Estimated costs of proposed structure option

The preliminary cost estimate for this option is based on a typical rate for this type of bridge of $4,000 per square metre.

Total base estimate is $3.6M.

This excludes GST, main Contractor's P&G, overhead and profit and estimating contingency.

4.2.8 Recommended design requirements and standards

Consideration needs to be given to the possibility of a rupture of the Wellington fault. Its current location is only indicative, and it is highly likely that this interchange bridge structure will either be immediately adjacent to it or span it. Designing to accommodate the expected lateral or vertical movements could prove economically unviable. The level of resilience required will therefore need to be established prior to proceeding to the preliminary design stage.

The below design requirements and standards are recommended:

- NZTA Bridge Manual SP/M/022, Third Edition, Amendment 3, 2018.
- AASHTO LRFD Bridge design specifications, 2014.
- BS EN 1998-5 Eurocode 8 Design of structures for earthquake resistance part 5, Foundations, retaining structures and geotechnical aspects, 2004.
- Wood J.H, Elms D.G. (1990). Seismic Design of Bridge Abutments and Retaining Walls. Road Research Unit Bulletin 84 Volume 2.
- Murashev A.K. (2003) Guidelines for design & construction of geosynthetic reinforced soil structures in New Zealand. Research report 239, NZ Transport Agency, Wellington.
- NZS 3101:2006 Concrete Structures Standard;
- NZS 3404:1997 Steel Structures Standard;
- AS 5100:2004 Bridge Design (where not covered by NZ standards);
- NZS 1170.5:2004 Structural Design Actions Part 5: Earthquake Actions – New Zealand;

- The New Zealand Building Code;
- Department of Building and Housing amendments to the New Zealand Building Code, Clause B1/VM1 Structure following the Canterbury earthquakes; and
- AASHTO LRFD Bridge Design Specifications, Seventh Edition (for design of the pile-column splices).

Retaining Walls

4.2.9 Description of structure option

The preferred retaining structure option is the Mechanically Stabilized earth Wall (MSEW) for the vast majority of retaining structures on the project. The MSEW option is generally preferred over others due its flexibility, long term resilience and its ability to absorb much of the energy released from a strong earthquake via internal deformation without detrimental effects and/ or losing its functionality.

The MSEW does not require a specially designed foundation, can vary at height and size depending on the design actions and functionality intent and is constructed from AP65 aggregate, and geogrids or steel straps for the case of bridge abutments. A facing is also part of the MSEW and may be selected to be flexible or rigid with appropriate performance considerations and adjustments for internal stability and whole of life acceptable performance.

Under static loading conditions the MSEW retaining structures resist the applied actions (traffic and dead load of structure) through the internal stability of the reinforced engineered fill and self-weight. Seismic loading is initially counteracted by the self-weight of the MSEW structure up to a critical (yield) acceleration, at which the MSEW blocks begin to displace horizontally. The magnitude of horizontal deformation increases with increasing acceleration, with the design accelerations reached prior to the propagation of internal plastic/ shear strains and/ or internal yielding resulting in internal instability.

The MSEW preclude the build-up of water pressures within or behind the wall over and above the allowance for a 1.0 m head of water within the reinforced engineered fill (behind the facing). Any potential increased water pressure on the rear of the facing is dissipated by the filters placed between the facing and the mechanically stabilized mass.

Where the site is constrained, or where limited excavation is expected, MSEW may not be the best retaining solution. These instances will be identified during the preliminary design phase and alternative retaining solutions explored. An example of this may be upslope of the Tirohanga connection.

4.2.10 Structural type

The MSEW is flexible type of a mass gravity retaining system.

4.2.11 Span arrangements

Not applicable.

4.2.12 Foundation type

No foundations required except for the case of a rigid facing being opted for. Then, a levelling unreinforced concrete pad is required to be constructed under the first facing element.

4.2.13 Proposed arrangements for construction

MSEW to be designed constructed along all wall arrangements required by the current geometric design.

4.2.14 Risks and hazards encountered

The following risks and hazards were considered:

- Seismic actions resulting from the DCLS and CALS performance requirements.
- Fault rupture.
- Additional horizontal thrust developed in the cascading wall configuration in the northern half of the interchange.
- Water levels and built up of pore pressures arising from the upslope.

4.2.15 Estimated costs of proposed structure option

The preliminary cost estimate for this option is based on a typical rate for this type of retaining structure of $1,250 per square metre.

This excludes GST, main Contractor's P&G, overhead and profit and estimating contingency.

4.2.16 Recommended design requirements and standards

The below design requirements and standards are recommended:

- NZTA Bridge Manual SP/M/022, Third Edition, Amendment 3, 2018.
- AASHTO LRFD Bridge design specifications, 2014.
- BS EN 1998-5 Eurocode 8 Design of structures for earthquake resistance part 5, Foundations, retaining structures and geotechnical aspects, 2004.
- Wood J.H, Elms D.G. (1990). Seismic Design of Bridge Abutments and Retaining Walls. Road Research Unit Bulletin 84 Volume 2.
- Murashev A.K. (2003) Guidelines for design & construction of geosynthetic reinforced soil structures in New Zealand. Research report 239, NZ Transport Agency, Wellington.

All cuts that cannot be supported via the MSEW option it is recommended to be designed using passive protection systems according to "Green R. (2016) Rockfall: Design considerations for passive protection structures, NZGS Guidelines".

It is stipulated in NZTA Bridge Manual, Section 6.1.2, Clause d. that "Where settlement and/or horizontal displacement limits are impractical or uneconomic to satisfy, or where the cost of ground improvement or other mitigation measures is very high in comparison with the project or structure cost, consideration should be given to making a request to the road controlling authority for accepting a lower design standard."

If such a case is identified during the initial stages of the MSEW design, it is recommended to request for a departure to carry out performance-based design based on the steps recommended in "Antonopoulos, I. Seismic Design of Geotechnical Structures for NCTIR. NZ Geomechanics News, Issue 96, NZGS, 2018".

5. Drawings and Documents

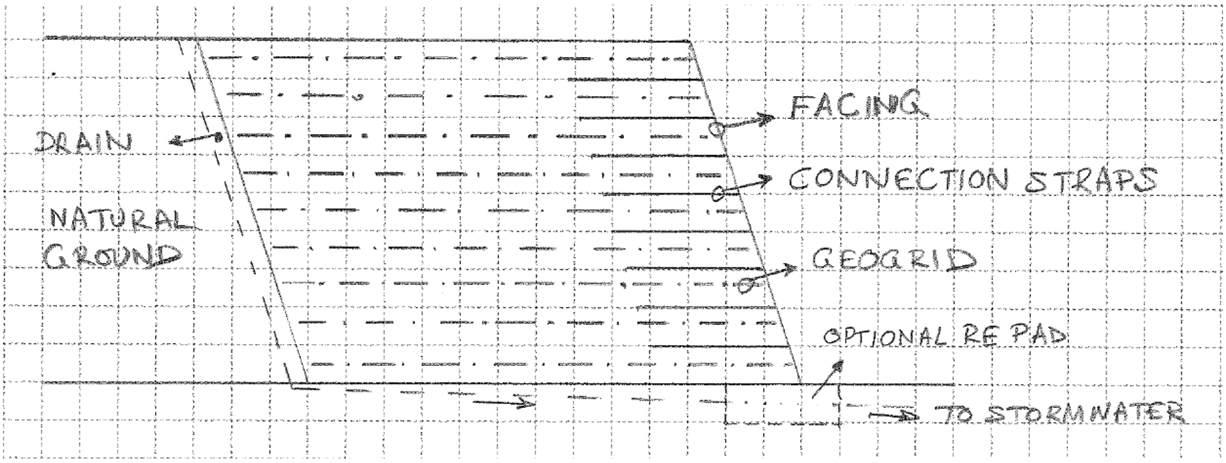
5.1 Drawings and documents accompanying the preliminary structure options report

River Bridge: Option 1 – Seven Span Super-T

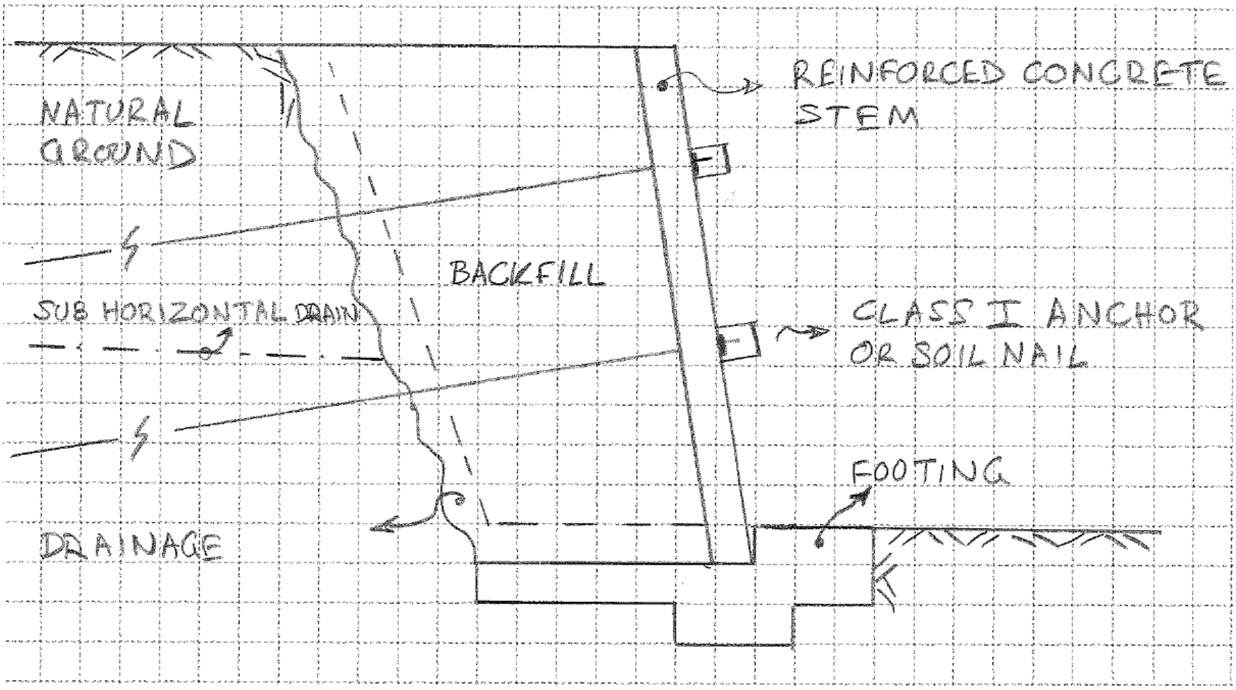
River Bridge: Option 2 – Three Span Variable Depth Twin Box Girder Bridge

River Bridge: Option 3 – Single Span Network Tied Arch

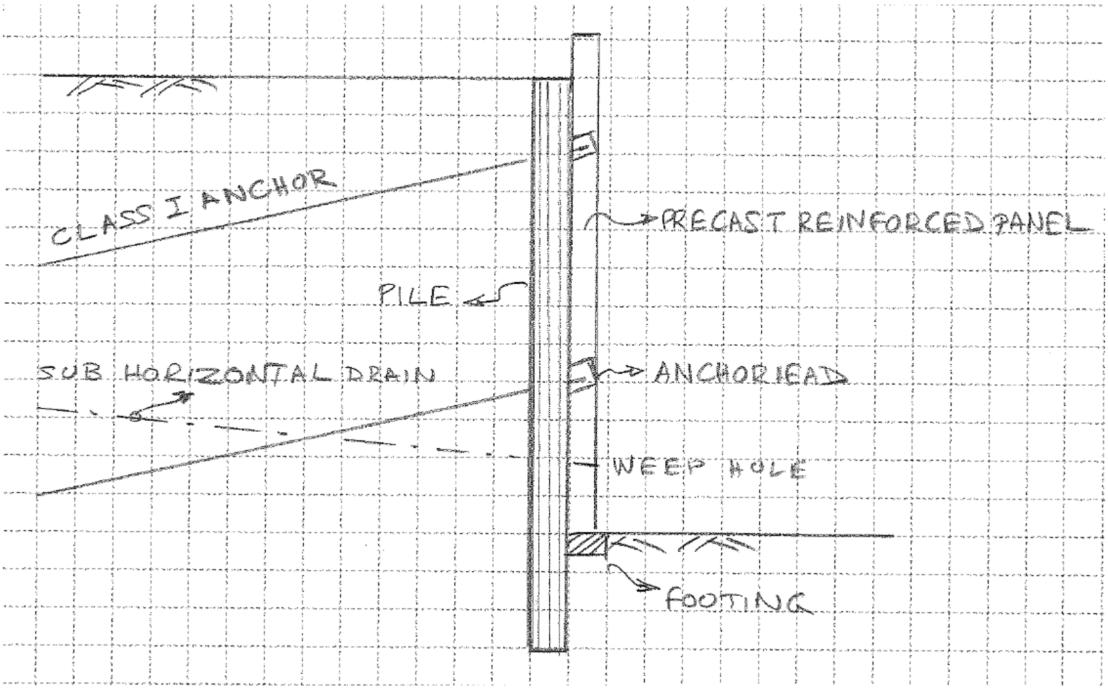
The below sketches show the concept of the three retaining wall options discussed in section 3 above. All sketches are not drawn to scale.

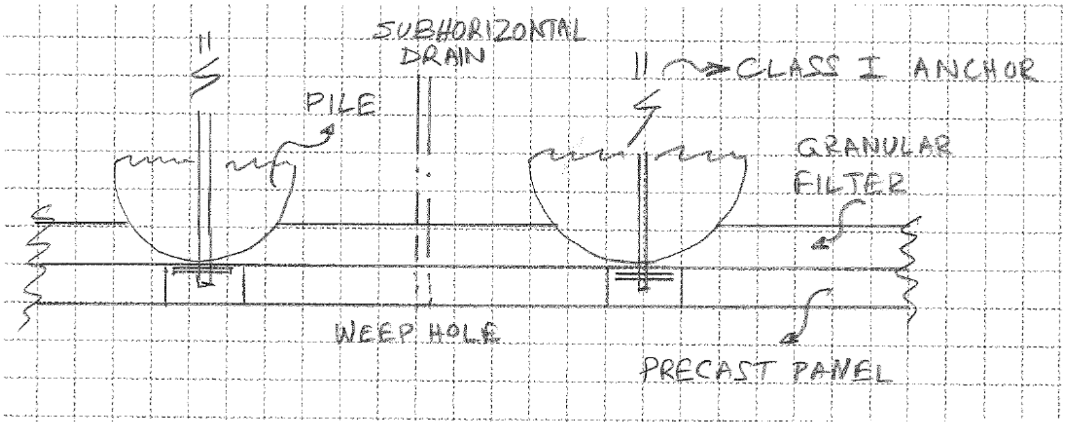


Retaining Wall Option 1: Mechanically stabilized earth walls (MSEW) option



Retaining Wall Option 2: Anchored reinforced concrete cantilevered (L-shaped) walls option





Retaining Wall Option 3: Hybrid anchored soldier pile wall option

6. Submission and Acceptance

6.1 Submitted to the NZ Transport Agency for acceptance:

9(2)(a)

Signed: [redacted]

Name: [redacted]

Name of Organisation: Stantec NZ Ltd

Date: 31/05/19

6.2 Accepted/Rejected on behalf of the NZ Transport Agency subject to the amendments and conditions below:

Signed:

Name:

Position held:

Date:

Amendments/conditions:

Appendix A River Bridge/Stop Bank Interaction

Melling Transport Improvements - River Crossing Structural Options

What:

- present the considerations for new Hutt River Crossing options and recommended structure type
- discuss a comparison of city side bridge abutments: land bridge vs integral with stopbank structure

Why: to generate alignment on what should be assumed for costing and land requirement purposes in the business case

In your draft report, can you please include the section on the option of integrating the bridge structure with the proposed GWRC stopbanks. We will explore this option with GWRC and HCC on the 19th July meeting and will subsequently seek a formal response. It would also be beneficial to include some examples of similar work done elsewhere either on state highway or local road network so as to provide confidence to GWRC/HCC that risk around scouring of stopbanks can be managed by sound technical design.

Events like Hurricane Katrina have shown that transitions are the most vulnerable locations in a line of flood defence. Tourment et al (2012) suggested that more than half of internal erosion problems are linked to some form of transition in a stopbank. Transitions are commonly the weakest link in the stopbank system, and it highlights the importance of careful design and detailing of any transition.

Special attention is needed in these locations to avoid failure. From a geometrical perspective, it is desirable to avoid any overflowing in these areas by providing slight increases in crest elevation. Overflow can be prevented by having the crest elevation of the stopbanks immediately adjacent to the structure slightly higher.

Potential for surface erosion or scour can be mitigated using appropriate measures (concrete, rock armour, Reno mattresses, gabions etc) to reduce the threat of erosion and scour on the stopbanks.

Given the historical external and internal problems associated with transitions which have led to stopbank failures, great care must be taken when carrying out the design of transition details.

Guidance from Chapter 9 – Design, International Levee Handbook, Ciria (2013), suggests the following:

- The detail must be considered in three dimensions (not just in plan or in cross-section)
- The magnitude of the characteristics of the hydraulic loads and external actions should be considered
- Potential failure mechanisms should be considered, and particular consideration give not issues such as uplift, internal erosion and hydraulic separation
- Erosion mechanisms should be identified and their potential impact on the design considered
- Appropriately robust design solutions should be selected
- A range of foreseeable loading scenarios should be considered (normal operating conditions, design flood events and extreme events more onerous than the design flood situation).

The design will also need to consider movement that could occur under a seismic event and whether gaps could occur that could weaken the stopbanks due to relative movement of the "softer" stopbank and the "harder" structure.

What is evident is that, internationally, concrete structures are commonly constructed through stopbanks. Examples of these are:

- Reinforced concrete spillways
- Crest walls
- Embedded walls
- Pipes, conduits and culverts

- Flood walls
- Bridge abutments

In response to the above questions, a Powerpoint presentation was presented by Stantec at the meeting. For completeness, this presentation is included below.

More detailed discussion eventuated during the presentation and several other requests were raised on this topic. These specific requests, and their associated responses, can be found in Appendix C of this report.

Melling Bridge Options

- Multi-Span Super-T
- Three span variable depth twin box girder
- Single span network tied arch

1

2

3

4

Melling Bridge Options

Multi-Span Super-T (Preferred)	3 Span Post-Tensioned	Network Tied Arch
Proven cost-effective	Significantly more costly than Super-T's due to more complex design and construction	Actual costs unknown at this stage, but two previous designs have been carried out, cost savings over more traditional construction types. Lighter sections result in less materials = cost saving.
Proven technology that can be taken on by most larger NZ contractors	Proven technology but is limited to a small number of large and specialist contractors	Relatively unknown, but well used internationally for spans significantly greater than proposed here. Complex fabrication probably limits it to only two fabricators in NZ (Howe and Eastbridge).
Proven resilience with average seismic mass	Proven resilience, but with higher seismic mass	Relatively unproven resilience in NZ, but overall a lighter structure, so less seismic mass.
Multiple spans allow for quick repair following large seismic event	As it is built as a balanced cantilever unit, if the abutment was impacted during an earthquake bridge is easily repairable. Impact on the piers is not so readily restored.	Only a single span structure so highly susceptible to fault rupture – large displacements could result in total bridge collapse.
Some piers likely in normal river flows, with increased number of piers when in spate increases risk of debris capture and scour	Only two piers each side of the main river channel, reduced risk of debris capture and scour when river in spate	Very low risk of flood debris capture and scour.
Durable	Durable	Likely to be higher maintenance than concrete, due to painting requirements
Urban design elements easily incorporated, although generally clean and uncluttered	Parabolic bridge soffit results in a pleasing elevation, concrete construction allows for urban design elements to be easily incorporated, although generally clean and uncluttered.	Aesthetically pleasing, landmark structure, would be the longest bridge of this type in NZ by some margin
Higher number of piers, but lower foundation loads. Possible risk of aquifer contamination	Two abutments and two piers resulting in high foundation loads. Risk of aquifer contamination.	Only two abutments, higher foundation loads. Deeper foundations due to higher loads increases risk of aquifer contamination.
Shallow deck profile (1.8m) so easier to tie-in over the stop banks to the existing constrained road network	Deck profile deeper (2.5m) so tie-in over the stop banks to the existing constrained road network is problematic	Expected to be a shallower deck profile (approx. 2.0m) than the post-tensioned option, but again would need careful consideration when tying-in to the existing constrained road network.

5

Melling Bridge

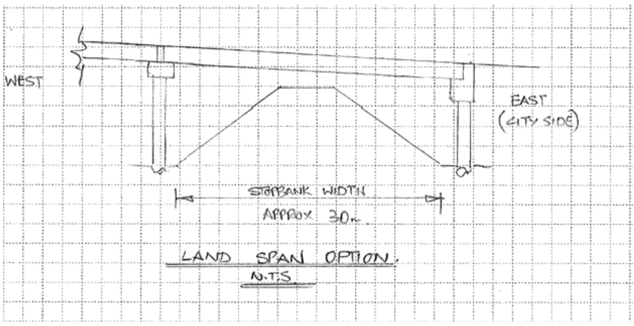
Abutment options

- Land span
- Bridge abutment built integral with stopbank

6

3

Melling Bridge



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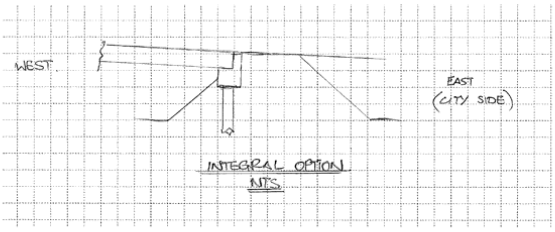
Melling Bridge



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Melling Bridge

What is GWRC's experience with, and basic concerns about, an integral abutment approach?

- Any historic issues?
- Maintenance issues?
- Other issues?

9

Melling Bridge

Local examples of abutment in stopbank:

- Melling Link Bridge

10

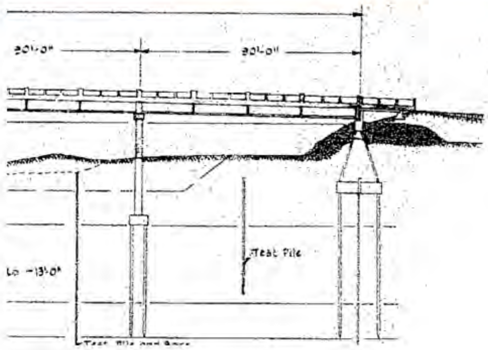
Melling Link Bridge (east abutment)

11

Melling Link Bridge (east abutment)

12

Melling Link Bridge (east abutment)



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Melling Bridge

Local examples of abutment in stopbank:

- Ewen Bridge

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Ewen Bridge (east abutment)

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Ewen Bridge (west abutment)

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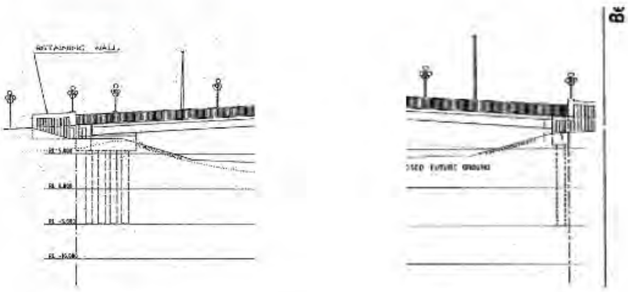
Ewen Bridge (east & west abutment)



17

Melling Bridge – East abutment

Another issue – High angle of abutment skew

18

Melling Bridge – East abutment

19

Appendix B Structural Options Tables

River Bridge Option Comparison (Interchange Bridge utilises the same preferred option)

Multi-Span Super -T (Preferred)	3-Span Post-Tensioned	Network Tied Arch
Proven cost-effective	Significantly more costly than Super-Ts due to more complex design and construction	Actual costs unknown at this stage, but two previous designs have been chosen based on cost savings over more traditional construction types. Lighter sections result in less materials = cost saving.
Proven technology that can be taken on by most civil NZ contractors	Proven technology but is limited to a small number of large and specialist contractors	Relatively unknown, but well used internationally for spans significantly greater than proposed here. Complex fabrication probably limits it to only two fabricators in NZ (Acme and Eastbridge).
Proven resilience with average seismic mass	Proven resilience, but with higher seismic mass	Relatively unproven resilience in NZ, but overall a light structure, so low seismic mass.
Multiple spans allow for quick repair following large seismic event	As it is built as a balanced cantilever even if the abutment was impacted during an earthquake bridge is easily restorable. Impact on the piers is not so readily restored.	Only a single span structure so highly susceptible to fault rupture – large displacements could result in total bridge collapse.
Some piers likely in normal river flows, with increased number of piers when in spate increases risk of debris capture and scour	Only two piers each side of the main river channel, reduced risk of debris capture and scour when river in spate.	Very low risk of flood debris capture and scour
Durable	Durable	Likely to be higher maintenance than concrete, due to painting requirements.
Urban design elements easily incorporated, although generally clean and uncluttered	Parabolic bridge soffit results in a pleasing elevation, concrete construction allows for urban design elements to be easily incorporated, although generally clean and uncluttered.	Aesthetically pleasing, landmark structure, would be the longest bridge of this type in NZ by some margin
Higher number of piers, but lower foundation loads. Possible risk of aquifer contamination	Two abutments and two piers resulting in high foundation loads. Risk of aquifer contamination.	Only two abutments, higher foundation loads. Deeper foundations due to higher loads increases risk of aquifer contamination.
Shallow deck profile (1.8m) so easier to tie-in over the stop banks to the existing constrained road network	Deck profile deeper (2.5m) so tie-in over the stop banks to the existing constrained road network is problematic	Expected to be a shallower deck profile (approx. 2.0m) than the post-tensioned option, but again would need careful consideration when tying-in to the existing constrained road network.

Retaining Walls – Option Comparison

Mechanically Stabilised Earth Walls (Generally preferred)	Anchored Cantilevered (L-shape) Walls	Hybrid Anchored Soldier Pile Walls (Preferred for confined retained structures)
Flexible structure	Rigid structure	Stiff structure
Good ductility	Limited ductility	Average ductility (better than L-walls)
Ability to absorb large earthquake forces through deformation (including fault rupture)	Unforgiving in a large earthquake, in particular during fault rupture when built continuously, would need to be built in sections to counter this and allow movement	Unforgiving in a large earthquake, in particular during fault rupture when built continuously, would need to be built in sections to counter this and allow movement
Can be easily modified via additional reinforcement and binders to meet acceptable deformation levels	The introduction of more anchors to resist high seismic loading would increase per sqm costs substantially	The introduction of more anchors to resist high seismic loading would increase per sqm costs substantially
Facing can be flexible or rigid - precast concrete or mesh – can be plain, patterned or vegetated.	Facing is only concrete - can be plain or patterned.	Facing is only concrete - can be plain or patterned.
Relatively quick and simple construction – low skill level	Time-consuming construction – high skill level required	Time-consuming construction – high skill level required
Walls of up to 20m high have been constructed.	Walls ≥8m are possible with appropriate anchor design	Walls ≥8m are possible with appropriate anchor design
Low bearing pressures on subgrade	Higher bearing pressures on subgrade	Lateral bearing pressures on subgrade
Large footprint (large excavation required)	Smaller footprint than MSEW	Smallest footprint, may be used in confined locations such as Tirohanga Road.

Appendix C Responses to PCN#22 Structural Requests

Following the issue of Stantec's draft Preliminary Structure Options Report, dated 17th July 2019, and a subsequent presentation to representatives of the NZTA, Greater Wellington Regional Council, Hutt City Council and RiverLink at Greater Wellington Regional Council's offices on the 19th July 2019, the NZTA have identified further structure related tasks to be included in the report.

This appendix has been formulated to address these additional tasks through further supporting information.

Request 1: Stantec is to review the Boffa Miskell (BM) report on the pedestrian bridge considerations and see if any outcomes from that report are useful for the road bridge.

The report being referred to is the Preliminary Design Landscape Architecture + Urban Design + Ecological Design Technical Report T-17/16, issued by BM in April 2018.

Section 5.3 of the report discusses the following key design considerations for the pedestrian/cycle bridge:

Key Design Considerations

- The span of the bridge-as measured between stopbanks is approximately 176 metres-this requires key considerations as to structral support
- The flood level envelope that the bridge has to avoid is defined by an arc from stopbank to stopbank at a rate of curvature of 20 metres transverse and 1 metre vertically.
- This envelope and the desire to land directly on top of the stopbanks with minimal ramping up from them to the deck are the most important parameters any proposed design must respond to.

The preferred footbridge option presented in the BM report is a 4-span structure stated as comprising "a simple rectilinear beam and straight columns. The language of the bridge is akin to a viaduct structure." The columns are equally spaced at 45 metres and "are conceived of as fins the same width as the deck."

A concept elevation and visualisation of the proposed 4-span footbridge are shown below (courtesy of the BM report):

Concept Elevation - Prefered 4-span bridge concept

Figure 93: Bridge forms prefered

Concept Visualisation - Prefered 4-span bridge Concept

The footbridge material choice is kept open at this concept stage to two options – steel and concrete.

The footbridge colour is stated as being driven by the bridge's "simplicity, boldness and the desire to retain a pure sculptural form. Excessive use of colour tends to detract from form."

The primary role of the footbridge deck surfacing is stated as "slip resistance, durability and longevity."

The footbridge lighting is "designed to provide the optimal lighting required while creating a soft and elegant silhouette of the bridge".

Considering the above key drivers for the footbridge, the preferred Super-T Melling River Bridge option is considered to have good correlation.

Request 2: Outline Discarded Bridge Options

Numerous bridge options were considered before settling on the final three options presented in the Preliminary Structure Options Report. The reasons for these options being discarded are as follows:

- **Single hollowcore bridge** – an economical and resilient option common throughout New Zealand and with a slender deck profile, but maximum span is only approximately 25m which results in an increased number of piers in the waterway. An increase in the number of piers is considered undesirable from a waterway and flood debris perspective.
- **Multi-span truss bridge** – this bridge has very good waterway clearance characteristics as the main structural elements are above deck level, however the side trusses of these bridges increase in height significantly as the spans increase resulting in large unsightly utilitarian structures with poor aesthetic appeal. The very wide deck (up to 30m) could also prove problematic for this structure type and may require a third central truss to improve rigidity.
- **Suspension bridge** – typically only cost effective for spans between 450m and beyond and the constrained areas behind the bridge abutments provide insufficient space for the cable anchorages. Cable anchorages also require firm strata at or close to the surface of the ground – this is not present at the Melling site. Higher propensity for aerodynamic behavior issues due to the high wind speeds in Wellington.
- **Cable-stayed bridge** – These structures are self-anchoring so not as dependent on firm strata foundation conditions as suspension bridges. The very wide bridge deck (up to 30m) could present significant torsional stability issues for this type of structure. Aerodynamic oscillation is less of a concern for these bridges when compared to suspension bridges but would still need serious consideration considering the high wind speeds in Wellington.

Request 3: Is a 4-Span twin-box girder viable to reduce the depth of the superstructure at the east stopbank?

Option 2 of the Preliminary Structure Options Report details a 3-span variable depth twin-box post-tensioned girder. A 3-span option was adopted to limit the number of piers in the river channel to two. The proposed spans are 60m/100m/60m. Using this configuration, the depth of the box girder at each pier would be approximately 5m and the depth at mid-span of the main span and abutments approximately 2.5m.

As part of this request Stantec have completed an additional concept arrangement for a 4-span variable depth twin-box post tensioned girder and can confirm that the spans would be in the order of 35m/75m/75m/35m. The depth of the superstructure at each pier would be approximately 3.75m, with the depth of the deck at the mid-span and at the stopbanks approximately 2m.

In conclusion, increasing the number of spans from 3 to 4 does result in a reduction of deck depth at the stopbank of approximately 0.5m, but even at this reduced depth the overall deck depth at the stopbank remains 0.25m deeper than the preferred Super-T option. It should also be remembered that due to the complexity of twin box girder construction the overall bridge cost would be approaching twice that of the more conventional Super-T option.

Request 4: Can a network arch bridge be used over river channel with another type over the floodway?

A question was raised during the presentation regarding the possibility of using a network tied arch over the normal flow river channel with a more traditional bridge type adopted each side for the approach spans. This combination of bridge types is certainly a viable option. However, network arch bridges do become problematic when deck width exceeds 25m or so, and therefore careful consideration should be given to it as a viable option at the next stage should it prove favourable. The arrangement would keep the piers supporting the main span out of the normal river channel, reverting to an additional pier in the flood plain to support the two spans on the city side (three piers in total between stopbanks). The photograph below shows a typical arrangement of this type.

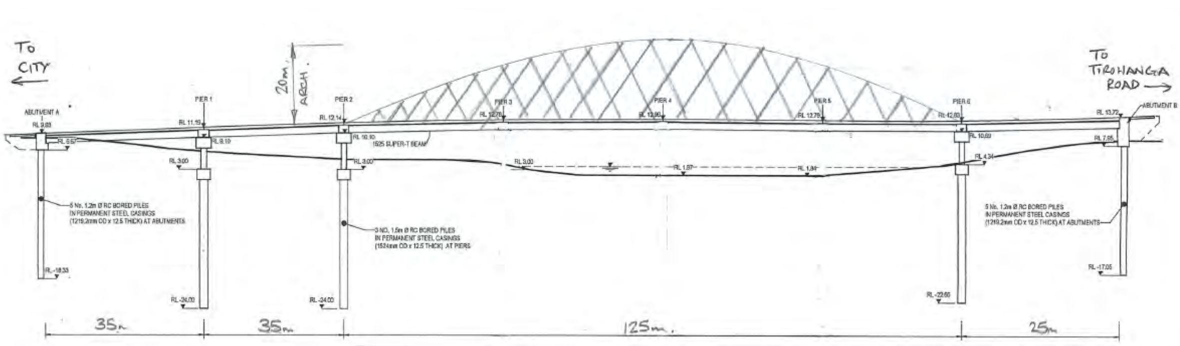
Hastings Bridge, spanning the Mississippi River in the USA

As can be seen in the above photograph, when compared to the piers supporting the adjacent shorter spans, more substantial piers are required to transfer the network arch loads into the riverbed. This can be considered to detract from the overall slender look normally associated with network tied arches, but this is subjective.

This arrangement is considered to have more resilience than the single span network tied arch, but less resilience than a conventional Super-T option. This is mainly due to the close proximity of the Wellington fault and the potential effects a fault rupture may have on a longer span structure of this nature. It is likely to take longer to reinstate this structure post-earthquake due to the potential for more damage (being a longer structure) and be more costly to repair/reinstate.

Furthermore, the overall width of the river bridge has now increased due to recent alterations to the road geometry. Serious consideration would need to be given to ensure the new deck widths remains within the acceptable range for bridges of this type, particularly regarding global stability.

As part of this request Stantec have briefly assessed a possible bridge arrangement and developed the concept detailed below. The proposal comprises a 125m long network tied arch with one 25m span on the western side and a further two 35m spans on the city (east) side. It is proposed to construct the three shorter spans using Super-T beams.



Network arch/Super-T concept (not to scale).

Request 5: Mitigation plan

GWRC noted that the impacts of building the abutment into the stopbank include reduction in freeboard and reduction in seismic, structural and erosion integrity of the stopbank.

In order to mitigate these and other issues the following mitigation plan is proposed as risk reduction measures:

- First and foremost, adopt best practice in design, choice of material and installation.
- Undertake site-specific assessments of structural and geotechnical risks for the site, including liquefaction and lateral spreading risks.
- Add diversity and redundancy where cost-effective
- Install restraints to restrict movement
- Adopt structure types that are can be easily repaired, parts are readily available and can be jacked up or reinstated quickly.
- Special attention to underground assets where they approach and cross bridges, including incorporation of flexible connections where appropriate.
- Develop a spare parts policy that takes into consideration emergency needs and likely delivery delays, especially for imported items. This includes ensuring that spare parts and so on are stored in locations likely to be accessible following earthquakes.
- Manage natural disaster risk via annual maintenance planning.
- Adopt a risk management template for inclusion in asset management plans. The template describes good practice in resilience planning, assisting inclusion of resilience considerations as a 'business as usual' activity.
- Set out communication and reporting arrangements for emergency responses.

The value of seismic mitigation is in principle the reduction in the overall community loss resulting from the mitigation work. The diagram below illustrates the issues.

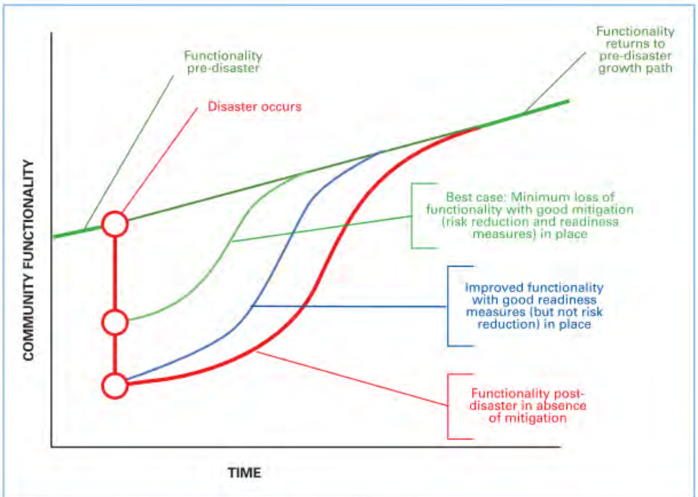


Figure 1: Community Losses With and Without Mitigation

Notes: Overall community losses are described by the shape under the functionality growth path (the size of the loss depends on the extent and duration of reduced functionality). The loss can be reduced by readiness steps by infrastructure owners (and others) – these steps facilitate an early return to the growth path. The best outcome will occur with good risk reduction and readiness in place (the shape is smallest in that case).

The figure was suggested by Prof Stephanie Chang, University of British Columbia, during her New Zealand visit in 2010.

The above advice is largely derived from the New Zealand Lifelines document entitled 'The Value of Lifeline Seismic Risk Mitigation in Christchurch' Summary Report – June 2012. This document summarises the main points from the report 'The Value of Lifeline Seismic Risk Mitigation in Christchurch' by Tony Fenwick for the New Zealand Lifelines Committee in June 2012 and the 'Risks and Realities: A Multi-Disciplinary Approach to the Vulnerability of Lifelines to Natural Hazards', prepared by the Christchurch Engineering Lifelines Group and published by the Centre for Advanced Engineering in 1997.

In direct response to the specific issues raised by GWRC at the meeting the following is noted:

- The slight reduction in freeboard at the stopbank location is countered by the upward vertical curve incorporated into the proposed bridge deck over the main river channel. Therefore, the minor infringement into the low velocity Q100 flood level at the abutments is more than compensated for by a significant deck height over the higher velocity Q100 water flows in the main river channel.
- The reduction in seismic, structural and erosion integrity of the stopbank is intended to be mitigated using approaches similar to that adopted immediately downstream on the Ewen Bridge. The use of concrete aprons and/or rock riprap armouring will be constructed as appropriate. It is inevitable that there will be some differential movement between a 'hard' and 'soft' structures but utilising the above measures it is considered a reasonable approach. A benefit with rock armouring is that it will remain flexible throughout its design working life and will move and settle during seismic events. Post-earthquake, if necessary, it is relatively easy to maintain/top up as required to restore the required protection.

Ewen Bridge showing rock armour and concrete flood and seismic protection measures at the east abutment stopbank

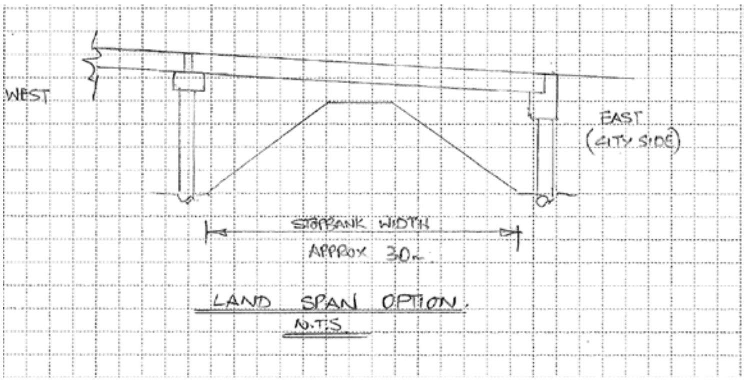
Request 6a: Incorporating a square abutment into the stopbank on the city side

During the Preliminary Structure Options Report presentation on the 19th July 2019 it was proposed to realign the eastern (city-side) stopbank to provide a perpendicular abutment for the river bridge. Stantec's initial proposal was not favoured by GWRC as it protruded too far into the flood plain. As a result of this feedback Stantec revisited the abutment position and moved it back in line with the centerline of the proposed stopbank. The sketch below indicates the details the new proposed realignment of the stopbank.

Stantec met with James Flanagan and Alistair Allan from Greater Wellington Regional Council on the 29th August 2019 to further discuss the new bridge abutment position. The revised stopbank realignment was agreed and accepted.

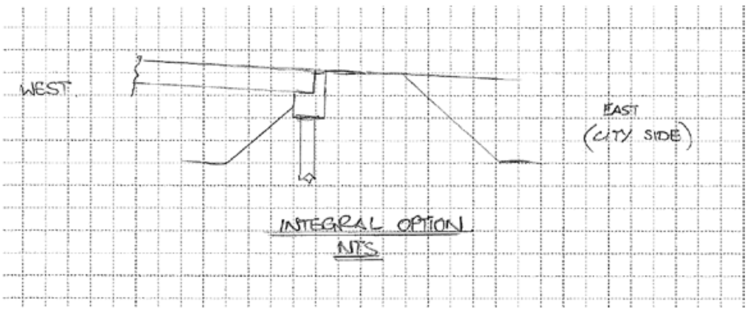
<u>Request 6b: Building the bridge abutment into the stopbank</u>

Originally, it was proposed not to impact on the stopbank whatsoever by spanning it with a flyover land span (see sketch detail below). This span was required to be approximately 30m long and 30m wide, so was not insignificant. This solution introduced significant difficulties in tying back into Rutherford Street with fill levels of over 2.7m required. Importing fill material of this depth would have required large retaining structures along Rutherford Street and impacted significantly on business entrances and other property accesses.



Land span option

In order to minimise the amount of build-up required on Rutherford Street it was proposed to make the bridge deck surface level with the top of the stopbank using an integral solution, as detailed below:



During Stantec's meeting with Greater Wellington Regional Council on the 29th August 2019 it was confirmed that the lowest road surface level (the channel) would be no lower than the Q440 level of the stopbank. This approach was agreed and accepted.

Request 6c: Adjusting the bridge deck transverse crossfalls from 3% to 2%.

Due to the maximum width of the bridge deck being approximately 30 metres at the Rutherford Street abutment, the originally proposed 3% crowned carriageway results in difference in level between the channel and road crown of approximately 450mm. This is significant and further impacts on the tying-in constraints on the city side of the bridge. In order to minimise the impact of the carriageway crown above the top of stopbank a 2% crossfall has been adopted locally. This allows the deck centerline to be reduced by a further 150mm thereby reducing the fill requirements on Rutherford Street.

Request 7: Can a cantilevered bridge be used on the existing Melling Link location?

A comment has been received from the Harvey Norman property questioning why a 'cantilevered bridge' cannot be used on the existing Melling Link Bridge location.

It is not clear exactly what Harvey Norman mean when they refer to a 'cantilevered bridge'?

In the true sense of the word a cantilevered bridge is fixed at one end and free at the other, similar to a springboard. This type of bridge is not considered an appropriate solution for the following reasons:

- The existing Melling Link Bridge is located at a pinch point in the river, therefore this is not the preferred location for a new structure long-term.
- The span is simply too large for a cantilevered bridge. Cantilevers are not very structurally efficient and therefore the section sizes required to achieve this arrangement would be massive, too restrictive on the waterway area and uneconomically viable.

On the other hand, Harvey Norman may be referring to a 'balanced cantilever' bridge. This is subtly different bridge type and is the same as that proposed in Option 2 of this report. The benefits and disbenefits of Option 2 can be found in section 3.1.2 and Appendix B so are not repeated here.

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Stantec

Appendix B Drainage Memo

Melling Interchange SH2 – Stormwater Strategy Approach – Standards Review

Overview

This section outlines the main aims and objectives of various national standards which support a stormwater strategy for the Melling Interchange.

The key reference sources used in this assessment are:

- Wellington City Council Water Sensitive Urban Design (WSUD);
- New Zealand Transport Agency P46: April 2016 – State Highway Stormwater Specification;
- New Zealand Transport Agency Stormwater Treatment for State Highway Infrastructure (May 2010);
- Regional Standards for Water Services - Wellington Region (November 2012);
- Water Sensitive Design for Stormwater - Auckland (March 2015).

Common terms used to describe stormwater treatment in the reference sources are:

- **SUD** – Sustainable Urban Drainage;
- **LID** – Low Impact Design;
- **WSUD** – Water Sensitive Urban Design.

The principles or LID and WSUD are similar, both focus on the introduction of systems which reflect natural treatment systems and at source control and treatment.

Stormwater management has evolved over the last two decades from the application of individual SUD systems through into more holistic LID and WSUD approaches. The latest guidelines on WSUD being promoted both by Wellington City and Auckland City.

Recommended approach for Melling Interchange

A more detailed assessment is recommended to determine the hydraulic capacity of the seven cross drainage culvert systems. The initial high-level assessment indicates a number of the cross-drainage culverts are undersized with a level of service between a 5- and 10-year storm event ARI (average return interval). These are likely to be at risk of local flooding which may or may not impede traffic flow on SH2 and may not comply with current NZTA requirements.

The catchment with the largest flow (Catchment D as shown on the attached catchment plan) drains the Harbour View Road Gully and is in the direct location of the proposed Melling St Interchange. Peak storm flows from this catchment are anticipated to be 10 cumecs for a 100-year storm event. The stormwater intake into the head of the culvert is located within a steep sided gully, crossed on the downward side by the Harbour View Road embankment. Culvert 4A, a 1350 mm internal diameter pipe directs stormwater on a 4% grade under Harbour View Road and discharges about 20m upstream of SH2 in an open channel, this pipe had a full flow capacity of 10.7m3/s.

The stormwater subsequently flows from Culvert 4A and enters a box culvert of approx dimensions 1.5m wide by 1.2m high, however records indicate the size of the crossing to be an 1800mm internal diameter pipe leading into the Hutt River.

The works associated with the proposed new bridge crossing and approach into Harbour View Road, will impact on the 1350mm pipe, open channel and entry point into the box culvert and require a new stormwater pipe to avoid the bridge piles and new earthworks.

The hydraulic capacity shortfall at several culverts may be resolved through the creation of a secondary overland flow path between Culverts 1, 2 and 3 and the installation of a new stormwater culvert. Likewise the capacity shortfall at Culvert 6 could be solved by the creation of a secondary overland flow path from Culvert 6 into Culvert 7.

A new stormwater collection system will be required to collect stormwater from the new Melling Interchange – the system should be designed to meet performance limits outlined in NZ Transport Agency standards, namely, providing a collection system capacity to meet a future 10 year ARI storm event (with climate change), and passing stormwater through a stormwater quality treatment device, either at source or located in downstream locations, prior to discharge into the Hutt River.

The recommended design approach is to minimise the volume of stormwater runoff needing conveyance and treatment by maximising the use of ground soakage and or mitigation storage through the use of Raingardens, Swales, Tree pits and Wetlands to both reduce the peak runoff flow and to remove contaminants, sediments and silts.

There is the potential to neutralise an increase in stormwater runoff flows from the additional seal area by providing permeable paving for surface treatment and through the use of SUD stormwater treatment devices including a wetland treatment zone.

Summary of Design Criteria from Local Authorities:

New Zealand Transport Agency Requirements

The New Zealand Transport Agency has requirements for stormwater conveyance, treatment and fish passage. Their policy both relates to cross drainage (drainage from outside of the immediate project area) and the collection and treatment of stormwater from within the project area.

The design philosophy is to separate between contaminated stormwater flows and clean stormwater to minimise the volume for treatment which ultimately makes treatment more effective, and also to apply a treatment train approach which considers both source control and treatment.

Additionally, the fundamental requirement for stormwater collection is to mitigate the impact on increasing stormwater volumes on the downstream receiving environment by either mitigation storage or by increasing the downstream system conveyance capacity.

The best control measure to apply in this regard is to look to introduce a range of surface treatment options to reduce the post development runoff potential down towards pre-development levels. i.e. by introducing permeable surface paving, tree pits, and or rain gardens or wetlands which remove peak flow runoff in part or in whole by varying degrees of ground soakage.

New Zealand Transport Agency P46 – State Highway Stormwater Specification (April 2016)

Levels of Service

- Maximum height for stormwater flows below road surface is 500mm for a primary conveyance level of service, typically for a 10-year storm event.
- Maximum height for stormwater flows below road surface is 200mm for a 100-year storm event.

- Minimum cover under traffic lanes 1.2m but in specific cases dispensation may be obtained for 0.6m cover - to be assessed on a case by case basis.

Stormwater treatment

- All collected road runoff flows should pass through a stormwater treatment device.
- Separate clean stormwater runoff from permeable surfaces (i.e. grassed batters) where possible to minimise stormwater volumes requiring treatment.
- Provide an isolation storage capacity at all stormwater treatment devices of 20 m^3 for spills.

Cross Drainage

- Existing natural cross drainage patterns of the contributing catchment shall be maintained where possible – i.e. same number of discharge points.
- The level of service required to protect NZTA assets is based on importance levels from the Bridge Manual and typically requires a minimum 10 year level of service without surcharge of the stormwater pipe (culvert), and a 100 year level of service without surcharging more than 2 metres above the pipe soffit level, whilst ensuring a minimum 500mm freeboard is provided to the seal edge.
- Cross culverts in wooded areas shall be assessed for the potential for blockage, defined as having a low, medium or high risk. Countermeasures may include overflow diversion, providing a secondary inlet and upstream debris traps.

Fish passage

- Requirements for fish passage shall be in accordance with resource consent requirements, local council guidelines, and the NZTA fish passage guidance for State Highways.

New Zealand Transport Agency Stormwater Treatment for State Highway Infrastructure (May 2010)

Stormwater conveyance should be considered in line with water quality and stream channel erosion mitigation.

Objectives

- Preventing existing flooding problems getting worse (requiring mitigation storage or increasing capacity of downstream systems).
- Treatment train approach applicable for water quality treatment and stormwater management (where several types of stormwater practices are used together). A treatment train approach ideally considers both source control and treatment.
- Control of stormwater energy through the use of energy dissipation devices, and appropriate selection of materials to provide resilience against erosion.

Treatment Options

- Selection of the most appropriate stormwater treatment option based on catchment area.

Wellington City Council Water Sensitive Urban Design - Current

WSUD - 'Series of holistic design and development practices'

Values

- Principally a collection of upstream collection devices which benefit stormwater quality and reduce peak stormwater loading on the piped collection system.
- Improves the visual and ecological amenity of sites and streets.
- Improves urban ecology and habitat.
- Provides passive irrigation to green infrastructure.
- Celebrates water within the urban context to provide education and a pride of place.

SUD Devices

- Raingardens (typically sized at 2% of its drainage area). Benefits: Biodiversity; Amenity; Detention; Stormwater quality: Minimal maintenance.
- Swales. Benefits: Treatment. Offers first flush stormwater separation for treatment and conveyance.
- Tree Pits. Benefits: Limited treatment through filtration.
- Wetlands to slow and treat stormwater and provide amenity, biodiversity and habitat.

Opportunities

- Integrate WSUD measures to support Council public space design policy objective 6: Sustainability.
- Provide riparian buffers.
- Mitigate adverse effects of stormwater runoff on downstream system.

Wellington Land Development Manual (2012)

Specification - Design requirements

- Type of Sumps for stormwater collection on local roads.
- Refers to regional standards for stormwater network design.

Regional Standards for Water Services - Wellington (November 2012)

Developed for Porirua, Upper Hut, Lower Hut, and Wellington City Councils

Objectives

- Stormwater must not be discharged to ground in a manner that may cause, or contribute to ground instability.
- Stormwater design shall include water quality treatment and discharge of contaminants and sediments into receiving aquatic environments.
- Use of Low Impact Design encouraged, reducing the flow and contaminants into receiving environments.
- Providing amenity and enhancing environmental quality and attractiveness of the area.

Level of Service

- The primary level of protection for the State Highway is set at a 20-year AEP storm return period – this is significantly lower than Porirua, Upper Hut and Wellington City Council who require a 100-year AEP storm return period level of service.
- Where no secondary flow path is available the level of service shall be a 100-year AEP storm return period for stormwater conveyance.

Hydrological Assessment

- The rational method may be applied to catchments less than 100 Ha, in order to determine peak runoff flows.

Water Sensitive Design for Stormwater - Auckland (March 2015)

Principles – change in focus from LID to WSUD to provide emphasis on freshwater management, particularly stormwater management.

Objectives

- Treatment Train approach.
- WSUD promotes the management of stormwater runoff as close to source as possible.
- Encourages range of surface treatments to reduce or eliminate stormwater runoff.
- Promotes range of Bio-retention devices (raingardens, tree pits and planter boxes).

Appendix C Geotechnical Report

Stantec

Melling Interchange Ground Investigation Report

This report has been prepared for the benefit of New Zealand Transport Agency. No liability is accepted by this company or any employee or sub-consultant of this company with respect to its use by any other person.

This disclaimer shall apply notwithstanding that the report may be made available to Greater Wellington Regional Council, Hutt City Council and other persons for an application for permission or approval or to fulfil a legal requirement.

Rev. No.	Date	Description	Prepared By	Checked By	Reviewed By	Approved By
1	13.08.2019	Preliminary Ground Investigation Report	9(2)(a) [redacted]			

1 Introduction

Stantec have been engaged by the New Zealand Transport Agency (NZTA) through Greater Wellington Regional Council (GWRC) for professional services to complete the Preliminary Ground Investigation for the Melling Interchange in Lower Hutt City.

This short Ground Investigation Report details preliminary factual information for the NZTA portion of work completed for the preliminary Melling Interchange Design and follows on from a Stantec PGAR dated February 2018.

2 Site Location and Site Description

The Melling Intersection and bridge is in the Lower Hutt suburb of Melling and connects SH2 across the Melling Bridge with Lower Hutt City. The project is in an area of complex geology that has large topographic changes and is adjacent to the Hutt River. Refer to Figure 1, Figure 2 and Figure 3 for the project aspect and location.

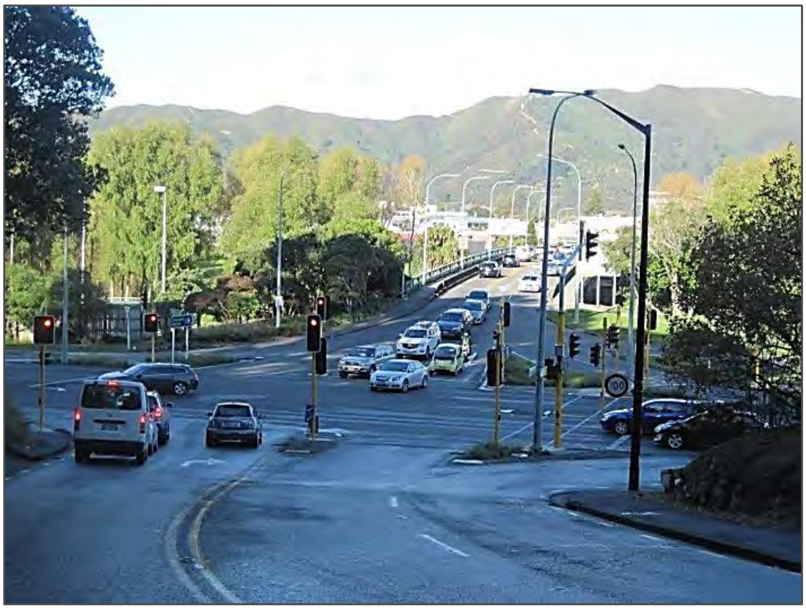


Figure 1: Melling Intersection viewed southeast towards Melling Bridge

Figure 2: Melling Intersection viewed northwest towards the Wellington Fault scarp and the suburb of Harbour View

Figure3: Melling Intersection IBC project location; Google Maps, Scale shown.

The specific site geotechnical test locations in this report can be found on the Geotechnical Test Location Plan marked in yellow (Attachment A).

3 Borehole Drilling

3.1 Borehole 18-1

Borehole 18-1 was undertaken by Griffiths Drilling NZ Ltd (GD) at location Easting 324345m, Northing 5436478 and surveyed using a hand held GPS accurate to between 3-5m (see Attachment A – Geotechnical Test Location Plan). The drilling of the borehole started on 8th July 2019 and was completed on 23rd July 2019. A terrestrial surveyed relative level is being undertaken and will be provided separately. The borehole was undertaken in compliance of the Greater Wellington Regional Council Consent Conditions Detailed in Appendix F.

The borehole was completed in the Melling Train Station car park. This required breaking out and removal of the concrete followed by an asphalt patch reinstatement including a flush toby cover installation. BH 18-1 was completed to a total depth of 30m below ground level (mbgl). Sonic drilling with dual casing was used to mitigate anticipated artesian pressure associates with the Waiwhetu Gravels. The hole was dual cased to a depth of 17mbgl, with single casing used to total depth of 30mbgl (see Figure 4). Core samples were collected and boxed, including standard penetration test (SPT) samples, which were double bagged and labelled (see Attachment C).

The borehole was backfilled as outlined in Figure 4 with the installation of two vibrating wire piezometers (VWPZ) undertaken and supervised by Geotechnics Ltd. The depths shown for the aquifer and aquiclude were predicted depths and not a representation of what was encountered during the ground investigation. A continual datalogger is currently in place as per the consent conditions; however, only the VWPZ at 17mbgl is currently functional and recording. GWRC has agreed this is acceptable to meet the requirements of the consent conditions as no artesian pressure was encountered in the Unit.

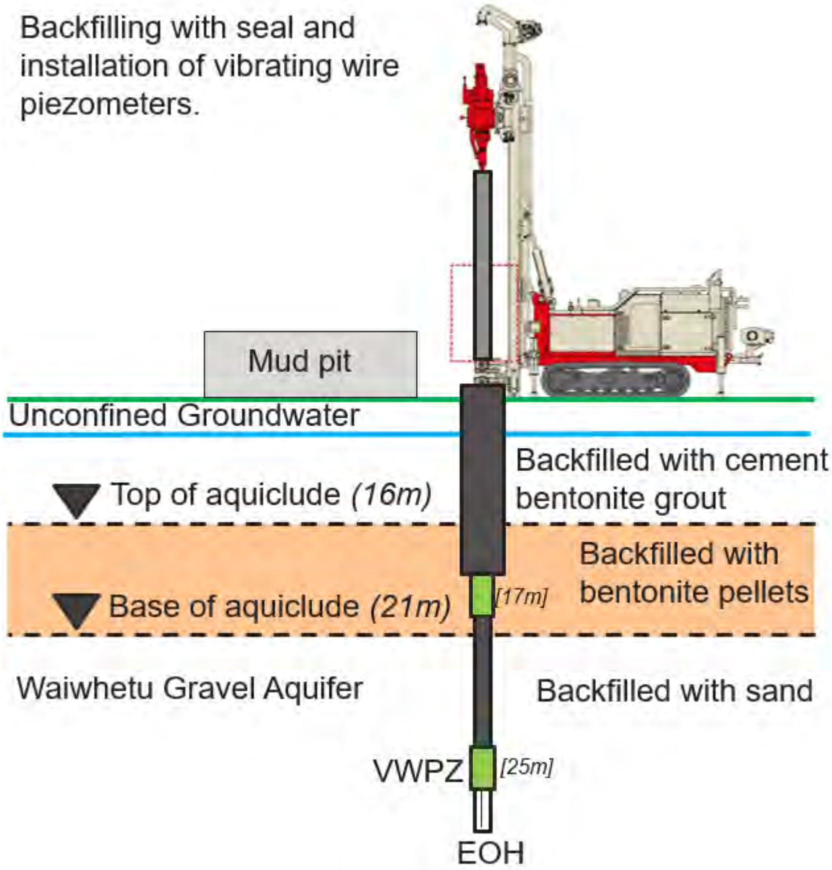


Figure 4: Install details of BH18-1. The aquiclude and aquifer depths shown were predicted depths and do not represent what was found during the ground investigation.

Clean sand was used as backfill between 21-30mbgl. Bentonite pellets were used from 16 to 21mbgl within lower permeability material. From ground surface to 16mbgl, a bentonite cement grout was used. The top 100mm was completed with an asphalt patch.

The borehole core consisted of an alternating sequence of alluvium comprising clay, silt, sand and gravel. The gravel varied from fine to cobble size inclusions of sub-rounded to sub-angular sandstone and siltstone. For further details see the borehole log in Attachment B. SPT measurements were taken at 1.5m intervals and showed a general trend of increasing strength with depth.

Unconfined groundwater was located between 3 and5mbgl when measured after an overnight hiatus in drilling. No artesian pressure was encountered; however, GD site staff noted there was a slight increase is pressure during drilling at 21m. For the purpose of complying with the consent conditions, it was assumed that the aquiclude was located from 16-21bgl and aquifer gravels were present from 21mbgl until total depth at 30m. This would require further ground investigation information to confirm assumptions.

3.2 Cone Penetration Tests (CPT) Tests

Five CPT tests were undertaken by GD; CPT18-9, CPT18-10, CPT18-11, CPT18-12, and CPT18-13. The CPT logs can be found in Attachment E and the location in Attachment A. The table below details the CPT tests undertaken. No installations or backfilling of CPT tests was required as no tests penetrated the Waiwhetu aquiclude.

Table 1: Details of the CPT tests undertaken

TEST LOCATION	DATE COMPLETED	COORDINATES		TOTAL DEPTH	COMMENTS
		Easting	Northing		
CPT18-9	25.07.2019	324447	5436246	10.0mbgl	Reached target depth.
CPT18-10	22.07.2019	324413	5436284	10.0mbgl	Reached target depth.
CPT18-11	25.07.2019	324317	5436339	4.2mbgl	Refused at 4.2mbgl.
CPT18-12	19.07.2019	324351	5436548	8.9mbgl	Refused at 8.9mbgl.
CPT18-13	16.07.2019	324351	5436555	-	Could not complete test. Tried two locations, both refused at less than 1mbgl.

CPT18-13 was unsuccessful, refusing twice during hand digging at 0.7mbgl. The location was on the side of State Highway 2 in an embankment comprising made ground fill of sub-angular sandstone and siltstone gravel. Both locations which were hand dug and refused on large cobbles/boulders which could not be removed by hand of pushed through with the CPT cone.

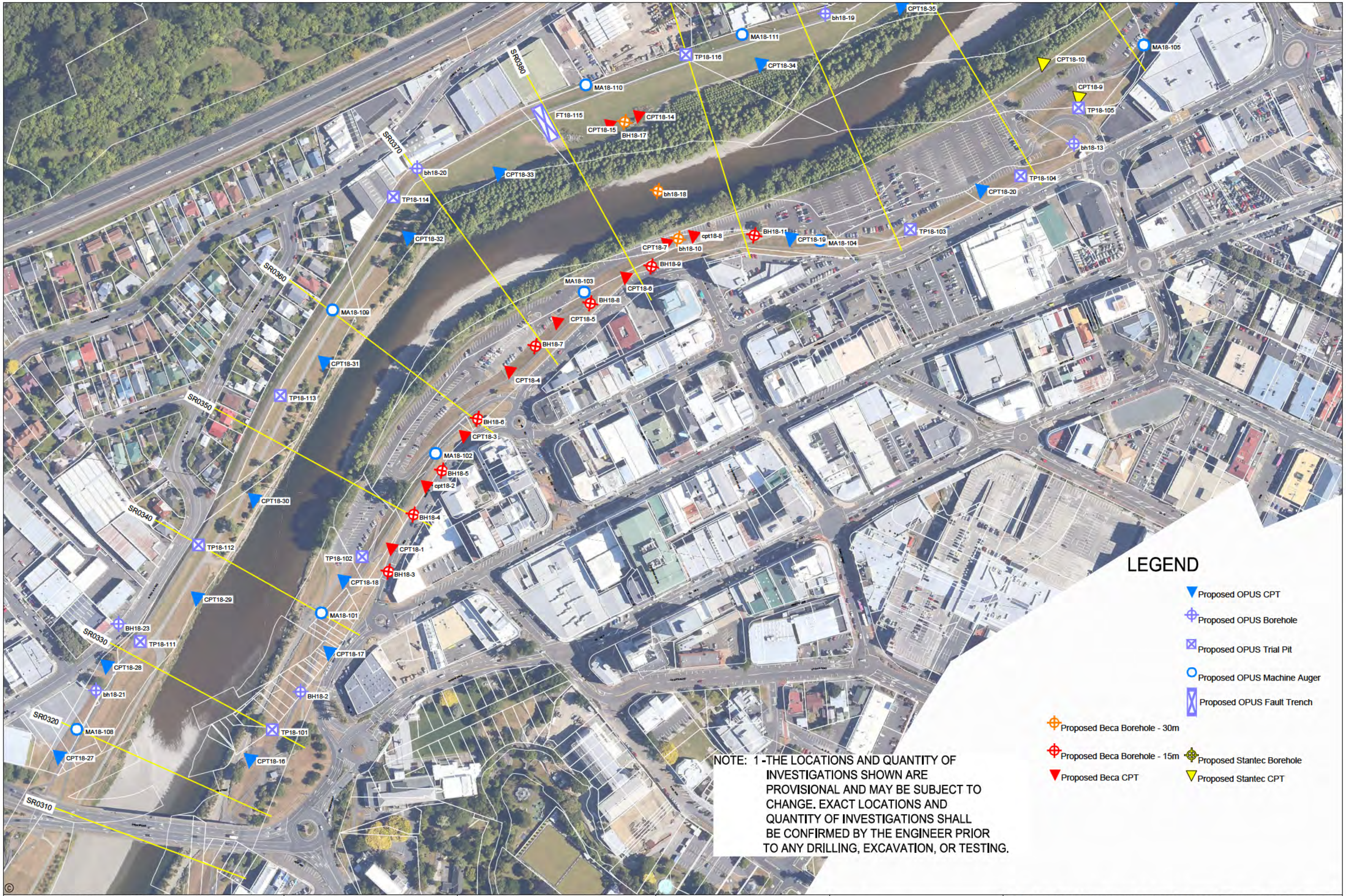
4 Further Work

As part of the wider Melling RiverLink Project, further geotechnical tests are being undertaken and overseen by Stantec (see Attachment A in red and blue). The further site work for Riverlink in planned for completion in 2019. In addition, the complete geotechnical investigation for the Melling Interchange will take place during the design phase. Incorporating this future ground investigation information into one interpretive ground model will produce a much more accurate representation to inform design for the Melling Interchange.

5 Attachments

Attachment A _ Geotechnical Test Location Plan
Attachment B _ Borehole Log (BH18-1)
Attachment C _ Core Photographs (BH18-1)
Attachment D _ Griffiths Drillers Log (BH18-1)
Attachment E _ CPT Logs (CPT18-09, CPT18-10, CPT18-11, CPT18-12).
Attachment F _ Approved Consents Document

Attachment A – Geotechnical Test Location Plan **(locations for the Stantec completed NZTA work highlighted in yellow)**



NOTE: 1 - THE LOCATIONS AND QUANTITY OF INVESTIGATIONS SHOWN ARE PROVISIONAL AND MAY BE SUBJECT TO CHANGE. EXACT LOCATIONS AND QUANTITY OF INVESTIGATIONS SHALL BE CONFIRMED BY THE ENGINEER PRIOR TO ANY DRILLING, EXCAVATION, OR TESTING.

©

This drawing is confidential and shall only be used for the purposes of this project.

REVISIONS				
			Proposed site investigations added from Beca (for Structures) and Stantec (for Melling Interchange) for tender	
No.	BY	DATE	DESCRIPTION	APPD

DESIGNED	9(2)(a) [redacted]
DRAWN	
APPROVED	DATE May 2018

SCALE:

0 — 100m

1 : 3000 at A3; 1:1500 at A1

N

NZ TRANSPORT AGENCY WAKA KOTAHI

RiverLink

Stantec

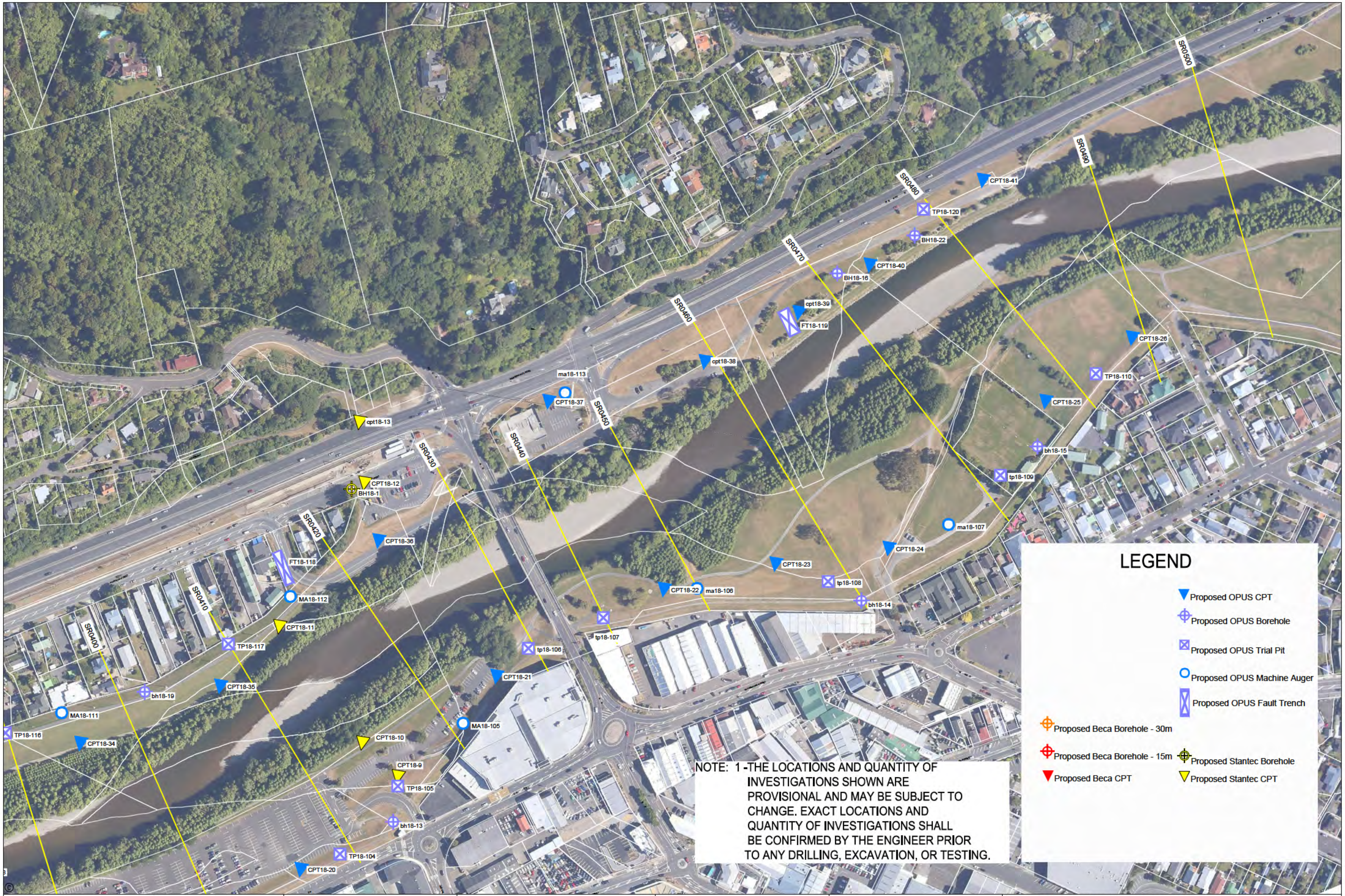
wsp | OPUS

Beca

CONTRACT 882PN MELLING INTERCHANGE RIVERLINK PROJECT

SITE INVESTIGATION LOCATION PLAN - SOUTH

A3	STATUS: TENDER	DRAWING NO: SB-DWG-4210	REV:



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REVISIONS			
			Proposed site investigations added from Beca (for Structures) and Stantec (for Melling Interchange) for tender
No.	BY	DATE	DESCRIPTION	APPD

9(2)(a) [redacted]

DRAWN

APPROVED | DATE | May 2018

SCALE: 0 — 100m

1 : 3000 at A3; 1:1500 at A1

NZ TRANSPORT AGENCY WAKA KOTAHI

RiverLink

Stantec — wsp — OPUS — Beca

CONTRACT 882PN MELLING INTERCHANGE RIVERLINK PROJECT

SITE INVESTIGATION LOCATION PLAN - NORTH

A3 | STATUS: TENDER | DRAWING NO: SB-DWG-4211 | REV:

Attachment B – Borehole Log (BH18-1)

BOREHOLE LOG

Job No: 310201126	Hole No: BH18-1
Sheet: 1 of 6	Started: 08-07-19
Finished: 23-07-19	Logged: 9(2)(a) [redacted]
Checke[redacted]	RL Surface: TBC
Datum: NZVD2016	

Stantec

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Wellington
Tel: 04 381 6700
Fax: 04 473 1982

Client: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council
Project: Melling Riverlink
Location: Melling Riverlink
Description: Sonic Drilled Hole - Dual cased (8":0-17.0mbgl; 6":17-30.0mbgl). Vibrating wire piezometers installed at 17.0mbgl, 25.0mbgl.
Easting: 324345m Northing: 5436478m Inclination: Vertical
Diameter (Dual Cased): 200mm to 17.0mbgl/150mm to 30.0mbgl

Depth (m)	Elevation (m)	Samples Type	Shear Vane (kPa) Peak Strength/ Residual Strength	Standard Penetration Tests Blows (Seating // 75mm/150mm, 225mm/300mm)	N Value/ Refusal Data	Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Graphic Log	Moisture Condition	Groundwater	Other Observations	Installation
0.0–1.5						MADE GROUND. Vaccuum excavation to 1.5m, asphalt, concrete and gravel. [FILL] (1.5)		moist	13-78-7 ATD ATD	Backfilled with bentonite grout from ground level to 17.0mbgl. A tremmie pipe extends from 0-17.0mbgl with the vibrating wire piezometer cable attached around the outside. This is grouted into place. A continuous data logger is operating inside a flush toby cover at ground level which was concreted into place and asphalt patching completed.	
1.5–2.05		SPT sample		2/3//1/0/1/1	N = 3	MADE GROUND. Light orangish grey, greywacke boulder recovered as cobble, sub-angular 60-200mm width, moderately strong, moderatley weathered, discolouration along defects (orange staining), some slightly open. [FILL] (2.05)		moist			
2.05–2.23						Fine to course sandy GRAVEL, orangish brown, well graded, very loose, gravel is sandstone/siltstone, sub angular to subrounded, moderately weathered. [ALLUVIUM] (2.23)		moist			
2.23–2.55						Light brown, clayey SILT, soft, high plasticity. [ALLUVIUM] (2.55)		moist			
2.55–2.7						Fine to cobble sandy GRAVEL, dark brown, well graded, loose. Gravel is sandstone/siltstone, sub-angular to sub-rounded. [ALLUVIUM] (2.7)		wet			
2.7–4.11		SPT sample (3.0)		4/3//5/6/6/6	N = 23	Fine to course sandy GRAVEL, light grey, well graded, medium dense. Gravel is sandstone/siltstone, sub-angular to sub-rounded. [ALLUVIUM] (4.11)		wet	12-7 ATD		
4.11–		SPT sample (4.5)		2/1//2/3/3/6	N = 12	Fine to course silty SAND, light bluish grey, with some gravel, well graded, medium dense. Sand is semi-lithified in places (hard to brake apart). Gravel is fine to cobble sandstone/siltstone, light grey, sub-angular to sub-rounded, increasing in frequency at base of unit. [ALLUVIUM]		moist	11-7 ATD		

Drilling Method: **Sonic Rig**	Casing: **200mm to 17.0mbgl / 150mm to 30.0mbgl**	Remarks: Datum: NZVD 2016
Contractor: **Griffiths Drilling**		
Equipment Type: **Sonic Rig**	Flush: **Water**	

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BOREHOLE LOG

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Fax: 04 473 1982

Client: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council	Job No: 310201126
Project: Melling Riverlink	Hole No: BH18-1
Location: Melling Riverlink	Sheet: 2 of 6
Description: Sonic Drilled Hole - Dual cased (8":0-17.0mbgl; 6":17-30.0mbgl). V brating wire piezometers installed at 17.0mbgl, 25.0mbgl.	Started: 08-07-19
Easting: 324345m Northing: 5436478m Inclination: Vertical	Finished: 23-07-19
Diameter (Dual Cased): 200mm to 17.0mbgl/150mm to 30.0mbgl	Logged: 9(2)(a) [redacted]
	Checked [redacted]
	RL Surface: TBC
	Datum: NZVD2016

Depth (m)	Elevation (m)	Samples Type	Shear Vane (kPa) Peak Strength/ Residual Strength	Standard Penetration Tests Blows (Seating // 75mm/150mm, 225mm/300mm)	N Value/ Refusal Data	Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Graphic Log	Moisture Condition	Groundwater	Other Observations	Installation
						Fine to course silty SAND, light bluish grey, with some gravel, well graded, medium dense. Sand is semi-lithified in places (hard to brake apart). Gravel is fine to cobble sandstone/siltstone, light grey, sub-angular to sub-rounded, increasing in frequency at base of unit. [ALLUVIUM]*[continued]* (5 65)		moist			
						Dark brown, organic, clayey SILT with some sand and minor gravel, firm. Organic odour. Gravel is sandstone/siltstone, fine, sub angular to sub-rounded. [ALLUVIUM] (6)		moist			
6.0		SPT sample		0/1//1/2/1/2	N = 6	Light brownish grey sandy SILT with some gravel, firm. Gravel is fine to cobble, sub-angular to sub-rounded sandstone/siltstone. Rootlets throughout. [ALLUVIUM] (7 5)		moist			
7.0											
		SPT sample		2/1//2/4/5/4	N = 15	Fine to coarse silty SAND with some gravel, well graded, firm. Light grey. Gravel is sub-angular to sub-rounded sandstone/siltstone. [ALLUVIUM] (8 56)		moist			
8.0											
						Light bluish grey clayey SILT with organic inclusions. Firm, high plasticity, black organics and remenant wood present. Organic odour. Can be moulded when wet. [ALLUVIUM] (9)		moist			
9.0		SPT sample		3/4//5/6/7/9	N = 27	Fine, dark grey SAND, uniformly graded. Medium dense. [ALLUVIUM] (9 46)		moist			
						Fine to cobble sandy GRAVEL. Dark grey, well graded with organic material (wood/tree remenants), medium dense. Gravel is sub-angular to sub-rounded sandstone/siltstone. Organics occur throughout but at 10.900 - 11.200 has a high concentration of tree remenants. [ALLUVIUM]		moist			

Drilling Method: **Sonic Rig**	Casing: **200mm to 17.0mbgl / 150mm to 30.0mbgl**	Remarks: Datum: NZVD 2016
Contractor: **Griffiths Drilling**		
Equipment Type: **Sonic Rig**	Flush: **Water**	

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Location: Melling Riverlink	Sheet: 3 of 6
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Diameter (Dual Cased): 200mm to 17.0mbgl/150mm to 30.0mbgl	Logged: 9(2)(a) [redacted]
	Checked: [redacted]
	RL Surface: TBC
	Datum: NZVD2016

Depth (m)	Elevation (m)	Samples Type	Shear Vane (kPa) Peak Strength/ Residual Strength	SPT Blows (Seating // 75mm/150mm, 225mm/300mm)	N Value/ Refusal Data	Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Graphic Log	Moisture Condition	Groundwater	Other Observations	Installation
						(10 3)		moist			
						Medium to coarse SAND with some gravel. Grey, well graded, medium dense, with some organic content (wood remenants) [ALLUVIUM] (10 5)		moist			
		SPT sample		8/15//8/9/10/10	N = 37	Fine to coarse GRAVEL with some sand. Light grey, dense, sub-angular to sub-rounded, moderately graded, gravel is sandstone/siltstone. Sand is medium to coarse. [ALLUVIUM] (11 08)		moist			
11.0						Fine to cobble GRAVEL, grey, poorly graded, dense with some sand. Gravel is sandstone/siltstone. [ALLUVIUM] (11 83)		moist			
12.0		SPT sample		13/11// 13/10/12/14	N = 49	Fine to medium silty SAND, grey, well graded, dense with some organics (black flecks throuhgout). [ALLUVIUM] (12 45)		moist			
13.0		SPT sample		3/5//8/9/6/7	N = 30	Fine to coarse gravely SAND becoming finer at base (13.300 to 13.500m). Grey, well graded, dense, becoming siltier at base. Gravel is fine to coarse, sub-angular to sub-rounded sandstone/siltstone. [ALLUVIUM] (13 95)		moist			
14.0						Fine to boulder, sandy GRAVEL. Grey, poorly graded, dense, gravel is sub-rounded to angular sandstone/siltstone. [ALLUVIUM] (14 4)		moist			
						Fine to coarse silty SAND. Bluish grey with organics with some gravel, poorly graded, medium dense. Gravel is sandstone/siltstone, sub-angular to sub-rounded, fine to course. [ALLUVIUM] (15)		moist			

Drilling Method: **Sonic Rig**	Casing: **200mm to 17.0mbgl / 150mm to 30.0mbgl**	Remarks: Datum: NZVD 2016
Contractor: **Griffiths Drilling**		
Equipment Type: **Sonic Rig**	Flush: **Water**	

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Client: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council	Job No: 310201126
Project: Melling Riverlink	Hole No: BH18-1
Location: Melling Riverlink	Sheet: 4 of 6
Description: Sonic Drilled Hole - Dual cased (8":0-17.0mbgl; 6":17-30.0mbgl). V brating wire piezometers installed at 17.0mbgl, 25.0mbgl.	Started: 08-07-19
Easting: 324345m Northing: 5436478m Inclination: Vertical	Finished: 23-07-19
Diameter (Dual Cased): 200mm to 17.0mbgl/150mm to 30.0mbgl	Logged: 9(2)(a) [redacted]
	Checked [redacted]
	RL Surface: TBC
	Datum: NZVD2016

Depth (m)	Elevation (m)	Samples Type	Shear Vane (kPa) Peak Strength/ Residual Strength	Standard Penetration Tests Blows (Seating// 75mm/150mm, 225mm/300mm)	N Value/ Refusal Data	Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Graphic Log	Moisture Condition	Groundwater	Other Observations	Installation
		SPT sample		6/8//8/6/5/6	N = 25	Fine to coarse gravelly SAND, grey with some organics. Poorly graded, medium dense. Gravel is fine to cobble, sub-angular to sub-rounded, sandstone/siltstone. [ALLUVIUM] (15 79)		moist			
16.0		SPT sample		5/6//9/10/12/7	N = 38	Silty CLAY. Light brownish grey, with some rootlets and organics. High plasticity, firm. With occasional gravel, medium to coarse, sub-angular to sub-rounded sandstone/siltstone. [ALLUVIUM] (16 95)		moist		Increase in fine grained cohesive material with high plasticity. Suspected top of Waiwhetu Aquiclude. Dual casing methodology undertaken to a depth of 17.0mbgl.	
17.0						Fine to coarse sandy GRAVEL. Light bluish grey, well graded, dense, sub-rounded to rounded, sandstone/siltstone with some organics. [ALLUVIUM] (17 71)		moist		Vibrating wire piezometer installed at 17.0mbgl, attached to a tremmie pipe and grouted into place.	VWPZ
18.0		SPT sample		4/6//7/10/10/11	N = 38	Gravelly CLAY. Light bluish grey, high plasticity, firm, with some organics. Gravel is fine to cobble, sub-rounded to rounded sandstone/siltstone. [ALLUVIUM] (18 45)		moist		Backfilled with bentonite pellets from 17.0-21 0mbgl to create a seal on top of the Waiwhetu Gravel and prevent mixing between the aquifer and the unconfined groundwater.	
						Fine to coarse sandy GRAVEL. Dark bluish grey, well graded, dense. Gravel is sub-angular to sub-rounded sandstone/siltstone. [ALLUVIUM] (18 9)		moist			
19.0		SPT sample		10/10//11/8/7/7	N = 33	Gravelly SILT with some sand. Grey with organics, high plasticity, firm. Gravel is fine to coarse, poorly graded, sub-rounded sandstone/ siltstone. [ALLUVIUM] (19 95)		moist			

Drilling Method: **Sonic Rig**	Casing: **200mm to 17mbgl / 150mm to 30.0mbgl**	Remarks: Datum: NZVD 2016
Contractor: **Griffiths Drilling**		
Equipment Type: **Sonic Rig**	Flush: **Water**	

Stantec

STANTEC NEW ZEALAND
Level 13, 80 The Terrace
Wellington
Tel: 04 381 6700
Fax: 04 473 1982

BOREHOLE LOG

Job No: 310201126	Hole No: BH18-1
Sheet: 5 of 6	Started: 08-07-19
Finished: 23-07-19	Logged: 9(2)(a) [redacted]
Checke[redacted]	RL Surface: TBC
Datum: NZVD2016	

Client: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council
Project: Melling Riverlink
Location: Melling Riverlink
Description: Sonic Drilled Hole - Dual cased (8":0-17.0mbgl; 6":17-30.0mbgl). V brating wire piezometers installed at 17.0mbgl, 25.0mbgl.
Easting: 324345m Northing: 5436478m Inclination: Vertical
Diameter (Dual Cased): 200mm to 17.0mbgl/150mm to 30.0mbgl

Depth (m)	Elevation (m)	Samples: Type	Shear Vane (kPa): Peak Strength/ Residual Strength	Standard Penetration Tests: Blows (Seating// 75mm/150mm, 225mm/300mm)	N Value/ Refusal Data	Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Graphic Log	Moisture Condition	Groundwater	Other Observations	Installation
						Fine to coarse silty SAND with some gravel. Light orangish brown, fine to coarse with blue grey silt. Poorly graded, dense. Gravel is fine to cobble, sub-rounded sandstone/siltstone increasing in frequency at base of run. [ALLUVIUM]*[continued]* (20 66)		moist			
						Sandy SILT with some mot led orange/black organics. Light bluish grey, firm, low plasticity. [ALLUVIUM] (21)		moist			
21.0		SPT sample		11/12//11/16	N = 50	Fine to cobble sandy GRAVEL. Orangish brown, well graded, very dense. Gravel is sub-angular to sub-rounded sandstone/siltstone with some sand. (Very wet and some pressure increase during drilling). [ALLUVIUM]		wet		Slight increase in water pressure during drilling. Suspected top of Waiwhetu Aquifer (Waiwhetu Gravel) although no artesian pressure encountered.	
22.0											
		SPT sample		6/14// 22/17/11	N = 50						
23.0											
24.0		SPT sample		7/19// 18/20/12	N = 50	(24 35)					
						Fine to coarse silty GRAVEL. Light orangish brown, well graded, very dense. Gravel is sub-angular to sub-rounded sandstone/siltstone with some sand. [ALLUVIUM]		wet			

Drilling Method: **Sonic Rig**	Casing: **200mm to 17.0mbgl / 150mm to 30.0mbgl**	Remarks: Datum: NZVD 2016
Contractor: **Griffiths Drilling**		
Equipment Type: **Sonic Rig**	Flush: **Water**	

Stantec

BOREHOLE LOG

STANTEC NEW ZEALAND
Level 13, 80 The Terrace
Wellington
Tel: 04 381 6700
Fax: 04 473 1982

Client: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council
Project: Melling Riverlink
Location: Melling Riverlink
Description: Sonic Drilled Hole - Dual cased (8":0-17.0mbgl; 6":17-30.0mbgl). V brating wire piezometers installed at 17.0m, 25.0m.
Easting: 324345m Northing: 5436478m Inclination: Vertical
Diameter (Dual Cased): 200mm to 17.0mbgl/150mm to 30.0mbgl

Job No: 310201126
Hole No: BH18-1

Started: 08-07-19
Finished: 23-07-19
Logged 9(2)(a) [redacted]
Checke [redacted]
RL Surface: TBC
Datum: NZVD2016

Depth (m)	Elevation (m)	Samples Type	Shear Vane (kPa) Peak Strength/ Residual Strength	Standard Penetration Tests Blows (Seating // 75mm/150mm, 225mm/300mm)	N Value/ Refusal Data	Material Description (Logging carried out in accordance with Guidelines for the Field Classification of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005)	Graphic Log	Moisture Condition	Groundwater	Other Observations	Installation
				7/15//50	N = 50	(25 25)		wet		Vibrating wire piezometer installed at 25.0mbgl.	VWPZ
		SPT sample				Fine to cobble sandy GRAVEL. Orangish brown, well graded, very dense. Gravel is sub-rounded, sandstone/siltstone. [ALLUVIUM] (25 725)		wet		Sand backfill from 21.0 to 30.0m depth.	
26.0						Fine to cobble sandy GRAVEL. Orangish brown, well graded, very dense. Gravel is sub-angular to sub-rounded sandstone/ siltstone, some disc shaped rounded cobbles. [ALLUVIUM] (26 35)		wet			
						Gravelly SILT. Light orangish brown (more grey at base of run) with some organics, medium to high plasticity, stiff (due to baked nature from drilling), some evidence of layering. [ALLUVIUM] (27)		wet			
27.0		SPT sample		20/22//50	N = 50	Silty GRAVEL with some sand. Light greyish brown, some plasticity in silt (could be rolled) but not high, very dense. Gravel is fine to cobble, well graded, sub-angular to sub-rounded sandstone/siltstone. [ALLUVIUM] (27 785)		wet			
28.0						SILT with some gravel. Light greyish brown, high plasticity, stiff, with some orangics. Gravel is fine to cobble, sub-angular to sub-rounded, more angular than the unit above. [ALLUVIUM] (28 3)		wet			
						Lost core (200mm) (28 5)					
29.0		SPT sample		8/28	N = 50	Fine to cobble sandy GRAVEL. Light orangish brown with some silt, well graded, very dense. Gravel is sub-angular to sub-rounded, well graded, sandstone/siltstone. Less silty than the unit above with some clay. Very wet when recovered. [ALLUVIUM] (30)		wet			

Drilling Method: **Sonic Rig**
Contractor: **Griffiths Drilling**
Equipment Type: **Sonic Rig**
Casing: **200mm to 17.0mbgl / 150mm to 30.0mbgl**
Flush: **Water**

Borehole Terminated at 30.0mbgl Target Depth

Attachment C – Core Photographs (BH18-1)

BOREHOLE CORE PHOTOGRAPHS: BH18-1

CLIENT: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council.
PROJECT: Melling Riverlink
JOB NO: 310201126

LOCATION: BH18-1
COORDS: 324345 m E 5436478 m N
DATE: 09-20 July 2019

Depth: 1.500 – 5.020 m

Depth: 5.020 – 8.120 m

BOREHOLE CORE PHOTOGRAPHS: BH18-1

CLIENT: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council.
LOCATION: BH18-1
PROJECT: Melling Riverlink
COORDS: 324345 m E 5436478 m N
JOB NO: 310201126
DATE: 09-20 July 2019

Depth: 8.120 – 11.080 m

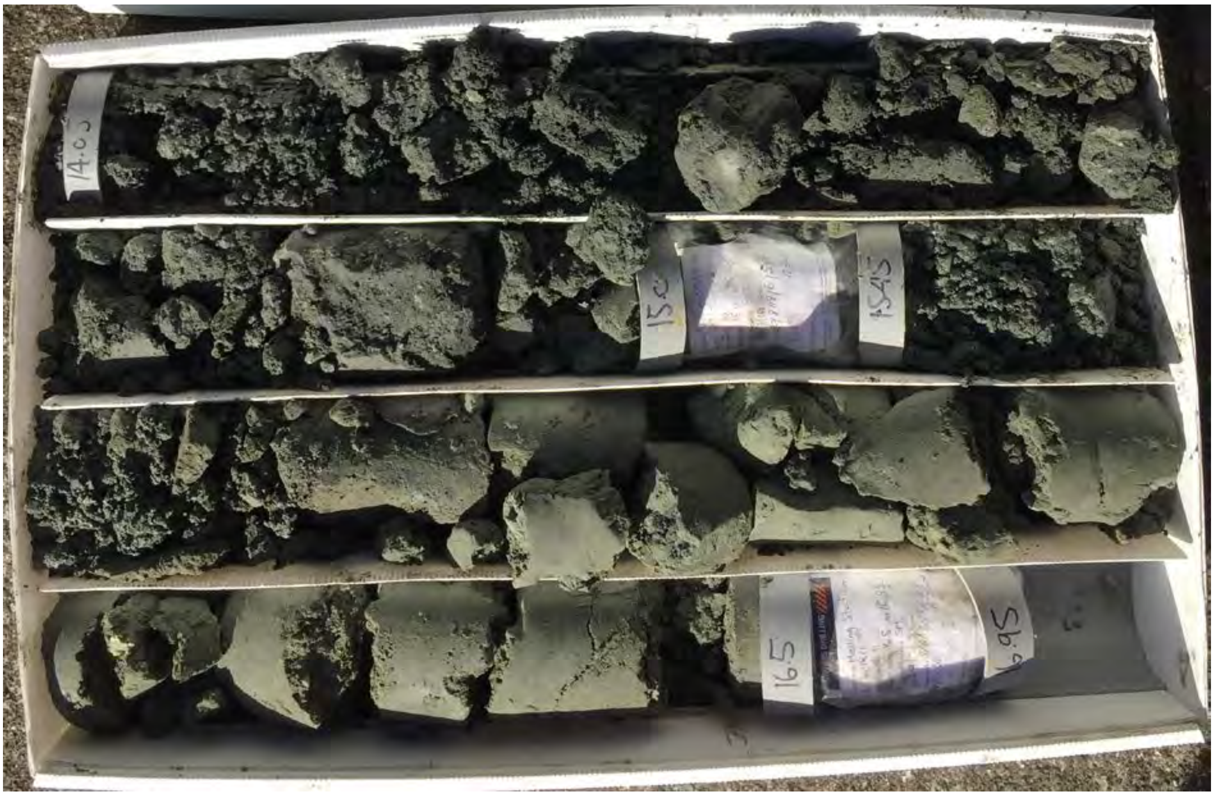
Depth: 11.080 – 14.050 m

Stantec

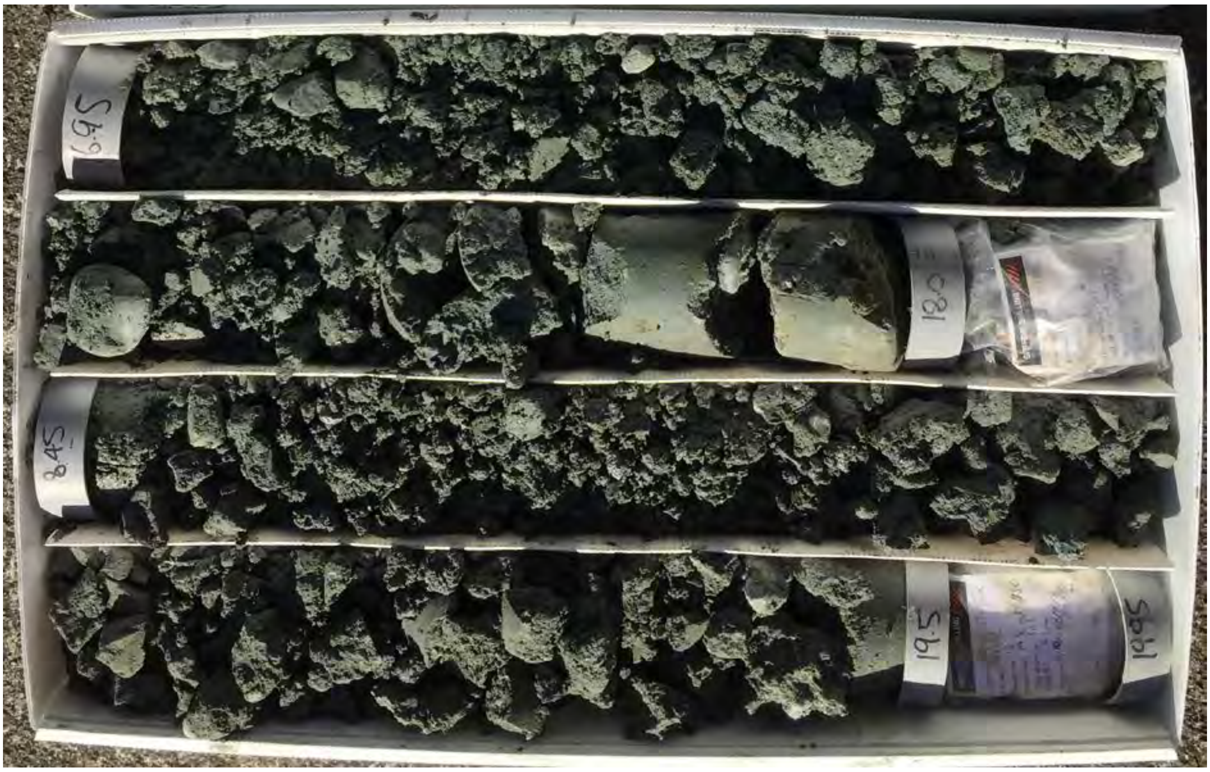
BOREHOLE CORE PHOTOGRAPHS: BH18-1

CLIENT: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council.
PROJECT: Melling Riverlink
JOB NO: 310201126

LOCATION: BH18-1
COORDS: 324345 m E 5436478 m N
DATE: 09-20 July 2019



Depth: 14.050 – 16.950 m



Depth: 16.950 – 19.950 m

BOREHOLE CORE PHOTOGRAPHS: BH18-1

Stantec

CLIENT: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council.

LOCATION: BH18-1

PROJECT: Melling Riverlink

COORDS: 324345 m E 5436478 m N

JOB NO: 310201126

DATE: 09-20 July 2019

Depth: 19.950 - 22.500 m

Depth: 22.500 – 25.250 m

BOREHOLE CORE PHOTOGRAPHS: BH18-1

CLIENT: New Zealand Transport Agency, Greater Wellington Regional Council, Hutt City Council.
LOCATION: BH18-1
PROJECT: Melling Riverlink
COORDS: 324345 m E 5436478 m N
JOB NO: 310201126
DATE: 09-20 July 2019

Depth: 25.250 - 27.758 m

Depth: 27.758 – 30.000 m

Attachment D – Griffiths Drillers Log (BH18-1)

GRIFFITHS DRILLING	SITE INVESTIGATION BORELOG	BH#	18-1
		JOB#	-

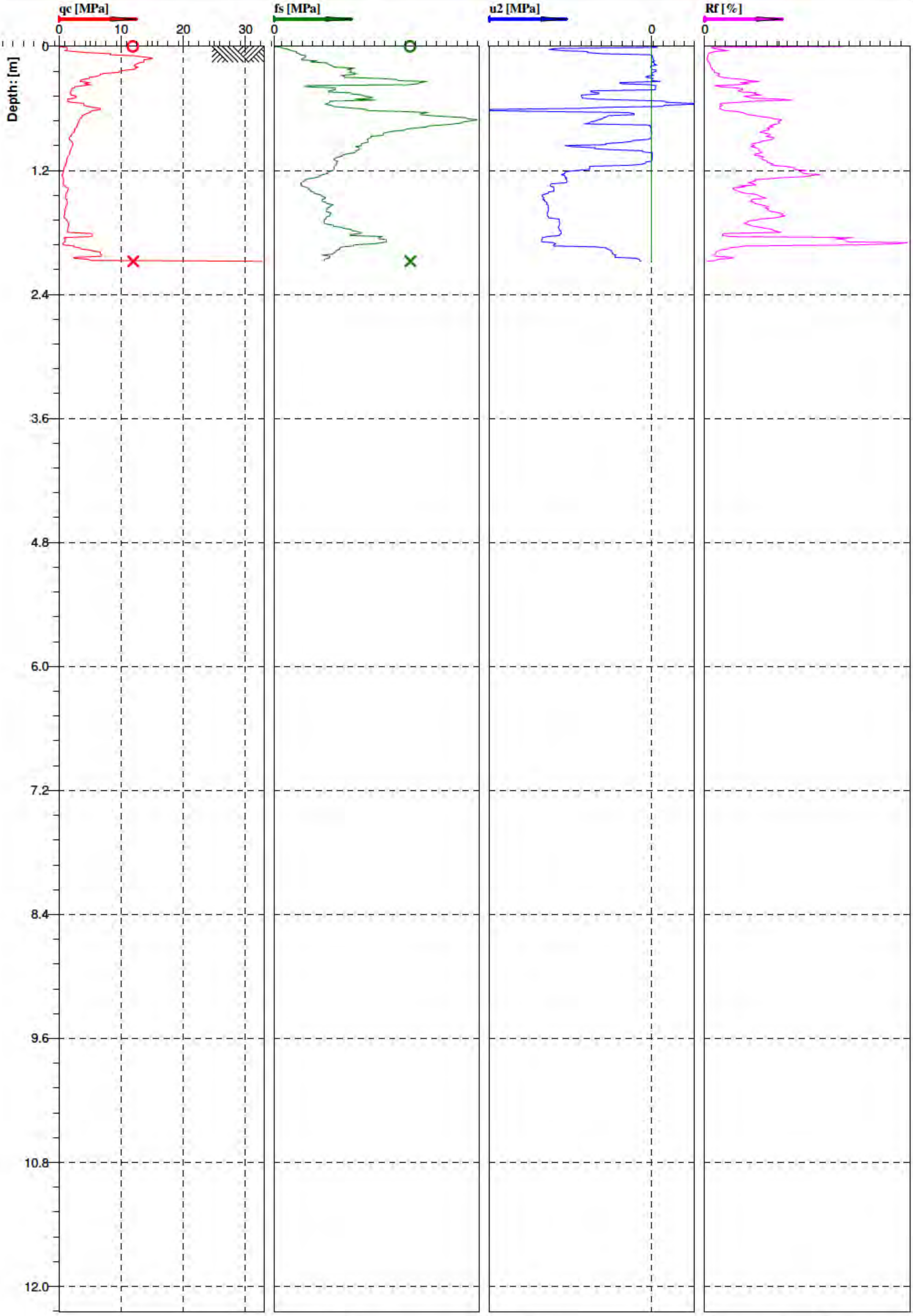
134 State Highway 58 Pauatahanui P: 045277346 F: 045277347 www.griffithsdrilling.co.nz					
Project:	Melling/Riverlink		Grid Ref:	N: -	
Location:	Melling Train Station			E: -	
Client:	Stantec	Operator:	9(2)(a) [redacted]		
DATE Start:	08/07/19	DATE Finish:	12/07/19	Page:	1 of 1

Drill Rig:	Sonic Fraste XL Duo	**SPT Hammer #:**	Auto
Drilling Method:	Sonic with SPT's	**Flushing Type:**	Water
Bore Diameter:	Sonic 4"	**Casing Diameter / Type:**	Sonic 6" & 8" outer
Bore Final Depth:	30.0m	**Casing Final Depth:**	8": 17.0m; 6": 30.0m

Layer Change Depth (mbgl)	Formation Drill Conditions: (L) – Loose, Unstable; (S) – Soft, Stable; (F) – Firm, Stable; (B) – Bands of hard and soft; (M) – Moderately Firm; (H) – Hard to penetrate. Fluids: (TL) Total Loss; (SL) Slow Loss; (WS) Water Struck; (NL) No Loss. **Geological Description** *Must Include: Colour, Texture, Composition, Fractures, Boundary type (gradual, abrupt?)*	Core Samples & Recovery			Standard Penetration Test (SPT)				
		From (m)	To (m)	Recovery (mm)	Cone Type	Depth	SPT Counts	N Value	Sample (mm)
0.00	Brown silty sandy gravel	0.00	1.50	-	SP	1.5	2/3//1/0/1/1	3	230
3.30	Change to Blue/grey sandy gravel with lots of silt	1.95	3.00	540		3.0	4/3//5/6/6/6	23	400
5.90	Blue/grey silt less gravel than previous, small to medium gravels with some organics	3.45	4.50	1050		4.5	2/1//2/3/3/6	12	270
9.40	Blue/grey sandy silt with gravels and cobbles	4.95	6.00	1050		6.0	0/1//1/2/1/2	6	450
11.00	Blue grey sandy silty gravels. Mostly	6.45	7.50	1050		7.5	2/1//2/4/5/4	15	360
	Small to medium trace of cobbles.	7.95	9.00	1050		9.0	3/4//5/6/7/9	27	190
	Scattered organic material.	9.45	10.50	1050		10.5	8/15//8/9/10/10	37	280
19.50	Layer of brown and blue mottled silt.	10.95	12.00	1050		12.0	13/11//13/10/12/14	49	340
20.80	Blue silty sand with organics.	12.45	13.50	1050		13.5	3/5//8/9/6/7	30	400
21.20	Brown small gravels. Trace of cobbles	13.95	15.00	1050		15.0	6/8//8/6/5/6	25	400
	With silt and course sand.	15.45	16.50	1050		16.5	5/6//9/10/12/7	38	400
27.00	Brown sandy silty gravel. Small to	16.95	18.00	1050		18.0	4/6//7/10/10/11	38	420
	Medium. Trace cobbles.	18.45	19.50	1050		19.5	10/10//11/8/7/7	33	300
30.00	EOB	19.95	21.00	1050		21.0	11/12//11/16 HB	50+	300
		21.30	22.50	1200		22.5	6/14//22/17/11	50+	350
		22.85	24.00	1150		24.0	7/19//18/20/12	50+	270
	Vibrating wire piezometers installed:	24.36	25.50	1110		25.5	7/15//50	50+	180
	VWP1: 25.0m	25.72	27.00	1275		27.0	20/22//50	50+	185
	VWP2: 17.0m	27.18	28.50	1350		28.5	8/28//HB	50+	0
		28.65	30.00	1350					

Water Level	Date / Time	Hole Depth	Water Level	Date / Time	Hole Depth
1.20	08/07/19 pm	12.0m	3.80m	12/7/19	27.00m
4.80m	11/7/19	-	1.30m	13/7/19	19.50m

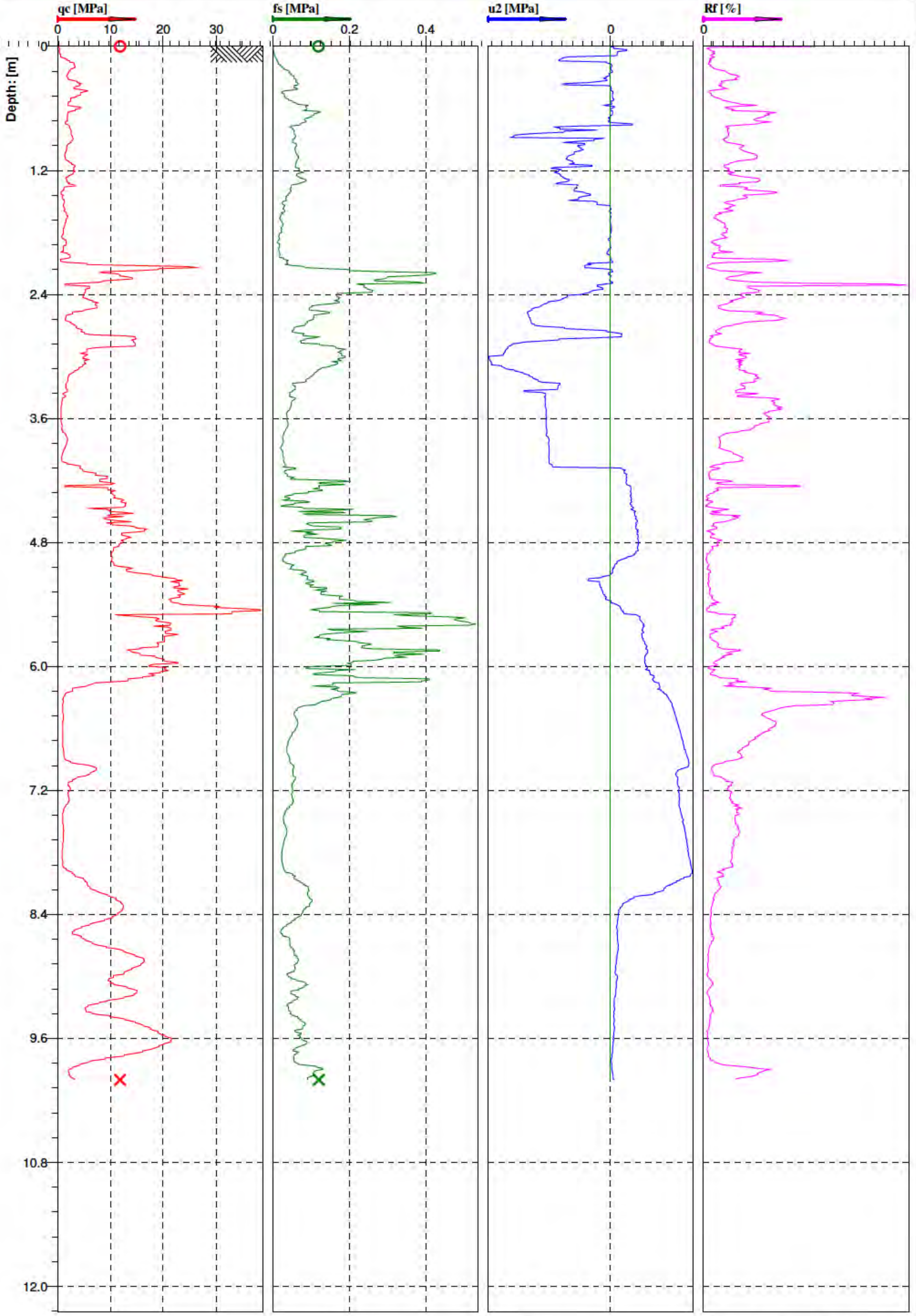
Attachment E – CPT Logs (CPT18-09, CPT18-10, CPT18-11, CPT18-12).



GRIFFITHS DRILLING

Cone No: 5336
Tip area [cm2]: 10
Sleeve area [cm2]: 150

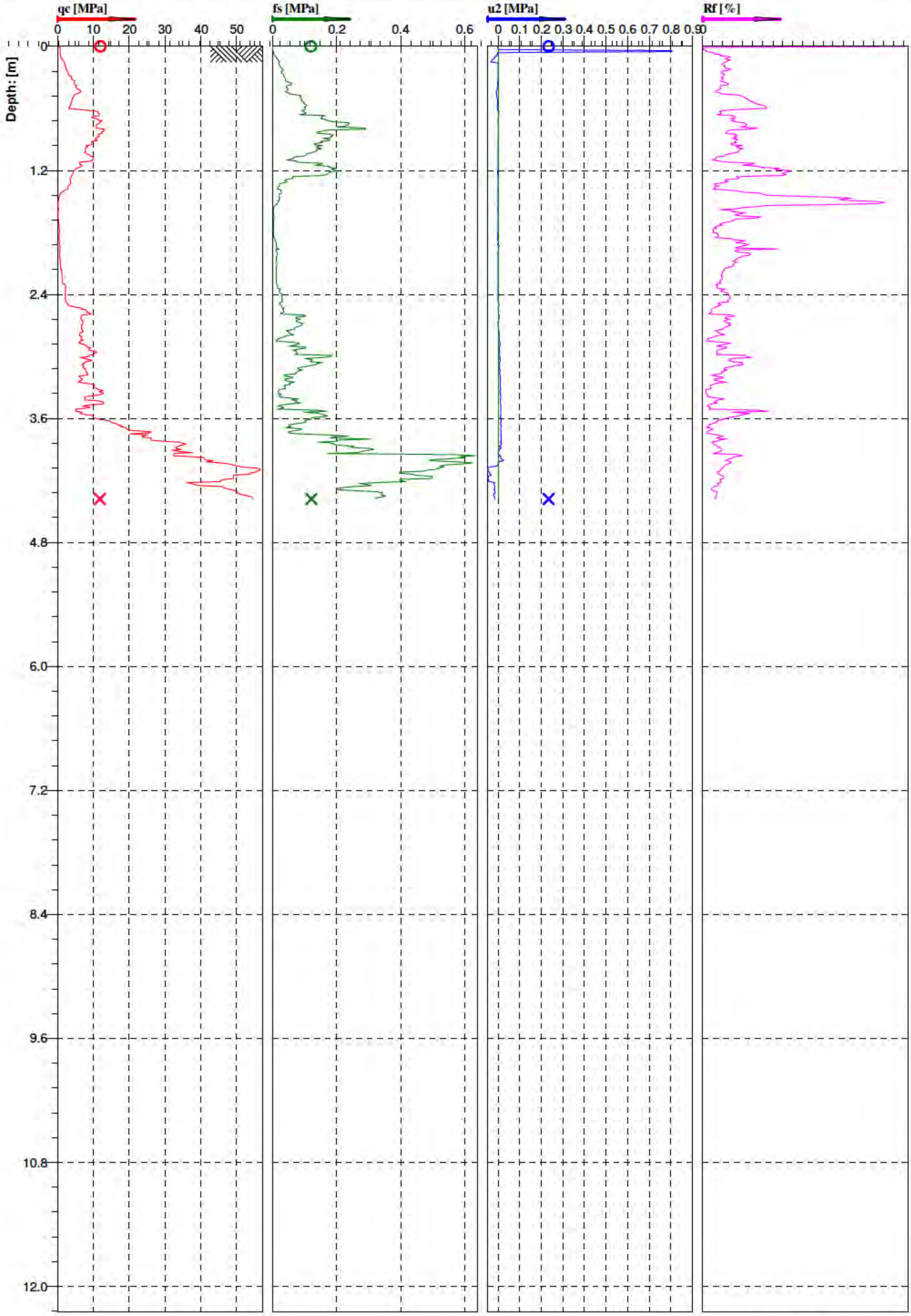
Location: Melling Riverlink	Position: -, -	Ground level: 0.00	Test No.: CPT 18 09
Project ID: CPT 18 - 09	Client: Stantec	Date: 22/07/2019	Scale: 1 : 50
Project: Melling Riverlink		Page: 1/1	Fig.:
Could not push cone any further		File: cpt 18 09.cpd	



Location: Melling Riverlink	Position: -, -	Ground level: 0.00	Test No.: CPT 18 - 10
Project ID: CPT 18 - 10	Client: Stantec	Date: 22/07/2019	Scale: 1 : 50
Project: Melling Riverlink		Page: 1/1	Fig.:
Reached target depth		File: 18 10.cpd	

GRIFFITHS DRILLING

Cone No: 5336
Tip area [cm2]: 10
Sleeve area [cm2]: 150

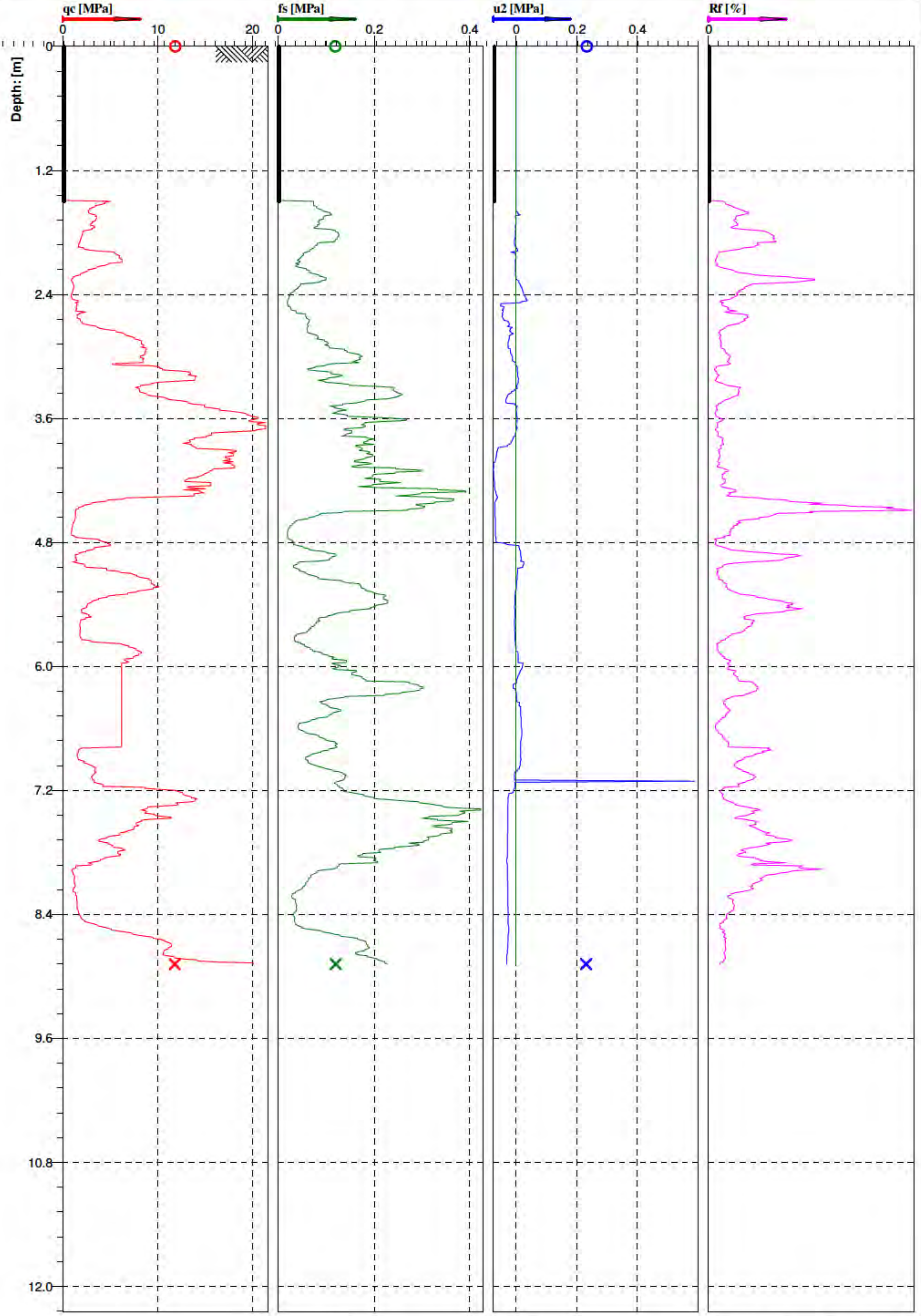


GRIFFITHS DRILLING

u2

Cone No: 5336
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Melling Riverlink	Position: -, -	Ground level: 0.00	Test No.: CPT18 - 11
Project ID: CPT 18 - 11	Client: Stantec	Date: 22/07/2019	Scale: 1 : 50
Project: Melling Riverlink		Page: 1/1	Fig.:
Anchor refusal		File: cpt18 11.cpt	



GRIFFITHS DRILLING

u2

Cone No: 5336
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Melling Riverlink	Position: -, -	Ground level: 0.00	Test No.: CPT18 - 12
Project ID: CPD 18 - 12	Client: Stantec	Date: 19/07/2019	Scale: 1 : 50
Project: Melling Riverlink		Page: 1/1	Fig.:
Could not push cone any further		File: CPT18-12.cpt	

Attachment F – Approved Consents Document

Stantec

Client Ref: Greater Wellington Regional Council

19 February 2019

Greater Wellington Regional Council
Shed 39, 2 Fryatt Quay
PIPITEA, WELLINGTON 6011
NEW ZEALAND

Attention: Alistair Allan, Rebecca Polvere
Melling Riverlink GSI 2018 contract

Dear Alistair Allan and Rebecca Polvere,

Melling Riverlink GSI 2018 Contract

Detailed below are the clarifications addressing the peer review for the Resource Consent requirements for the Melling Riverlink Ground Investigation.

Please also find attached the Tonkin and Taylor Peer Review comments with reference to where they are addressed within the Griffiths Drilling Methodology and Geotechnics engagement documents.

ACTION REQUIRED BY RESOURCE CONSENT AGREEMENT	RESPONSIBLE CONSULTANT	FURTHER DETAILS
A geologist is to be on site during all drilling activities.	STANTEC, OPUS, BECA	
A geologist is to log/monitor on site during all drilling activities to identify aquiclude.	STANTEC, OPUS, BECA	This includes the assurance that once 0.5m of material identified as the aquitard is identified the drilling will cease. If drilling is to advance to greater depths dual casing methodology will take place. Whether dual casing is required from surface will be assessed on a site by site basis depending on the location of the borehole.
A geologist will be on site during all CPT drilling activity to identify aquiclude and prevent penetration into the aquifer.	STANTEC, OPUS, BECA	All CPTs will be undertaken after the boreholes to have a better understanding of the ground conditions and groundwater levels.
Well/borehole numbers will be applied for prior to drilling on site.	STANTEC, OPUS, BECA	Borehole numbers and locations have been assigned on attached borehole plan.

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Christchurch 8141

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FAX +64 4 473 1982

Geotechnics will be engaged through Griffiths Drilling to install up to three vibrating wire piezometers (VWPZs) per hole if required depths are reached.	GEOTECNICS	The VWPZ's will be required in each borehole that penetrates through the aquiclude. If the borehole is required to penetrate through the aquiclude into the aquifer, a VWPZ will be placed above it, within it and below it.
Geotechnics will be engaged through Griffiths Drilling to monitor each VWPZ during the completion of the drilling contract.	GEOTECHNICS	Readings from the data logger will be taken every 6 hours and uploaded to the Geotechnics server daily. Notifications of groundwater pressure exceedances will be sent in the daily upload to Greater Wellington Regional Council, Griffiths Drilling and Stantec. Readings of VWPZs will be reviewed fortnightly by Geotechnics.
Geotechnics will be engaged directly through Greater Wellington Regional Council to monitor the VWPZ for a period of 5 years.	GEOTECHNICS/APPOINTED CONTRACTOR	Readings from the data logger will be taken every 6 hours and uploaded to the Geotechnics server daily. Notifications of groundwater pressure exceedances will be sent in the daily upload to Greater Wellington Regional Council, Griffiths Drilling and Stantec. Readings of VWPZs will be reviewed fortnightly by Geotechnics. A report will be produced annually for 5 years and will include an overview of pressure readings, details of any trigger levels breached and information on the conditions of the monitoring equipment.

If you require any more information, please do not hesitate to contact me.

Yours sincerely

9(2)(a) [redacted]

Stantec New Zealand

Encl.: Griffiths Drilling Methodology Melling Riverlink Project
Geotechnics Monitoring Regime Melling Riverlink Project
Proposed Borehole Location Plan
Barite Material Datasheet
Tonkin and Taylor Peer Review Spreadsheet

Griffiths Drilling Methodology Melling Riverlink Project (including step by step schematic)

GRIFFITHS DRILLING

Methodology – Melling & Riverlink Project v.3

Date: 18/02/19

Additional Information Requested 11/12/18 – NTC-5

	Schematic drawings of how dual casing methodology will be implemented Methodology for implementation of dual casing methodology will be as per that outlined in the original methodology.
	Boreholes will be drilled prior to any CPT testing being competed. This will allow a better understanding of the depths of the aquitard at each site. 03 06 13
	Vibrating Wire Piezometers will only be installed where dual casing drilling methodology is used to demonstrate a grout seal has been achieved. A total of three VWP's will be installed if the appropriate depths are reached.
	Griffiths Drilling will provide monitoring and reporting for the duration of their contract. This will be done through Geotechnics as a sub-contractor. Geotechnics are specialists in this field and are appropriately experienced to complete this monitoring and reporting.
	Methodology for installation of VWP 11 15 We propose to install the VWPs using two different methodologies dependent on the installation depth. The VWPs to be installed within the aquifer and the aquitard will be installed using the traditional method. VWPs to be installed above the aquitard will be installed using the grout-in method. Please see the two methodologies attached. **Equipment** For all boreholes, with the exception of BH18-18, we propose to supply and install Geokon standard VWPs. For BH18-18 we propose to use Geokon heavy duty VWPs and armoured cable to help withstand the expected movements in the river bed (see Geokon datasheet attached). 06 The data loggers that we propose to use are Frontier Data Loggers (see datasheet attached). The units are self-contained, meaning no solar power or additional battery pack is necessary to power each unit. The expected battery life of a 3 channel Frontier Logger logging 6 hourly and transmitting daily in an area with strong mobile network signal strength is 3 years. Shorter logging intervals, poor mobile network signal strength or more frequent transmission of data will reduce battery life. The Frontier Data Logger unit's battery is encased in epoxy and is not user replaceable. When the battery is depleted, a new Frontier Logger unit will need to be acquired to resume monitoring. The price for replacement units will be subsidised with trade-in of depleted units. The subsidised rate will vary depending on the number of replacements required and the timing of this undertaking. **Protection** Flush toby boxes will be used for protection of the loggers. The XL Well Cover 350 mm will be used for all boreholes except BH18-18 and the SD400 Well Cover will be used for BH18-18 to allow more space for the larger, stiffer armoured cable (information attached). 06 **Data Collection and Reporting** Readings from each VWP will be taken every 6 hours and data from each logger will be uploaded to the Geotechnics FTP server daily. Notifications of groundwater pressure exceedances will be sent during the daily upload to GWRC, Griffiths Drilling and Stantec. Readings of VWPs will be reviewed daily by Geotechnics for the first 2 weeks following an installation into each borehole then weekly until the end of the drilling construction. A report for each borehole will be issued 2 weeks after installation. The report will cover the installation details and a summary of the initial results. 11 15 A summary report will be issued at the completion of the drilling construction and will include an overview of pressure readings from each VWP, details of trigger levels reached and information of the condition of the monitoring equipment. We trust that this satisfactorily meets your needs. We look forward to receiving your instruction to proceed and to working with you on this project. You can confirm your acceptance by returning the attached signatory form. Alternatively, we will take your written instruction to proceed as confirmation that you accept this proposal.

Action plan to be followed should a borehole seal fail:

1. Geotechnics to notify Griffiths Drilling and GWRC that there has been a change at the borehole location and the borehole seal may have failed.
2. Griffiths Drilling to schedule in relevant access permit depending on hole location.
3. Drill rig and grout plant to be mobilised to borehole location.
4. Larger diameter casing to be drilled over the top of the existing borehole and seated into the aquitard. The annulus between the new casing and the original grouted installation to be grouted with a cement bentonite grout. The larger diameter casing is to be left in the ground.
5. If a new VWP installation is required, a new borehole would need to be drilled and the installation would be completed as per the original methodology.
6. New bore log and installation records to be provided by Geotechnics and Griffiths Drilling two weeks after the installation, as though this was a newly drilled hole.

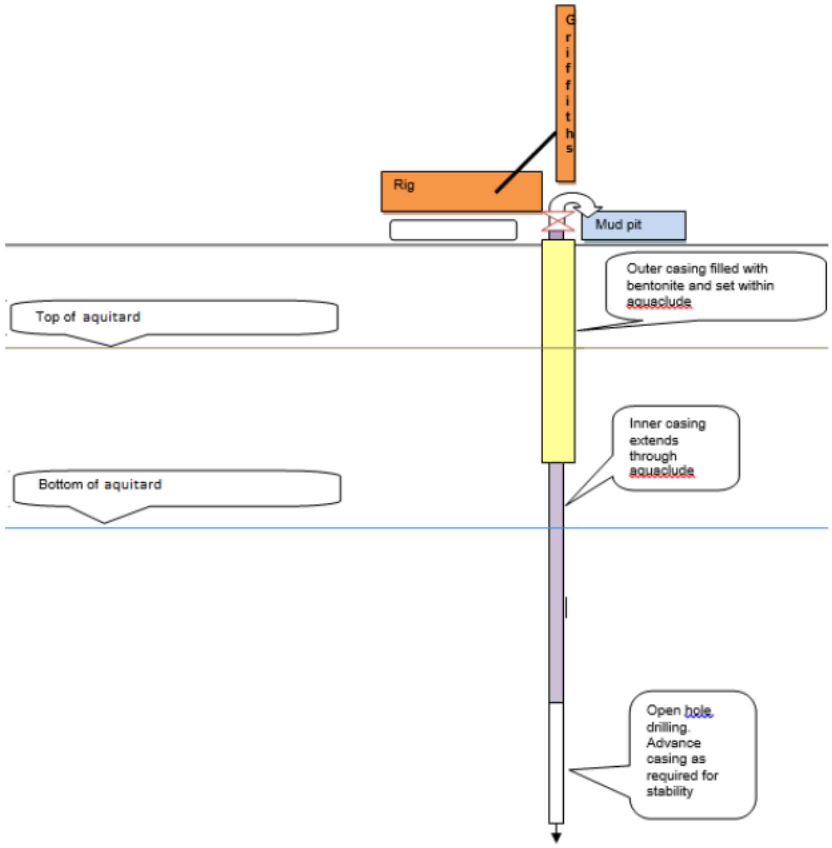
NOTE: Pricing cannot be provided for carrying out these remedial measures or re-drilling of boreholes as variables such as site access, material pricing, and extent of remediation are all unknowns. Pricing to complete this would be provided on a site by site basis upon the event occurring.

Original Methodology:

Project / site	**Melling & Riverlink Geotechnical Site Investigations**
Resource Consent	Resource Consent Approval was issues to Stantec 10/08/18. All works are subject to the provision and approval of this document. Consent Number: **WGN180466 [35599]** Well numbers have not yet been provided. These are to be provided before any drilling works can commence. A site plan has been drafted showing all proposed site locations.
Scope	Construction of boreholes, including CPT's, within the Lower Hutt Groundwater Zone and within the bed of the Hutt River associated with geotechnical investigations for the Riverlink and Melling Intersection Improvement projects. This document outlines the procedure for advancing bore holes through the aquaclude in the Hutt Valley and controlling artesian water and accidental flow to surface. The following has been requested prior to any physical works taking place for this project. These points have been addressed in the following section of this document. A detailed technical report detailing the procedures and mitigation measures proposed to ensure that the Taita Alluvial and Waiwhetu Artesian aquifers are protected. The technical report shall include but not be limited to: i. a description of the depth that the dual-casing technique will be employed ii. a description of the purpose of the drilling fluid monitoring and how success/failure will be measured iii. a description of mitigation measures in the event drilling fluid leaks/spills iv. an assessment of the potential effects of the bentonite and cement on the aquifer v. a methodology for monitoring the effectiveness of the sealing process both immediately (during construction) and in the long term vi. an assessment of the mitigation options available should sealing of the aquifer be unsuccessful vii. a description of how the contractor will identify if the CPT's do not effectively self-seal and require the addition of bentonite clay viii. a description of how the sealing of bores/CPT's will be monitored ix. a description of the measures to be used to assess if the CPT/bore hole seal is stable x. confirmation of the method for calculating the density of the grout in the annulus between the dual-casing to ensure persistent groundwater flows are not experienced xi. A description of the relevant turbidity levels required to stop works and the processes that are (or will be) in place to ensure works stop in a timely manner.
Report	i) **A description of the depth that dual-casing technique will be employed:** 03 Following discussion with Greater Wellington Regional Council, it has been determined that the following techniques and procedures will be adopted when completing the proposed drilling investigation programme. 06 13 Due to the uncertainty surrounding the exact depth of the aquitard in this area, it would be best to complete the boreholes first to establish this depth, and programme the CPT's for after completion of the boreholes. This can of course be on a 'per-area' basis to ensure programme deadlines are still met. The CPT testing will follow the drill rigs movements around the site locations. Prior to drilling, discussion will be had with 9(2)(a) [redacted] from Wellington Water to see whether the drilling can coincide with pump operation at the Waterloo Well Field. 03 This may aid drilling in that it will lower the head of pressure while drilling, but could also pose risks of aquifer contamination if a negative pressure were to occur. Discussion with Wellington Water will be had regarding this. For drilled boreholes on this project the procedure will be as follows. The borehole will be advanced, with both the driller and the site geologist noting any change in material recovered. If and when the driller and/or the geologist see a change in material in line with what would be expected of the aquitard, all drilling will cease. If the geologist wishes to advance the borehole any deeper, dual casing must be installed in order to provide control measures should the aquitard be breached. In areas of higher risk of connectivity, dual 02

surface.

To install dual casing, the outer casing will be drilled and installed into but not breaching
the aquitard material (approx. 12-15m but to be determined on a per site basis by the site 07
geologist) with the final 1m of material left inside the casing. This will be achieved by
drilling 0.5m of the aquitard to confirm that this is definitely the aquitard, and then 'pushing' the
casing the following 1m to seat this into the aquitard material. The outer casing shall be filled with a
bentonite mud mixed appropriately to control the artesian head estimated at each site
should it be required. The inner casing shall be lowered into the outer casing, aligned and 09
then the bore drilled further to the target depth with sampling done as required. The setup
for this is illustrated in the diagram below. Note the outer casing is proposed to be 10" and
inner casing 5" for BH18-18 in the Hutt River, and 8" and 5" for the rest of the bores. 06



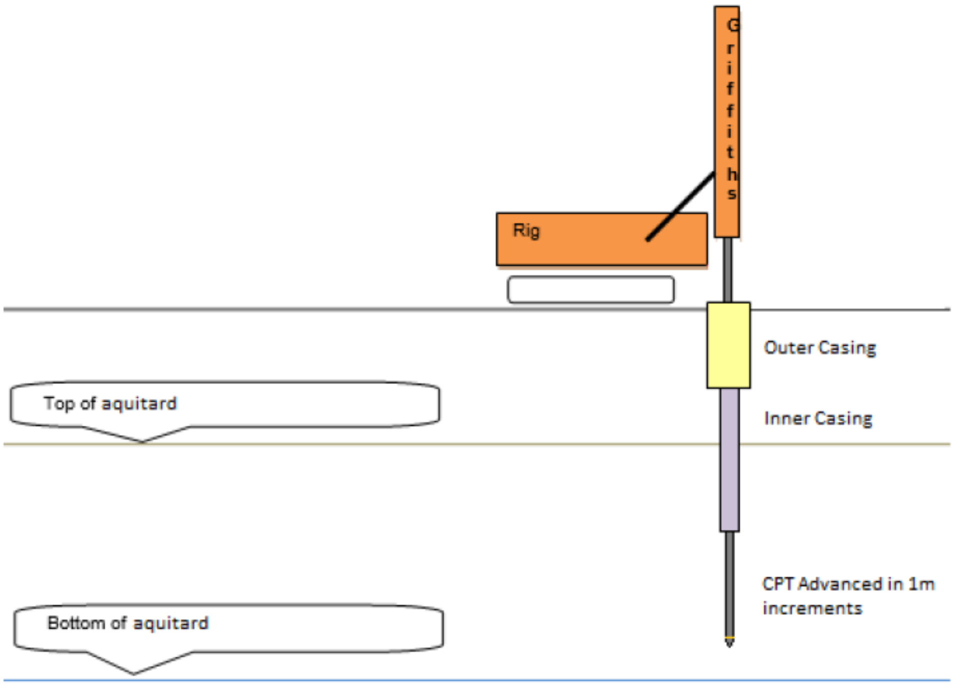
Proposed methods of controlling flow of artesian water are as follows. The first method
will be to allow the water to flow at the surface, and either containing this in water storage 05
/ filtration tanks, or to divert this clean water to a known outlet close to the drill site. The
flow of water would only be present while the drilling operations take place. Overnight and
during any downtime during the day, an extra length of casing can be added above ground level
which will enable the head of pressure to be equalised and therefore stop the flow of water. Note that
it is not possible to have this extra length of casing on during drilling with the drill rig at ground level. If
this were to be used while drilling, the drill rig would need to be raised. This can be done by building
a structure to raise the rig to the level of the head of pressure.

When sealing up a drilled borehole that has penetrated the aqutard, this will be backfilled with a
mixture of clean washed filter media such as clean gravels (through water bearing stratum),
bentonite pellets for 2m above this to seal off the aquitard, and bentonite cement grout
above this. The cement / bentonite grout mix will be pumped into the borehole using a 17
tremie line to ensure this is grouted from the bottom up. As this is done, the steel drill
casing will be retracted. This will seal off the aquitard and control the artesian water
pressure. Note that no cement will be used in the water bearing material. While backfilling 10
is being completed, the head of water pressure will be controlled by adding a length of
casing above ground level, which will stop the flow of water and will allow decommissioning of the
bore to be completed. All reinstatement will be completed in accordance with New Zealand
Environmental Standard for Drilling of Soil and Rock (NZS 4411:2001).

The only exception to the reinstatement methodology outlined above will be for BH18-18,
which will be backfilled with clean gravels through the water bearing materials, and then 06
with bentonite pellets to approx. 2m BGL. From here the casing will be retracted and it is
expected that the river gravels will collapse, sealing the hole.

When completing SPT tests in the Petone Marine Beds, Barite will be used to reduce the head of pressure and in turn allow the test to be completed without the results being adversely affected. 05

With regards to advancing CPT's in this area, a CPT should not be advanced without having completed boreholes in the area first so that a clear understanding of the aquitard depth has been established. Following this, the geologist will advise the final termination depth of the CPT's. Most CPT's are not expected to go any deeper than 10m BGL. Should these need to be advanced deeper than the estimated depth of the aquitard, this will need to be done in combination with advancing dual casing using a drill rig. This would be advanced in increments to allow natural ground to still be tested for the CPT, but also allowing sufficient control measures to be in place in case of accidental breach of the aquitard. It is proposed that casing / CPT is advanced in 1m increments for the duration of the test. An option here would also be to initially advance the CPT test to ~10m depth, and then advance drilled dual casing to this depth before carrying on testing. Reinstatement of this will be via the same methodology as that proposed for the boreholes.



ii) **A description of the purpose of the drilling fluid monitoring and how success/failure will be measured**

Drilling fluid monitoring can be carried out upon request and will be via turbidity testing. The number of samples required and the trigger levels for this should be determined by Wellington Water.

iii) **A description of mitigation measures in the event drilling fluid leaks/spills**

GD plan on using a combination of silt cloth, bunding, trenches, soakage pits and silt fencing (dug into the ground) to control runoff from the drill sites. Where possible drilling fluids will be re- circulated in the drill hole. Upon completion of each borehole, any excess drilling fluids or spoil will be removed from site. GD would also complete regular site inspections to ensure that the correct environmental controls have been implemented on site, including a pre-start walkover to identify any waterways or stormwater systems that are in close proximity to the drill site, and that will require protection. 12

For the Hutt River site in particular, protective absorbent cloth will be laid on the drill pad, with bunding used to surround the drill site. This will enable any contaminants to be contained immediately, and will allow water to pass through while stopping any silt or other contaminants from entering the waterways.

iv) **An assessment of the potential effects of the bentonite and cement on the aquifer**

Bentonite is a naturally occurring swelling clay mineral. It can be buried safely while having no impact on the environment. When drilling into the Aquifer, the following measures will be implemented and monitored:

- Monitoring soil conditions as drilling progresses in order to identify the aquitard and allow appropriate placement of the outer casing.
- Placing cement or grout via a tremie tube under as low pressures and flows as practical to minimise the risk of it discharging out of the base of the outer casing.
- Monitoring the amount of cement and grout used against the expected amount and ceasing works if the bore is taking greater than expected volumes.
- Not using cement grout in the Waiwhetu Gravel or Petone Marine Beds. This will ensure there is zero risk of contaminating the aquifer with cement grout. Only clean gravels will be used to backfill the borehole in the water bearing material.
- Monitoring of water levels will be taken at regular intervals during well construction.

v) **A methodology for monitoring the effectiveness of the sealing process both immediately (during construction) and in the long term**

Verification of seal conditions will be carried out at 48hrs and 7days following completion. This will ensure that the seal is permanent.

An alternative / addition to this would be to install a series of vibrating wire piezometers in a cross section of bores across the project area. This would enable water pressures to be monitored. The final depths of these would be confirmed by the site geologist.

vi) **An assessment of the mitigation options available should sealing of the aquifer be unsuccessful**

Where a seal is unsuccessful, Griffiths would re-mobilise a rig to site immediately, drill larger diameter casing over the borehole and re-grout the bore using a cement bentonite grout via tremie line. This would be completed using the same methodology as that outlined earlier in this document. 12

Should the first mitigation measure not work, an alternative to this would be to pressure grout the borehole. To do this a steel flange would be welded onto the casing. Each would be fitted with a shutoff valve to permit shutoff of grout at refusal pressure, and to still allow the grout pump to be moved onto another hole if needed, while still maintaining pressure in the completed hole. The flange assembly should also be fitted with a blowoff valve and a control valve to check the hole back pressure before the flange assembly is removed. 12

Diameter of the remediation borehole: Where 10" outer casing is used (BH18-18), 12" casing would be used to drill over the top of the existing casing. Where 8" is used, 10" would be used to drill over the top. 14

vii) **A description of how the contractor will identify if the CPT's do not effectively self-seal and require the addition of bentonite clay**

As mentioned earlier in this document, the CPT's will not be advanced any deeper than 10m BGL without having dual casing in place, and following the advancing / retracting methodology outlined earlier in this document.

viii) **A description of how the sealing of bores/CPT's will be monitored** 11
Covered above. This can be through the used of vibrating wire piezometers to monitor water pressure. The requirements surrounding this will be confirmed by GWRC and the site geologist. 15

ix) **A description of the measures to be used to assess if the CPT/bore hole seal is stable**
Covered above.

x) **Confirmation of the method for calculating the density of the grout in the annulus between the dual-casing to ensure persistent groundwater flows are not experienced**

08

TABLE 1
TOTAL PRESSURE ABOVE TOP OF CONFINED AQUIFER (HYDROSTATIC PRESSURE) FOR FLOWING ARTESIAN WELLS

Depth to Top of Flowing Aquifer (feet)	Artesian Head Above Ground Surface (feet)					
	5	10	15	20	25	30
10	6.5	8.7	10.8	13.0	15.2	17.3
20	10.8	13.0	15.2	17.3	19.5	21.7
30	15.2	17.3	19.5	21.7	23.8	26.0
40	19.5	21.6	23.8	26.0	28.1	30.3
50	23.8	26.0	28.1	30.3	32.5	34.6
75	34.6	36.8	39.0	41.1	43.3	45.5
100	45.5	47.6	50.0	52.0	54.1	56.3
125	56.3	58.4	60.6	62.8	65.0	67.1
150	67.1	69.3	71.4	73.6	75.8	78.0
175	78.0	80.1	82.3	84.4	86.6	88.7
200	88.7	91.0	93.1	95.2	97.4	99.6
225	99.6	101.7	104.0	106.0	108.2	110.4
250	110.4	112.5	115.7	117.0	119.0	121.2

Adapted from the Michigan Department of Environmental Quality Water Bureau, Lansing, Michigan

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Material	Weight	Hydrostatic Pressure
Barite Slurry:	18 - 22 lb/USgal	.96 - 1.1 psi/ft
Neat Cement and Bentonite @ 6 gal water/sack:	15.0 lb/USgal	.78 psi/ft
Bentonite Slurry Grout:	10.4 lb/USgal	.54 psi/ft
Bentonite Slurry Grout:	9.5 lb/USgal	.49 psi/ft

GROUTING MATERIAL SUITABILITY

	Heavy Enough To Overcome Hydrostatic Pressure	Not Heavy Enough To Overcome Hydrostatic Pressure
(dark shading)	Neat Cement @ 15 lb/USgal	All Bentonite Grouts
(light shading)	Neat Cement @ 15 lb/USgal or Bentonite Grout @ 10.4 lb/USgal	Bentonite Grouts lighter than 10.4 lb/USgal
(no shading)	All standard grouts have enough weight to overcome hydrostatic pressure of the flow.	

Drilling Muds

To determine the extra weight of drilling mud needed to counteract the pressures of the artesian aquifer during rotary drilling, the estimated artesian head and the depth to the top of the aquifer is needed. The following formula can be used to estimate the additional weight of drilling mud needed to control the flow during the drilling process: 04

$$\text{Additional mud weight} = \left(\frac{8.34 \text{ lbs/USgal} \times \text{height of water above ground level (ft)}}{\text{Depth to top of aquifer (ft)}}\right) + 0.4 \text{ lbs/USgal}$$

Where:
One USgallon of water weighs 8.34 pounds
0.4 lbs/USgallon is a safety factor

Example

If the depth to the top of the aquifer is 75 feet and the height of water above ground is estimated to be 10 feet, the additional weight of drilling mud needed would be (8.34 x 10/75) + 0.4 = 1.5 lbs/USgal.

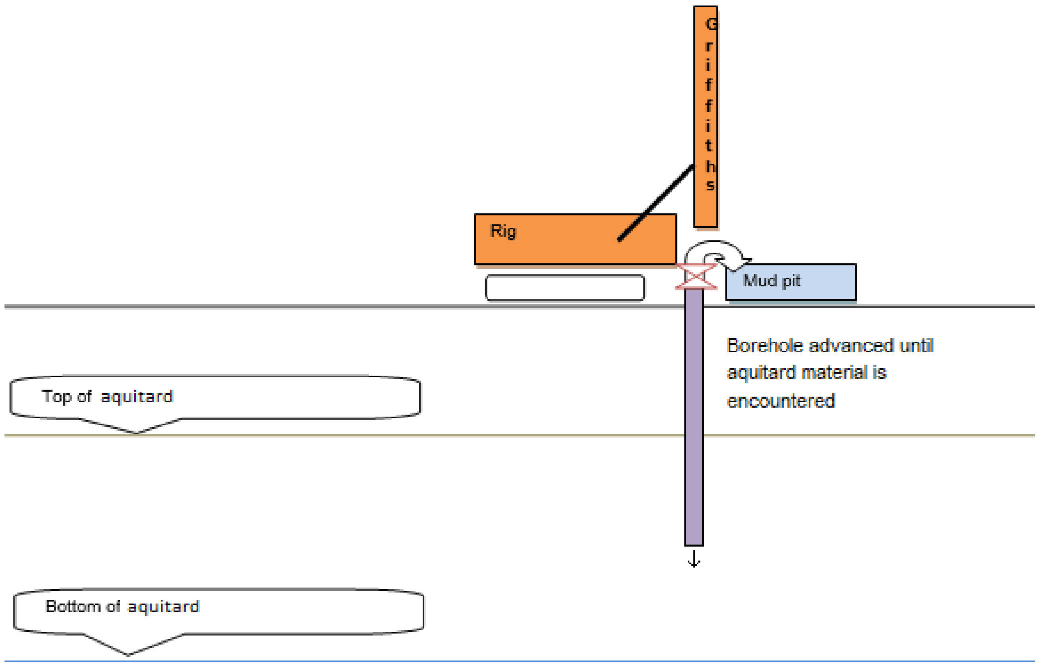
Properly mixed, fresh drilling mud will normally weigh about 9 pounds per US gallon. Drilling mud can be made heavier by adding drilling clay, drilling gel and special solids such as barite. However, some drilling gels are treated with polymers to build viscosity and become difficult to pump before their weight significantly increases. Therefore, some drilling gels have limited ability for control of flows. Mud weights of up to 15 pounds per gallon can be achieved using weighting materials such as powdered barite.

	Barite MSD in relation to environmental precautions: Material is a natural mineral product and will not cause adverse effects to the water system other than turbidity from suspended particles. 01 xi) **A description of the relevant turbidity levels required to stop works and the processes that are (or will be) in place to ensure works stop in a timely manner.** If Griffiths Drilling are notified of a spike in turbidity levels at nearby bores at the time drilling is being completed, all drilling will cease until Wellington Water advise that drilling can continue. The turbidity levels required will need to be discussed with Wellington Water. 04 Griffiths are not able to monitor turbidity. Wellington Water are the only ones able to complete this monitoring. Griffiths would need to be in regular contact with WW in order to ensure this is monitored during the drilling programme.
Other documents to supply	• As Built following completion of the water well • Drillers bore log

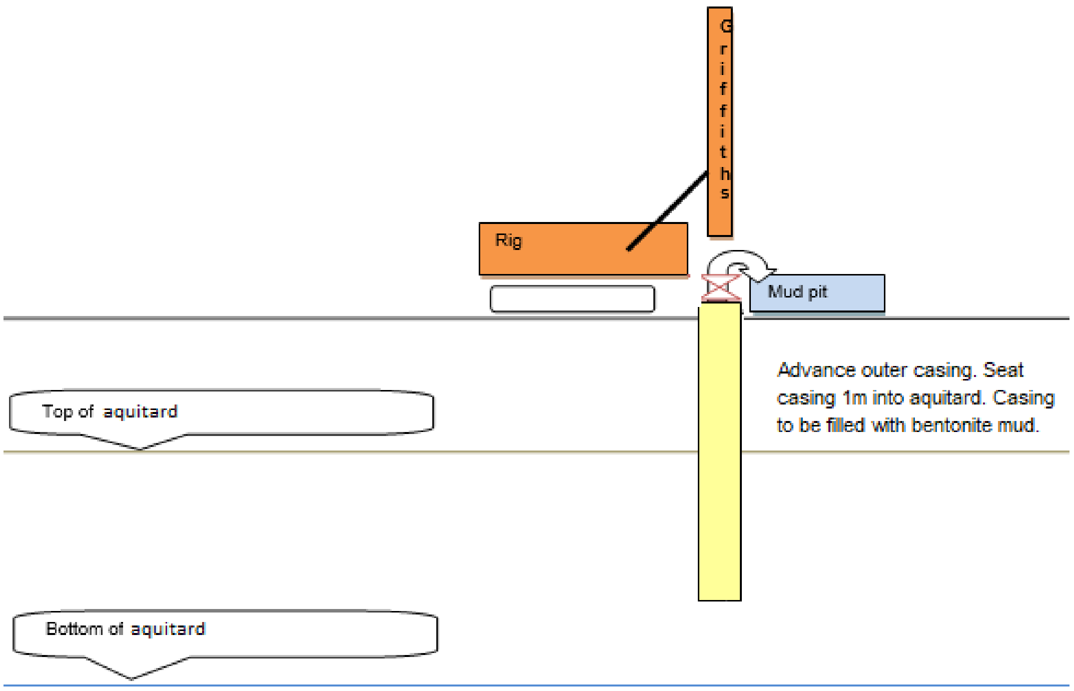
Prerequisites	• Submit technical report for approval by GWRC.
	• Provide seven days advanced notice of the intention to undertake works authorised by this consent. Notice must be emailed to:
	  o Greater Wellington Regional Council, notifications@gw.govt.nz; and
	  o Wellington Water Limited
	    9(2)(a) [redacted]
	• Disinfect tooling before drilling or completing CPT's using Decon90.

GRIFFITHS DRILLING

Step 1: Drill rig setup and borehole advanced until aquitard material is encountered.

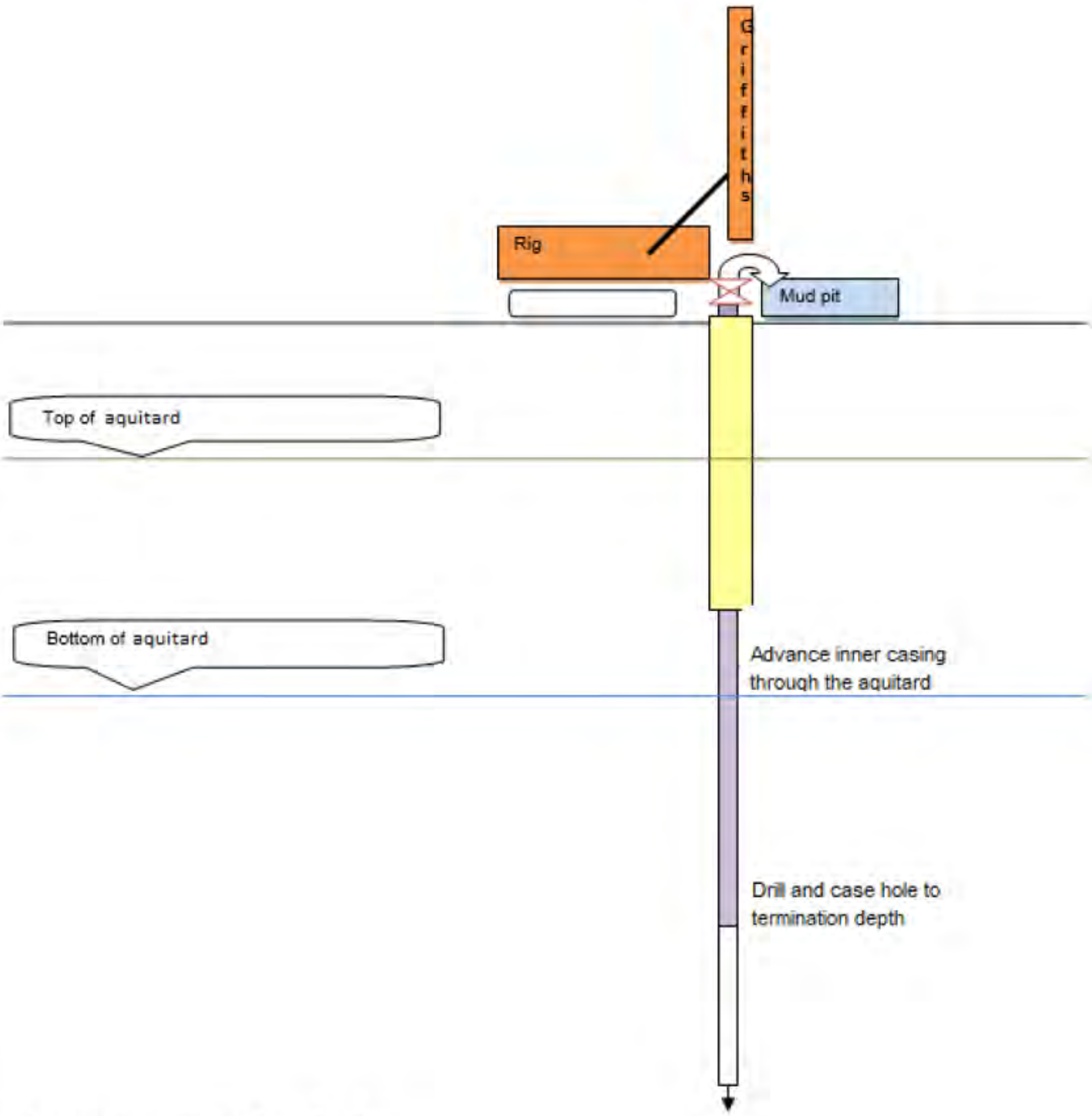


Step 2: After depth to aquitard has been established, dual casing (outer) installed, and seated 1m into the aquitard. Casing filled with bentonite mud which is then left to hydrate before step 3.



GRIFFITHS DRILLING

Step 3: Extend inner casing through the aquitard. Drill and case borehole to termination depth.

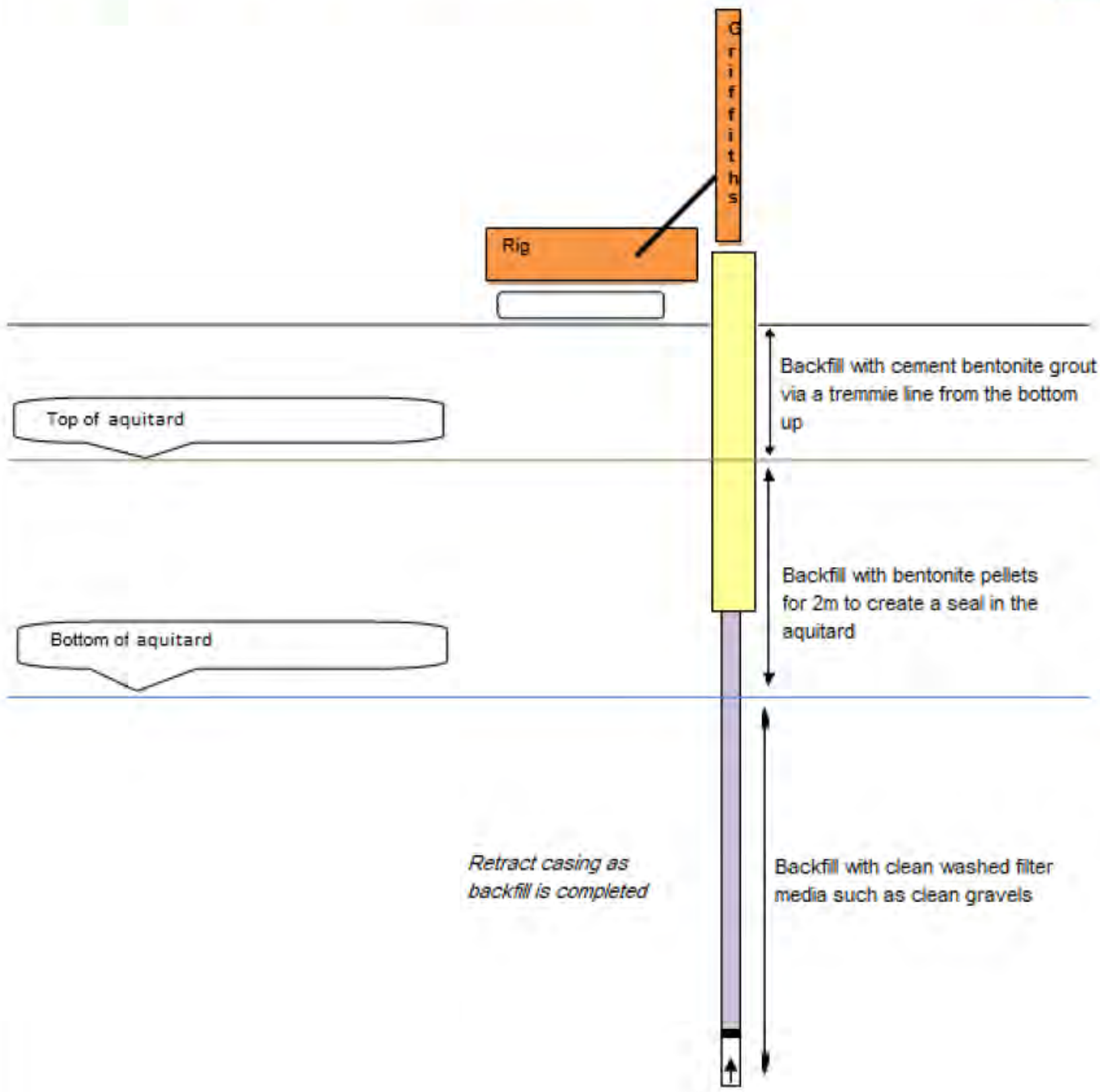


Artesian pressure control methods:

Proposed methods of controlling flow of artesian water are as follows. The first method will be to allow the water to flow at the surface, and either containing this in water storage / filtration tanks, or to divert this clean water to a known outlet close to the drill site. The flow of water would only be present while the drilling operations take place. Overnight and during any downtime during the day, an extra length of casing can be added above ground level which will enable the head of pressure to be equalised and therefore stop the flow of water. Note that it is not possible to have this extra length of casing on during drilling with the drill rig at ground level. If this were to be used while drilling, the drill rig would need to be raised. This can be done by building a structure to raise the rig to the level of the head of pressure. 08

Step 4: Backfill of borehole.

When sealing up a drilled borehole that has penetrated the aquitard, this will be backfilled with a mixture of clean washed filter media such as clean gravels (through water bearing stratum), bentonite pellets for 2m above this to seal off the aquitard, and bentonite cement grout above this. The cement / bentonite grout mix will be pumped into the borehole using a tremie line to ensure this is grouted from the bottom up. As this is done, the steel drill casing will be retracted. This will seal off the aquitard and control the artesian water pressure.
Note that no cement will be used in the water bearing material. While backfilling is being completed, the head of water pressure will be controlled by adding a length of casing above ground level, which will stop the flow of water and will allow decommissioning of the bore to be completed. All reinstatement will be completed in accordance with New Zealand Environmental Standard for Drilling of Soil and Rock (NZS 4411:2001). 10



Geotechnics Monitoring Regime Melling Riverlink Project

GEOTECHNICS

Our Ref: GWN MELLING RIVERLINK GWRC
7 January 2019

GWRC c/o Stantec New Zealand
Level 14,
80 The Terrace
Wellington 6141

Attention: Andrew McLeod

Dear Andrew

Melling Riverlink
Vibrating Wire Piezometer 5 Year Monitoring Rev1
Offer of Services

Thank you for your invitation to provide a quote/estimate for the above project. Geotechnics will be able to provide you with the monitoring of Vibrating Wire Piezometers (VWP) detailed in the pricing schedule below. Quantities, specifications and associated totals herein have been provided on the basis of your emails dated 11 and 19 December 2018.

Item	Description	Unit	Rate ($)
1.0	Monitoring/ Reporting based on 37 x data loggers (includes data hosting, data review and reporting)	per month	2,783
2.0	Adjustment rate for Monitoring/ Reporting based on 1 x data logger (includes data hosting, data review and reporting)	per data logger	41
3.0	Data logger battery replacement (includes supply and installation)	per data logger	633
4.0	Data logger antenna (includes supply and installation)	per data logger	143

Health & Safety

Geotechnics is committed to providing and maintaining a safe and healthy working environment at all of our places of work. In line with this commitment, and as required by health and safety legislation, we will consult, cooperate and co-ordinate our activities with you and others who will be working on the project. To assist us in this, please let us know if you have any specific health and safety planning and implementation requirements, which are relevant to our services (including known risks) so that we can review these with you.

Equipment

The data loggers that we propose to use are Frontier Data Loggers (supplied as part of the drilling contract). The units are self-contained, meaning no solar power or additional battery pack is necessary to power each unit. The expected battery life of a 3 channel Frontier Logger logging 6 hourly and transmitting daily in an area with strong mobile network signal strength is 3 years. Shorter logging intervals, poor mobile network signal strength or more frequent transmission of data will reduce battery life. The Frontier Data Logger unit's battery is encased in epoxy and is not user replaceable. When the battery is depleted, a new Frontier Logger unit will need to be acquired to resume monitoring. The price for replacement units will be subsidised with trade-in of depleted units. The subsidised rate for the supply and installation of a single unit is included as item 3.0 in the pricing table above.

The Vodafone cellular signal is expected to be strong at each site, however, as the data loggers are required to be installed below ground level, the signal strength may be impeded. A rate for the supply and installation of a single unit is included as item 4.0 in the pricing table above.

Protection

Flush toby boxes will be used for protection of the loggers (they are included in the supply and installation offer submitted to Griffiths Drilling). The XL Well Cover 350 mm will be used for all boreholes except BH18-18 and the SD400 Well Cover will be used for BH18-18 to allow more space for the larger, stiffer armoured cable (information attached).

Data Collection and Reporting

Readings from each VWP will be taken every 6 hours and data from each logger will be uploaded to the Geotechnics FTP server daily. Notifications of groundwater pressure exceedances will be sent during the daily upload to GWRC, Griffiths Drilling and Stantec. 15

Readings of VWPs will be reviewed fortnightly by Geotechnics and a report will be produced annually for 5 years and will include an overview of pressure readings from each VWP, details of trigger levels reached and information of the condition of the monitoring equipment. 15

Monitoring rates are included in the pricing table above. Item 1.0 is the monthly rate for 37 x data loggers and Item 2.0 is the adjustment rate for a single data logger should the quantity of data loggers required changes. If the instrument numbers were to increase or decrease by 15% or more, we reserve the right to review our per test rate.

We trust that this satisfactorily meets your needs. We look forward to receiving your instruction to proceed and to working with you on this project. You can confirm your acceptance by returning the attached signatory form. Alternatively, we will take your written instruction to proceed as confirmation that you accept this proposal.

GEOTECHNICS LTD

9(2)(a) [redacted]

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Wellington Manager

7-Jan-19
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Pricing Considerations

General

- The rates quoted have been established based on the indicative instrument numbers quoted. If the instrument numbers were to increase or decrease by 15% or more, we reserve the right to review our per test rate.
- All rates/prices are GST exclusive.
- Terms of Payment: 20th of the month following the date of our invoice(s) or as arranged before commencement of the job.
- Rates are valid for 90 days from the date of this proposal subject to exchange rates.
- No retentions are to be deducted.
- Geotechnics Ltd Testing Services General Terms & Conditions (attached) apply. These terms will apply in precedence to any terms and conditions in any purchase order or other confirming document that you may issue to us.

Specific

Instrumentation

- Geotechnics cannot be held responsible for any data that is available later than scheduled or irretrievable due to factors outside our control.
- The Frontier Logger units require Vodafone mobile phone signal at each site to provide transmission of data. Weak signal at any given site may reduce the battery life of the unit. Geotechnics will install devices assuming that the signal is adequate at each site. During installation, if it's determined that the signal is marginal/weak at any given site we will propose installation of an antenna upgrade.
- Geotechnics cannot be held responsible for damage to instruments outside of our control. We will take due care to protect equipment and make site personnel aware of our instrumentation during installation. Reasonable effort will be made to protect devices from tampering/theft/vandalism with use of suitable hardware. We cannot make any assurance that these measures will be adequate protection for this site.

Acceptance

Geotechnics Ref	GWN MELLING RIVERLINK GWRC
Date	7 January 2019
Contract	Melling Riverlink Vibrating Wire Piezometer 5 Year Monitoring Rev1

Confirmation by Customer			
I/we acknowledge that I/we have read the Offer of Services (including the Pricing Considerations) for the above contract and the attached Geotechnics Ltd Testing Services General Terms & Conditions (including the limitations of liability), and I/we accept those terms and authorise the above.			
Customer	GWRC C/o Stantec New Zealand		
Contact	Andrew McLeod		
Signature			
Name		Date	
Reference/Purchase Order			

Please provide the following information if different from your address:	
Customer Name and Address	Invoicing Name and Address (if different)

Please return one signed copy to of Geotechnics at or to the address on the letterhead.

GEOTECHNICS LTD - TESTING SERVICES TERMS AND CONDITIONS

1. GENERAL

All Services are carried out on the basis of the following terms and conditions and the attached Special Conditions (if any), unless otherwise agreed in writing.

2. INTERPRETATION

In these terms and conditions, unless the context indicates otherwise: "Customer" means the party named in the Contract, who employs the Company to undertake the Services and its successors and permitted assigns; "Company" means Geotechnics Limited and its successors and assigns; "Contract" means this Master Work Order Agreement comprising the relevant Work Order, these terms and conditions and the attached Special Conditions (if any); "GST" means goods and services tax payable in terms of the Goods and Services Tax Act 1985; "PPSA" means the Personal Property Securities Act 1999; "Project" means the project named in the relevant Work Order for which the Services are to be provided; and "Services" means the services to be performed by the Company for the Customer (as set out on the relevant Work Order) and includes any incidental goods expressly contemplated by the Work Order to be provided by the Company in carrying out the Services ("Goods").

3. SERVICES

3.1 The Company performs the Services solely for the benefit of the Customer with respect to the Project, and the benefit of the Services, including any data or opinions contained in any report prepared for the Customer, may not be used in other contexts or for any other purpose without the prior review and agreement of the Company.

3.2 The Company shall not be liable for any delay or non-performance arising from or attributable to circumstances beyond its control (including, but not limited to, acts of God, labour disputes, transportation delays and delays in the supply of goods and services by suppliers to the Company) and reserves the right to charge for any such delay whilst on site at the stand-by rate specified in the Special Conditions or otherwise at the average hourly charge-out rate of the Company s personnel who are delayed on site.

3.3 The Company shall not be liable for any delay or for exceeding the estimated or quoted price because of non-disclosure or withholding of information relevant to the Project by the Customer or its contractors or agents.

3.4 Where the Customer directs that certain specialists supply services as part of the Project, the Company shall be responsible only for the co-ordination of such services and materials into the Project as a whole.

3.5 All rights of entry, services information and approvals (other than those expressly required by this Contract to be provided by the Company) required to enable the Company to perform the Services shall be secured by the Customer.

3.6 The Company is not responsible for the make good of any damage to surfaces or subsoil arising from any investigative or other works necessary for the performance of the Services.

3.7 The Company will have in place a health and safety management plan for the Services and will comply with any health and safety plan operated by the Customer or third party in control of the site. The Company must be provided with site hazard and safety information, and will not be obliged to commence any work until its personnel have completed a site safety induction.

4. QUOTATIONS AND ESTIMATES

4.1 The Company shall use its best endeavours to perform the Services at the quoted or estimated price using its current resources. Unless expressly indicated otherwise, the quoted or estimated price:

a. assumes the Services will be undertaken during the Company s normal business hours (7.30am to 5pm) Monday to Friday excluding public holidays; and

b. does not include any allowance for any site survey work (assumed to be done by the Customer s surveyor), any traffic management or road control, or any earthworks or vegetation clearance (access to the site assumed to be of a reasonable standard and the site reasonably level).

4.2 A quoted price for supply of Services is valid for 90 days, and subsequently shall be deemed to be withdrawn.

4.3 Where an estimated price is provided, the Customer will receive the full benefit of any lesser cost for the supply of the Services, but the Company reserves the right to charge a higher price where time involved or the costs for the supply of the Services exceed the estimate.

5. PAYMENT

5.1 Payment for all Services is due on the 20th of the month following the date of issue of invoice. In the case of Projects of greater than one month s duration, invoices may be issued on a monthly basis. Interest shall accrue on a daily basis and be payable on all overdue sums at 12% per annum from the date payment is due until the date payment is received in full. The Company also reserves the right to recover from the Customer all expenses and legal costs of the Company (calculated between solicitor and own customer) in relation to obtaining or seeking to obtain remedy of default in payment by the Customer.

5.2 All prices quoted or estimated are exclusive of GST. The Customer shall pay at the time when payment is due pursuant to clause 5.1 any GST payable in respect thereof.

5.3 If any payment is overdue, the Company may withhold or suspend supply of the Services and the licensing of any rights until such payment is made.

6. CONFIDENTIALITY AND PUBLICATION OF RESULTS

6.1 The Customer shall provide the Company free of cost with all information about the Project or otherwise relevant to enable the Company to obtain a clear understanding of the Customer s requirements for the Services. The Company shall keep in confidence all confidential information it has received from the Customer except confidential information in the Company's possession prior to receipt from the Customer or which subsequently comes into the public domain (other than as a result of unauthorised disclosure by the Company).

6.2 The Customer shall keep in confidence all confidential information it has received from the Company except confidential information in the Customer's possession prior to receipt from the Company or which subsequently comes into the public domain (other than as a result of unauthorised disclosure by the Customer).

6.3 The Company shall keep in confidence the results of work undertaken on behalf of, and paid for by, the Customer. The Company may publish any results with the prior written approval of the Customer.

6.4 The Customer shall refer any proposed publication of test results or other work undertaken by the Company to the Company for approval, such approval not to be unreasonably withheld. The Company's approval may be withheld if the Company believes in good faith and on reasonable grounds that the proposed publication does not completely and accurately represent the results of the work undertaken.

6.5 The use of the names, symbols or abbreviations of "Geotechnics Limited" in conjunction with any proposed manufacturing or marketing of Services shall require the prior written approval of the directors of the Company.

7. OWNERSHIP

Any drawings, specifications and other documents provided by the Company are the property of the Company whether the work for which they are made is completed or not. Property in any Goods provided under this Contract shall pass to the Customer only on the full performance of the obligations of the Customer, including the payment of all amounts payable, and the Company shall for the purposes of the PPSA have a security interest in those Goods and proceeds.

8. INTELLECTUAL PROPERTY

Unless otherwise agreed in writing prior to the commencement of this Contract, all intellectual property rights pre-existing or arising from or developed in the course of undertaking the Services shall remain with or vest in the Company.

9. LIABILITY & INSURANCE

9.1 If all, or any part of, the Services are acquired for the purposes of a business, the provisions of the Consumer Guarantees Act 1993 shall not apply in relation to those Services. The following provisions of this clause 9 apply to the extent permitted by law.

9.2 The maximum aggregate liability of the Company in respect of this Contract (whether in contract, tort or otherwise) shall be limited to five times the sum paid by the Customer to the Company for the Services provided (exclusive of GST and disbursements) with a maximum limit of $500,000.

9.3 The Company shall not be liable for any special, indirect, incidental or consequential damages nor for any lost profits or injury arising from the provision of the Services under the Contract.

9.4 The Company shall not be liable for damages of any type whatsoever (including all related costs) sustained by or awarded against the Customer or a third party arising from the Customer's or a third party s manufacture, use or sale of any Goods supplied by the Company under this Contract (or any product or process developed from or incorporating the same).

9.5 If the Company is found liable to the Customer (whether in contract, tort or otherwise) and the Customer and/or a third party has contributed to the loss or damage, the Company shall only be liable to the proportionate extent of its own contribution.

9.6 The Company shall hold and maintain for the duration of the Services public liability insurance for $1 million and, if the Services require the use of any motor vehicle, motor vehicle liability insurance for $1 million. The Company will, on request by the Customer, provide certificates evidencing the currency of those insurances.

10. TERMINATION

10.1 Subject to clauses 10.2 and 10.3, the Contract shall terminate upon the earlier of:

a. completion of the Services by the Company and payment by the Customer; or

b. mutual agreement of the parties.

10.2 The Company, without liability on its part, shall have the right to cancel the Contract (so far as it remains unperformed) wholly or in part, or any other contract which has not been completed, with immediate effect by giving written notice to the Customer, and all sums outstanding (whether legally demanded or not and whether then due or not) shall become immediately due and payable to the Company if:

a. the Customer breaches these terms and conditions, including default in any payment on the due date; or

b. the Customer goes into liquidation, bankruptcy, statutory management or receivership or becomes insolvent or unable to pay its debts or enters into an arrangement or composition with its creditors.

10.3 The Company may terminate the Contract by notice to the Customer of at least 14 days.

10.4 Any termination of the Services shall be without prejudice to the rights of either party in existence prior to termination, in particular for unpaid moneys due to the Company.

11. NOTICES

Any notices or other communications to be given hereunder may be delivered personally, or sent by prepaid post or facsimile to the last known address of the addressee and shall be deemed to have been given two working days after posting or, in the case of personal delivery or facsimile, on the date of delivery or facsimile transmission.

12. ASSIGNMENT

The Customer shall not assign its rights or obligations hereunder without the prior written consent of the Company. No assignment by the Customer shall be effective unless and until all outstanding amounts are paid to the Company.

13. DISPUTE RESOLUTION

The parties will in good faith in the first instance use their best endeavours to resolve any dispute themselves. If the dispute cannot be resolved by the parties themselves within a reasonable time, they must explore whether the dispute can be resolved by use of mediation or other alternative resolution technique. If the dispute is not so resolved within a reasonable time, either party may refer the dispute to arbitration by a sole arbitrator under the provisions of the Arbitration Act 1996. The arbitrator will be appointed by agreement between the parties within 15 working days of written notice of referral by the referring party to the other or, failing agreement, by the President of the Arbitrators and Mediators Institute of New Zealand or his or her nominee. Nothing in this section 13 shall prevent either party initiating court proceedings seeking urgent interlocutory relief.

14. GOVERNING LAW

This Contract shall be governed by the laws of New Zealand and the parties submit to the non-exclusive jurisdiction of the courts of New Zealand and any courts who may hear appeals therefrom.

July 2016

XL Traffic Rated Well Cover 350mm

Extra Large & Traffic Rated

With an OD of 350mm the XL Cover is ideal for installations where more room than usual is needed around the well head: for example, remediation work, or where instrumentation needs to be hidden around the top of the well.

Features:

- All cast iron lid and base for strength, with a sheet metal skirt to reduce overall weight
- Well ID tag on lid
- Traffic rated design certified by an independent laboratory to meet or exceed H20 and AASHTO M306 roadway loading requirements
- O-ring sealed
- Watertight rubber washers around bolts
- Non-slip surface

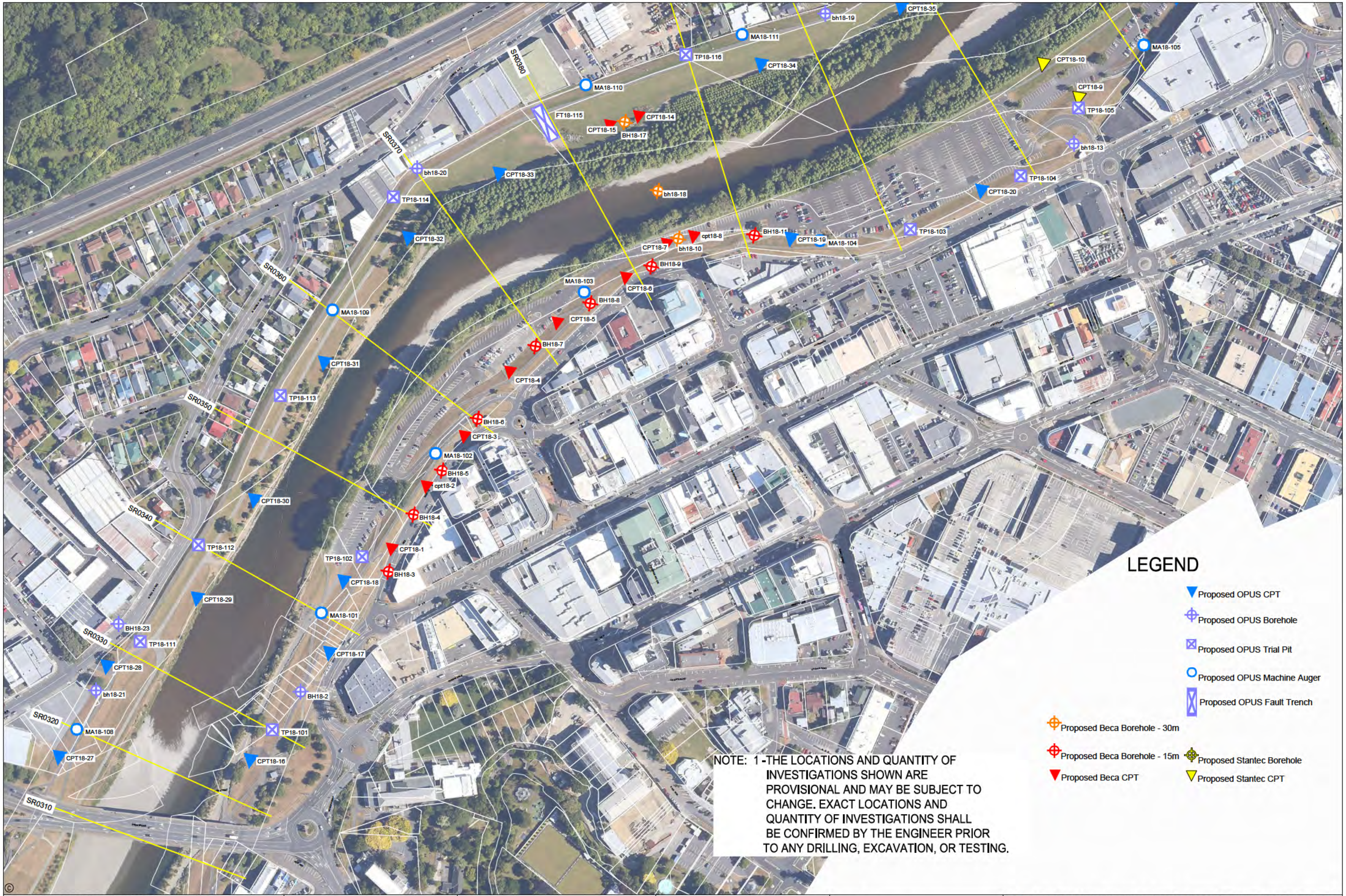
Large Manhole Cover

SD400 – A Large Well Cover for Remediation

The SD400 Cover is designed mainly for remediation work where bulky equipment may need to be around the well head. This large cover with a hinged lid offers wide access, with an easy lid opening. It can be ordered with or without a sheet metal skirt fitted.

- 600mm diameter opening
- 850mm overall diameter
- All ductile iron cast construction with sheet metal skirt (500mm long)
- Hinged lid requires only 1 key to lift up
- Designed to be cemented into the ground flush
- 40 ton load rating

Proposed Borehole Location Plan



This drawing is confidential and shall only be used for the purposes of this project.

REVISIONS				
No.	BY	DATE	DESCRIPTION	APPD
			Proposed site investigations added from Beca (for Structures) and Stantec (for Melling Interchange) for tender	

DESIGNED	9(2)(a)
DRAWN	
APPROVED	
DATE	May 2018

SCALE:
0 100m
1 : 3000 at A3; 1:1500 at A1

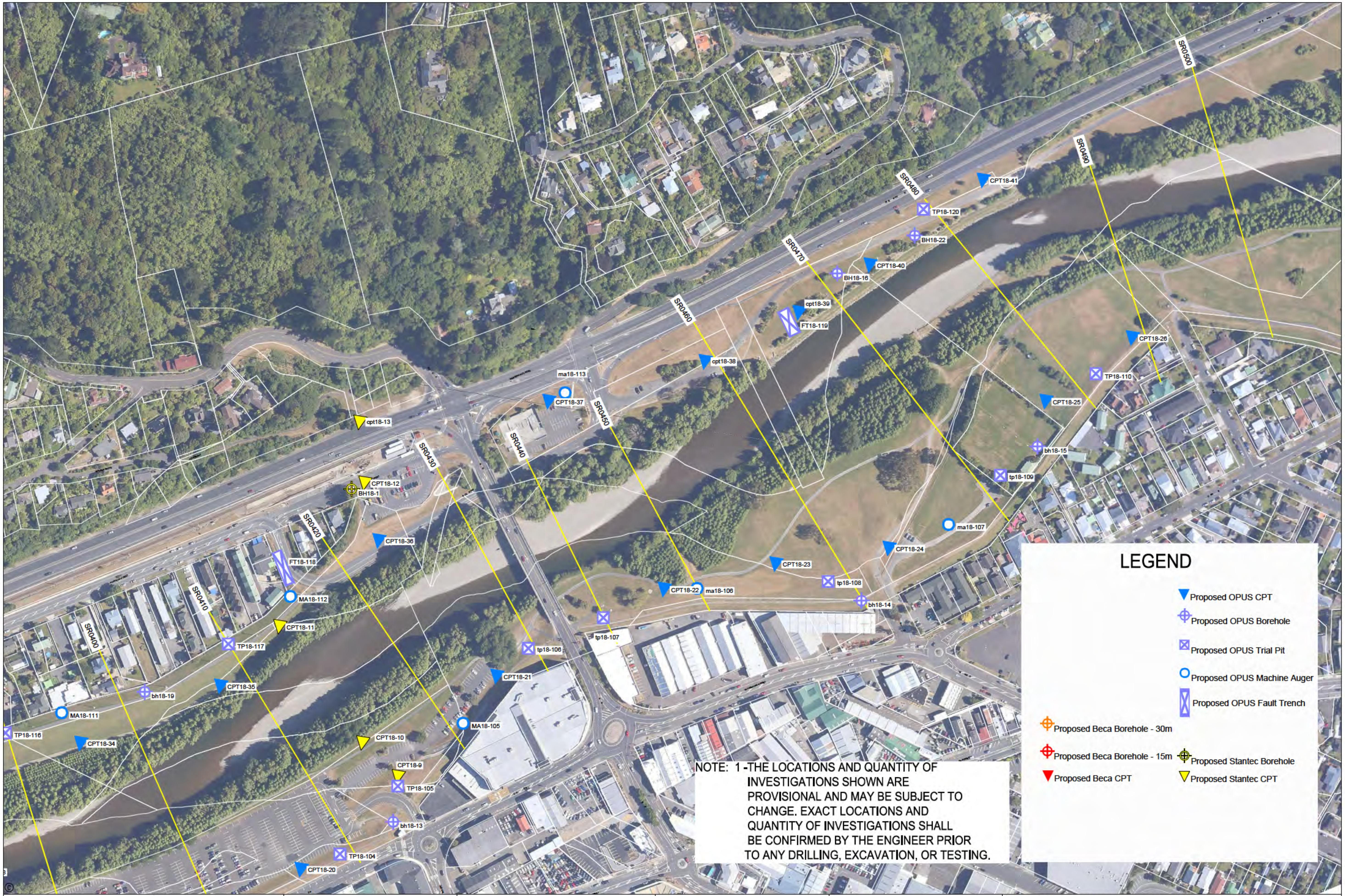
N

NZ TRANSPORT AGENCY WAKA KOTAHI
RiverLink
Stantec
wsp OPUS
Beca

CONTRACT 882PN MELLING INTERCHANGE RIVERLINK PROJECT

SITE INVESTIGATION LOCATION PLAN - SOUTH

A3	STATUS: TENDER	DRAWING NO: SB-DWG-4210	REV:



This drawing is confidential and shall only be used for the purposes of this project.

REVISIONS				
No.	BY	DATE	DESCRIPTION	APPD
			Proposed site investigations added from Beca (for Structures) and Stantec (for Melling Interchange) for tender	

9(2)(a) [redacted]

DRAWN

APPROVED | DATE | May 2018

SCALE: 0 — 100m

1 : 3000 at A3; 1:1500 at A1

N

NZ TRANSPORT AGENCY WAKA KOTAHI

RiverLink

Stantec | wsp | OPUS | Beca

CONTRACT 882PN MELLING INTERCHANGE RIVERLINK PROJECT

SITE INVESTIGATION LOCATION PLAN - NORTH

A3 | STATUS: TENDER | DRAWING NO: SB-DWG-4211 | REV:

Barite Material Datasheet

Safety Data Sheet – Barite

INDUSTRIAL MINERALS CO.

Section 1: Product and Company Identification

Product Identifier: Barite
Product Names: Barite, Baryte, Bar

Product uses: various industrial uses

Manufacturer:
Industrial Mineral Company
7268 Frasinetti Road
Sacramento, California 95828

Emergency Telephone Number: 916-383-2811
Telephone Number for Information: 916-383-2811

Section 2: Hazards Identification

Carcinogen

Irritant (skin and eye)
Skin Sensitizer
Reparatory Track Irritant

OSHA/HCS status: This naturally occurring clay is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200)
Classification of the substance of mixture: OSHA –Carcinogenicity (inhalation) - Category 1A and Specific organ toxicity (Repeated Exposure) (Respiratory tract through inhalation) – Category 1
Exposure limits for Crystalline Silica: The current American Conference of Government Industrial Hygienist Threshold limit value for crystalline silica is: 0.1 mg/m^3
Signal Word: Danger
Hazard Statement Cancer Hazard. Contains quartz (crystalline silica) which may cause cancer. Risk of cancer depends upon duration and level of exposure to the dust. Not an acute hazard. Prolonged inhalation of dust may cause lung injury. Inhalation of high concentrations of dust may cause mechanical irritation and discomfort of the respiratory tract. Repeated exposure may have chronic effects. Can cause skin, respiratory, and eye irritation.
Precautionary Statement: Wear protective gloves, eye, and respiratory protection. Avoid breathing dust.

Section 3: Composition Information

Natural Occurring mineral, exact chemical composition varies.

Chemical Name	Common Name	CAS Number	%
Quartz (Silica)	SiO_2	14808-60-7	10-12
Barite	$BaSO_4$	13462-86-7	80-84
Mica/Illite	$(K,Na,Ca)(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH,F)_2$	12001-26-2	<6
Calcite	$CaCO_3$	13397-26-7	<2

Section 4: First-Aid Measures

Eye Contact: If eye contact occurs, rinse immediately with plenty of water. If irritation persists, seek medical attention
Skin Contact: Wash thoroughly with water. If irritation persists, seek medical attention
Inhalation: Move victim to fresh air in well ventilated area. If coughing or irritation persists, seek medical attention
Ingestion: Consult physician and/or obtain competent medical assistance

Section 5 Fire Fighting Measures

General Fire Hazards: Not flammable
Extinguishing Media: Use appropriate extinguishing media for surrounding fire
Special Fire Fighting Procedure: None

Section 6: Accidental Release Measures

Clean-up Methods: When dust is generated it may over expose cleanup personnel to dust. Using respirators or wetting the material is recommended. When dry sweeping use NIOSH approved respirators when dust levels exceed exposure limits
Personal Precautions and Personal Protective Equipment: Wear appropriate protective equipment and clothing during clean-up. If dusty conditions exist use approved respirators.
Environmental Precautions: Material is a natural mineral product and will not cause adverse effects to the water system other than turbidity from suspended particles.

Section 7: Handling and Storage

Handling Procedures: Wear the appropriate eye protection and avoid dust contact with eyes. Minimize dust generation and accumulation. Wear the appropriate respiratory protection when in poorly ventilated areas. Use good industrial hygiene practices.

Section 8: Exposure Controls/Personal Protection

Airborne Exposure Limits:

Silica component limit
OSHA PEL: TWA 10 mg/m^3 (respirable)
OSHA PEL : TWA 30 mg/m^3 (total dust)
CAL OSHA PEL: TWA 0.1 mg/m^3 (respirable)
CAL OSHA PEL: TWA 0.3 mg/m^3 (total dust)

Engineering Measures: Use local exhaust ventilation to control exposure below applicable limits
Personal Protective Equipment (PPE):
Respiratory: Avoid actions that cause dust exposure to occur. Use local or general ventilation to control exposures below applicable exposure limits. NIOSH or MSHA approved particulate filter respirators should be used. Respirator and/or filter cartridge selection should be based on the ANSI Standard Z88.2.

Eyes: When working around activities where dust can contact the eyes, wear safety glasses or goggles to avoid eye irritation or injury. Wearing contacts without sealing goggles is not recommended.
Skin and Body: Protective Clothing is not essential

Section 9: Physical and Chemical Properties

Appearance: Tan to grey **Physical state**: Powder **pH**: 8 **Melting/Freezing Point**: no data available **Evaporation Rate**: NA **Vapor Pressure (mm HG)**: 0 (approximately) **Relative density**: NA **Solubility in water at 100 C:** 0 (approximately) **Decomposition temperature:** no data available **Viscosity:** NA	**Odor:** none **Odor threshold:** No data Available **Flashpoint:** NA **Boiling Point:** NA **Flammability:** Not Flammable **Vapor Density**: NA **Specific Gravity**: 4.1 **Partition coefficient**: No data available **Auto-ignition temperature**: NA

Section 10: Stability and Reactivity

Reactivity: No dangerous reactions are known under normal conditions of use
Chemical Stability: Stable
Possibility of Hazardous Reactions and Conditions to Avoid: None known
Incompatibility: None Known

Section 11: Toxicological Information

Possible Health Effects:
Target Organs: Skin, Eyes, and Respiratory system
Exposure Routes: Inhalation, skin or eye contact
Symptoms:
Short Term: Shortness of breath and/or coughing associated with dust inhalation.
Long Term Exposure (Chronic): Steady and prolonged exposure to dust concentrations high than LTV without approved respirator could cause silicosis, a chronic disease of the lungs marked by acute fibrosis, may cause cancer based on animal data.
Effects of Silicosis
Bronchitis/chronic obstructive Pulmonary Disorder
Increased susceptibility to Tuberculosis
Scleroderma
Possible Renal
Symptoms of Silicosis
Shortness of breath, fever fatigue, loss of appetite, chest pain, dry non-productive cough, respiratory failure, death.

OSHA, IARC, and NTP Carcinogen Classifications				
Chemicals with recognized Carcinogen Potential	CAS#	OSHA	IARC	NTP

Quartz (Crystalline Silica)	14808-60-7	Yes	Yes – Group 1	Yes

Section 12: Ecological Information

Eco toxicity: None Known
Biochemical oxygen demand (BOD5): None known
Chemical oxygen demand (COD): None known
Products of Biodegradation: None known
Toxicity of the products of biodegradation: None known
Bioaccumulation Potential: None known
Potential to move from soil to groundwater: None Know
Other adverse effects: None known

Section 13: Disposal Considerations

Personal Protection: Refer to section 8 for proper PPE when disposing of waste material
Appropriate disposal containers: No special requirements
Appropriate disposal methods: Disposal of this product should comply with the requirements of environmental protection and waste disposal legislation and any regional or local authority requirements.
Physical and chemical properties that may affect disposal: Dust should be minimized in disposal by either transporting in seal containers or wetting dust before transport
Sewage disposal: do not dispose of into sewage systems, material will settle out of water and clog pipes.
Special precautions for landfills or incineration activities: None

Section 14: Transport Information

Regulatory Information	UN Number	UN Proper Shipping Name	Transport Hazard Class	Packing Group Number	Bulk Transport Guidance	Special Precautions
DOT Classification	Not Regulated	-	-	-	-	-
TDG Classification	Not Regulated	-	-	-	-	-
ADR/RID Class	Not Regulated	-	-	-	-	-
IMDG Class	Not Regulated	-	-	-	-	-
IATA-DGR Class	Not Regulated	-	-	-	-	-

Section 15 Regulatory Information

TSCA – Toxic Substances Control Act – EPA Quartz and other chemicals are listed in the TSCA Chemical Substance Inventory

California Prop. 65 WARNING: This product contains a chemical known to the State of California to cause cancer. (Prop. 65 – California Health and Safety Code Section 2549 Et Seq)
SARA/Title III (Emergency Planning & Community Right-to-Know Act This mixture contains no substances at or above the reporting threshold under section 313, based on available data.

Section 16: Other Information

Definitions
ASTM –American System of Testing and Materials
OSHA – Occupational Safety & Health Administration
IARC – International Agency for Research on Cancer
NTP – National Toxicogmail.com
HCS – Hazardous Communication Standard
CAS – Chemical Abstract Service
ACGIH – American Conference of Governmental Industrial Hygienists
CAL-OSHA – California Occupational Safety & Health Administration
OSHA PEL – OSHA Permissible Exposure Levels
OSHA STEL - spot exposure for a duration of 15 minutes, which cannot be repeated more than 4 times per day with at least 60 minutes between exposure periods.
TLV – Threshold Limit Value
TWA – Time Weighted Average
TLV-TWA –Time weighted average Threshold limit value
TLV-STEL – Shot-term exposure limit Threshold limit value
TLV-C – Ceiling Limit – absolute limit that should not be exceeded at any time

Revisions: Existing MSDS revised to new GHS format. Revision Date 08/31/2015

The information presented herein has been compiled from sources considered to be dependable and is accurate and reliable to the best of our knowledge and belief but is not guaranteed to be so, nothing here in is to be construed as recommending any practice or product in violation of any patent, law, or regulation. It is the user's responsibility to determine the suitability of any material for a specific purpose and to adopt such safety precautions as may be necessary. We make no warranty as to the results to be obtained in using any material and, since conditions of use are not under our control, we must necessarily disclaim all liability with respect to the use of any material we supply.

Tonkin and Taylor Peer Review Spreadsheet

Melling & Riverlink Geotechnical Site Investigations

T+T Peer Review Comments
Stantec Review Comments
Documents Reviewed
1. "Methodology - Melling & Riverlink Project" by Griffiths Drilling

Review Date 18-Feb-19
Revision DRAFT
Reviewed by LRA

No.	Section / Paragraph / Sentence	T+T Comments	Designer Comments	Additional Requests from Meeting	STANTEC Review - Reference in Drilling Methodology
1	i) Paragraph 1	Consent holder to confirm number, location and depth of proposed boreholes and CPTs.	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT Confirmed with updated location plan	Provide material datasheet for barite within the methodology	**Appendix A - site plan, table of borehole depths. Page 7-8 GD methodology - Barite material datasheet information.**
2	i) Paragraph 2	Agree that drilling for the proposed 15m deep borehole should cease once aquiclude has been identified, and in our opinion, should not penetrate more than 1m into the aquiclude in any case. Double casing must be implemented if drilling is to progress any further than 1m into aquiclude.	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT A geologist must be present on site during drilling to identify aquitard.	Well numbers will need requesting prior to drilling on site	**GD methodology - Statement of methodology for dual casing if aquitard is penetrated (pages 3 - 5). Cover letter - Statement of geologist on site during drilling works. Statement that well numbers will be assigned prior to drilling.**
3	i) Paragraph 3 - *Another factor to consider is the location of the Wellington Fault……. and as a result of this we don't believe it would require dual casing to drill to the proposed 30m depth.*	The exact location of the Wellington fault may not be definitive and isn't that part of this investigation to locate the Wellington fault location. Additionally, it is not prudent to discount that there is connectivity between the aquifer and the proposed borehole or assume that Waiwhetu Artesian Aquifers is not present at this stage. We are of the opinion that these boreholes should also be double cased until sufficient investigation data is available to confirm that they are not.	REQUESTED ADD INTO METHODOLOGY TO CLOSE OUT Boreholes will be programmed prior to CPT testing to allow better identification of aquiclude. Drilling will be advanced down to the aquitard and advance 1m to confirm. Drilling will then cease whilst an assessment is undertaken as to whether the aquitard has been reached. Dual casing will then commence. In areas of higher risk of connectivity dual casing will be employed from surface.	As discussed in previous meetings, include Jeremy McKibbon at Wellington Water in methodology document to detail contingency of reporting should pressure change due to drilling within the aquitard.	**GD methodology - Statement to complete boreholes prior to CPTs, that a geologist and driller will assess whether the aquitard has been reached before commencing dual casing if borehole need to be advanced further. Also see step by step schematic of drilling. See page 3 for specific inclusion of Jeremy McKibbon's involvement in discussions around water pumping/drilling timing (pages 1-3).**
4	i) Paragraph 3 - *For all other <u>30m</u> boreholes on this project, Griffith's had allowed to drill and install 12m dual casing prior to advancing the boreholes to full depth.*	The outer casing must be advanced <u>as required</u> to ensure that they penetrate adequately into the aquiclude and not puncture it (not just 12m - could be 10m could be 15m). The top of aquiclude should be identified by the on-site geologists so that termination of the outer casing may be confirmed to the drillers.	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT Must case into the aquitard if drilling exceeds 1m. A geologist must be present on site during drilling to identify aquitard.	Detail what is required for drilling fluid monitoring, i.e. turbidity? Samples? Trigger values?	**GD methodology - Statement of methodology for dual casing if aquitard is penetrated (pages 3 - 5). Statement that if a spike in turbidity levels is noted in nearby bores drilling with cease but that this will be managed by Wellington water (page 7&8). Cover letter - Statement of geologist on site during drilling works.**
5	i) Paragraph 3 - *This had not been allowed for any other boreholes……. had not been sighted by Griffiths.*	We assume this refers to the 15m deep boreholes. If double casing is not proposed for these boreholes then the methodology should allow for termination of these boreholes once the <u>top of the aquiclude</u> is reached. In our opinion, in any case they should not penetrate more than 1m into the aquiclude.	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT Drilling will be advanced down to the aquitard and advance 1m to confirm. Drilling will then cease whilst an assessment is undertaken as to whether the aquitard has been reached. Dual casing will then commence.	Detail how head of pressure will be managed in Petone Marine Beds so can take SPT without effecting results	**GD methodology - statement of methodology for dual casing/step by step schematic (page 3-4), statement detailing that barite will be used to control head of pressure and not effect SPT results (page 5).**
6	i) Paragraph 4	We agree that the proposed depth of 20m for the CPT is deep and is most likely to puncture the aquiclude and we agree the difficulty in backfilling a CPT hole. The investigation should be phased in such a manner that the boreholes are drilled first to get an idea of the likely level of the aquiclude and the CPTs advanced to stop at the top of the aquiclude. If this cannot be incorporated into the drilling programme then a conservative estimate of the top of aquiclude should be identified through a desktop study of available ground information in the area.	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT Boreholes will be programmed prior to CPT testing to allow better identification of aquiclude. Most CPT's will be terminated at depths of around 10m however if they are required to go deeper the CPT will be advanced down to the aquitard and advance 1m to confirm. The test will then cease whilst an assessment is undertaken as to whether the aquitard has been reached. Dual casing will then commence. In areas of higher risk of connectivity dual casing will be employed from surface.	Specifically talk about BH18-18 and the use of bentonite pellets rather than cement (if required) and the reasons for.	**GD methodology - Statement to complete boreholes prior to CPTs, that a geologist and driller will assess whether the aquitard has been reached before commencing dual casing if borehole need to be advanced further. Also see step by step schematic of drilling. BH18-18 is addressed on pages 3-4 specifically backfilling on page 4.**
7	i) Paragraph 5 - *The general procedure…… with the final 1m of material left inside the casing .*	We assume the methodology here is to drill 0.5m to 1m into aquiclude to confirm that aquiclude is present and the outer casing will be "pushed in" another 1m into the aquiclude without removing material inside to obtain a seal. Please confirm.	See above		**GD methodology - Statement that GD will drill 0.5m into the aquitard and then "push" casing the following 1m to seat this in the aquitard material (page 4).**
8	i) Paragraph 5 - *The outer casing shall be filled with a bentonite mud…. should it be required.*	Please confirm if bentonite mud will be introduced inside the inner casing to control artesian pressures? Have you considered extending the casing above existing ground level?	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT Not practical to extend the casing above ground level. Include options in methodology to control the artesian pressures, i.e. use of barite/bentonite/scaffolding required.		**GD methodology - Statement of how barite will be used to control artesian pressure (page 7 and 8). See also dual step by step schematic. Step by step schematic also states structure can be erected if required.**
9	i) Paragraph 5 - *The typical setup for this is illustrated in the diagram below.*	Please confirm the diameter of the outer casing and inner casing.	250mm/125mm		**GD methodology - Stated on page 4.**
10	iv)	Consider using only bentonite seal within the aquiclude i.e. no cement to minimise potential risk of cement migration into the aquifer. Can bentonite pellets be used to seal the bore within the Waiwhetu Gravels and Petone Marine Beds?	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT Include detailed plan of back filling, i.e. bentonite pellet plug for 1m with bentonite cement seal to surface.		**GD methodology - Details of bentonite/cement backfill (Pages 4-5). See also step by step schematic.**
11	v)	How is verification of the seal conditions carried out? Are there any considerations of installing vibrating wire piezometers as part of the monitoring?	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT Requested to see installed in all boreholes and CPTs that penetrate the aquitard however will need to confirm with GWRC that this is the approach they would like to take.		**GD methodology - Details of vibrating wire piezometers, installation and frequency of monitoring (page 1 and 6).**
12	vi)	Please confirm the diameter of this remediation borehole and termination depth. Will pressure grouting be considered if the proposed mitigation method does not work?	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT Include details of pressure grouting in methodology should a breach occur.		**GD methodology - Details of pressure grouting on page 6.**
13	vii)	The aquiclude is usually not a thick uniform band of "soft silt". We do not consider terminating CPT based on "operator identifying soft silt" adequate - refer comment 6.	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT change working in methodology		**GD methodology - Statement to complete boreholes prior to CPTs (page 1 and 3).**
14	vii)	Please confirm the diameter of this remediation borehole and termination depth. Will pressure grouting be considered if the proposed mitigation method does not work?	See above		**GD methodology - Details of pressure grouting on page 6.**
15	viii) and ix)	See comment 11. Consider vibrating wire piezometers at 3 levels - Waiwhetu Gravels, below the aquiclude, above the aquiclude to robustly assess that sealing is successful.	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT Requested to see installed in all boreholes and CPTs that penetrate the aquitard however will need to confirm with GWRC that this is the approach they would like to take.		**GD methodology - Details of vibrating wire piezometers, installation and frequency of monitoring (page 1 and 6). Geotechnics methodology page 1.**
16	x)	Please confirm if barite will be used in your mix as it appears unlikely that a bentonite cement mix is adequate to control expected artesian? If barite is to be used please provide evidence that this is will not contaminate the groundwater. Have you considered the use of bentonite mud together with extending casing above existing ground level?	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT As above include detailed plan of back filling, i.e. bentonite pellet plug for 1m with bentonite cement seal to surface.		**GD methodology - Statement of how barite will be used to control artesian pressure (page 7 and 8). See also dual step by step schematic.**
17	Reinstatement of BH18-18 in the Hutt River	If river gravels (likely to be highly permeable) is present below 1m-2m below existing ground level, have the risk of bentonite/cement grout leaking through the gravels into the river considered?	REQUESTED ADD INTO METHDOLOGY TO CLOSE OUT As above include detailed plan of back filling, i.e. bentonite pellet plug for 1m with bentonite cement seal to surface.		**GD methodology - Details of bentonite/cement backfill (Pages 4-5). See also step by step schematic.**

Appendix D Safety in Design Report

SH2 MELLING INTERCHANGE DBC

SAFETY IN DESIGN REVIEW

PREPARED FOR NZ TRANSPORT AGENCY

June 2019

Stantec

QUALITY STATEMENT

PROJECT MANAGER		PROJECT TECHNICAL LEAD
9(2)(a) [redacted]		9(2)(a) [redacted]

9(2)(a) [redacted]

PREPARED BY		
9(2)(a) [redacted]	....	28/06/2019
CHECKED BY		
9(2)(a) [redacted]	....	28/06/2019
REVIEWED BY		
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REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
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A	June 2019	Final	9(2)(a) [redacted]			

SH2 Melling Interchange DBC

Safety in Design Review Review

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1. Introduction

1.1 Purpose of this document

This Safety in Design Report has been prepared for the Detailed Business Case phase of the SH 2 Melling Interchange project. This document outlines the process identified for the safety in design review, and the outcomes of the Safety in Design Review (SiDR) Workshop.

This report outlines the legal context of Safety in Design (SiD) and documents the approach taken by the design team to identify the risk events associated with the project, record the risk events and the relevant action proposed or undertaken to reduce the likelihood of the risk event occurring to as low as reasonably practicable.

1.2 Project details and roles

The project details and structure are as follows:

Project Name	SH2 Melling Interchange
Project phase	Detailed Business Case
Project customer (Client)	NZ Transport Agency
Owner of infrastructure	NZ Transport Agency
Designer	Stantec New Zealand Ltd

2. Project definition

2.1 Project background

SH2 provides access for people and freight between Wellington City and Hutt City (and the districts beyond). It connects communities and supports the resource sector (commuting work trip) which is the backbone of the region's economy. The geographically dispersed nature of the wider Wellington region (long and narrow requiring tidal transportation movements) means the Wellington Region is highly reliant on its transport system (including SH2) to move people and goods between regional centres.

The SH2 is identified as a strategic route that receives and distributes traffic into and out of Wellington and Upper and Lower Hutt. The highway plays a pivotal role in connecting the southern and northern Wellington region by providing for tourist, commuter, and economic trips. SH2 at the intersection of Melling Link requires a new grade separated interchange to relieve congestion and overcome safety concerns at the current at-grade intersection. SH2 traces the Alpine fault line so is a key route at risk from a resilience perspective.

The delivery benefits of the project include:

- Creation of construction jobs within the Wellington Region
- Improved driver safety (grade separation and road barriers)
- Increased efficiency and heavy vehicle management (reduced congestion)
- Reduced driver frustration
- Improved level of service
- Improved travel times
- Promotion of alternative modes (improved bike lanes and PT facilities)

In 2017, Stantec was engaged by NZTA to provide a detailed business case for the proposed interchange improvements and a new river crossing into the Hutt City CBD. The project area is shown in Figure 2-1 below.

Figure 2-1: Project locality map

2.2 Project Scope

The project scope includes the initial design of the interchange, two bridges, significant lengths of retaining wall, six signalised intersections, bike underpasses, and drainage improvements.

3. Scope of the SiD process

3.1 Legal context

Under the Health and Safety at Work Act 2015, designers of civil works and structures need to integrate hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of the product being designed. This should encompass all design including facilities, hardware, systems, equipment, products, tooling, materials, energy controls, layout, and configuration.

3.2 Project life cycle

The project life cycle is the process of managing the entire lifecycle of an asset from concept, through design and construction, to operation, maintenance and decommissioning. The design team has various points throughout this cycle where it can influence the safety outcomes of the project, for example, from providing investigation information right through to end user specifications and demolition advice. Figure 3-1 shows the general life cycle of a road infrastructure project.

Figure 3-1: Project life cycle diagram

3.3 Principles of safe design

To adopt a safe design approach for a project requires consultation with all relevant stakeholders to determine the hazards associated with the project, and to apportion the risks (design, construction, operation and maintenance, and demolition) to the parties best suited to manage them. All efforts are to be made to reduce risks involved to as low as reasonably practicable.

Construction and demolition activities are generally not addressed as a designer's responsibility unless specifically requested, however, a good design can assist in these areas.

The key elements that impact on achieving Safety in Design are:

- **Coordinate, communicate and cooperate** – use effective team collaboration to identify project health and safety risks so that all those involved with the asset are safe guarded; understanding the implications of decisions on others

- **Persons with Control** - people who make decisions affecting the design of project can promote health and safety at the source.
- **Project Lifecycle** - safe design applies to every stage in the project lifecycle - from concept through to disposal. It involves eliminating hazards and/or minimising risks as early in the lifecycle as possible.
- **Systematic Approach** - the application of hazard identification, risk assessment and risk control processes to achieve safe design.
- **Safe Design Knowledge and Capability** – people with control over design should either demonstrate or acquire the necessary safe design knowledge and capability.
- **Information Transfer** – essential for the safe design approach is the effective communication and documentation of design and risk control information, between those involved in each phase of the asset lifecycle.

3.4 Client obligations

It is the Principals responsibility to provide information on existing hazards associated with a project, make decisions relating to potential risks, hazards, and the mitigation measures identified by the Safety in Design process (e.g. endorse and accept), and if required, rule on what is reasonably practicable.

The Client has an obligation to consult with:

- the designer (if a designer has designed civil works or structures that are, or are part of, construction work) about how the construction work, in connection with the design, can be undertaken in a way that prevents or minimises all risks to health and safety
- the project manager for the construction work – about how the construction work can be planned and managed in a way that prevents or minimises all risks to health and safety
- the principal contractor for the construction work – about how the construction work can be undertaken in a way that prevents or minimises all risks to health and safety.

The Health and Safety at Work Act provides that if the Principal is aware of any information about hazards and risks relating to the site, at which the construction work is to be undertaken, the Principal must give this information to the designer, project manager or principal contractor.

3.5 Designers obligations

Designers have a responsibility to co-operate, communicate and co-ordinate with others to ensure the safety of all those who may be affected by the asset. This includes positively influencing a project through the effective planning and management of risks. All parties must recognise the need to consider operation, maintenance, decommissioning and demolition requirements.

Designers have obligations under the Health and Safety at Work Act to prevent or minimise risks in the design of the works so that the design does not adversely affect the workplace health and safety of persons:

- During construction of the works
- When the works have been constructed and are being used for the purpose for which they were designed
- During routine maintenance.

The responsibility for achieving a safe design may rest with one or more parties who are in control or manage the design functions (the design team). This could extend to all others who are directly involved in the design activity.

4. Risk management

4.1 Risk management process

The risk management process undertaken for this project is in accordance with AS/NZS ISO 31000:2009 *Risk Management – Principles and Guidelines*, and NZTA's ***Health and Safety in Design Minimum Standard***. The general risk management process is:

- Establish the risk context
- Risk Assessment (Assess consequence and likelihood)
- Risk Treatment (Apply mitigation measures)
- Monitor and Review

This process is illustrated below in Figure 4-1: Risk Management Process.

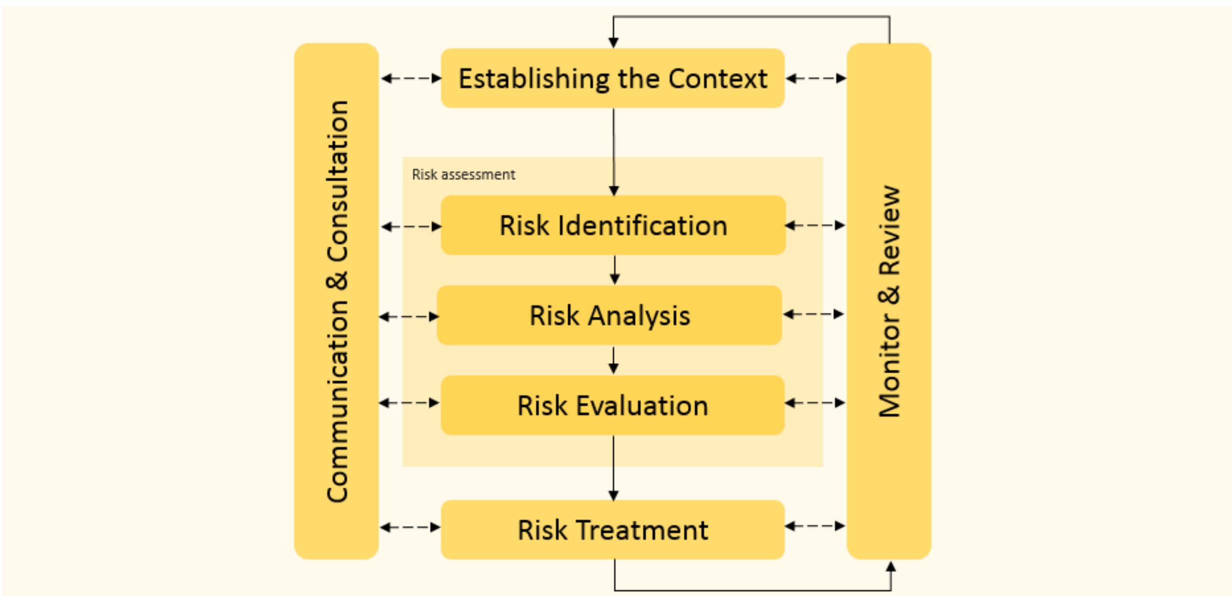


Figure 4-1: Risk Management Process

4.2 Establishment of risk context

The objective of establishing the risk management context is to define the framework that the risk management process is to follow for the project. Specifically, the context of the risk management process will:

- define the objectives of the risk analysis process
- define the scope of the risk assessment including specific inclusions and exclusions
- define the risk assessment methodology
- define the way performance and effectiveness is evaluated in the management of risk

4.3 Risk assessment

4.3.1 Risk identification

Safety in Design risk identification considers the risk sources, impact and events that may create safety related risk. The following hazard areas were considered during the SiDR;

- Construction
  - Ground stability
  - Hazardous environments
  - Working near water
  - Working conditions or locations
  - Existing utility services
  - Restricted working conditions (proximity to hazards)
  - Confined spaces
  - Hazardous construction
  - Working at height
  - Access and live traffic
  - External interfaces
- Design related hazards
- Maintenance, refurbishment and repair
- Operational issues
  - Site
  - Health and welfare
  - Occupational
- Environment and/or planning
- Demolition
- Competence

4.3.2 Risk analysis – Likelihood and Consequence

The *AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines* defines risk analysis as involving *"…consideration of the causes and sources of the risk, their positive and negative consequences, and the likelihood that those consequences can occur."*

In considering the magnitude of an identified risk, a determination is first made is on the likelihood or probability of the identified risk occurring during the project. The various levels used to describe likelihood in the analysis of risk is shown below in Table 4-1.

Table 4-1: Risk Likelihood

Likelihood Level	Likelihood Definition
Almost Certain	Very likely to occur during the life of the project, possibly several times
Likely	Likely to occur during the life of the project
Possible	May occur during the life of the project. Has occurred on similar project
Unlikely	Unlikely to occur during the life of the project.
Very Unlikely	Very unlikely to occur during the life of the project.

Following determination of project risk likelihood, the consequence level of the risk occurrence is then determined. The various levels used to describe consequence in the analysis of risk is shown below in Table 4-2.

Table 4-2: Risk Consequence

Consequence Level	Consequence Definition
Catastrophic	Could result in fatality
Major	Could result in permanent total disability
Moderate	Permanent partial disability, injuries or illness that may result in hospitalisation
Minor	Injury or illness resulting in one or more lost work days(s)
Insignificant	Injury or illness not resulting in a lost work day

4.3.3 Risk evaluation

Risk evaluation undertaken for the project is based on the following risk assessment matrix. The likelihood and consequence levels determined in the risk analysis stage are used to evaluate or rate the risk via a two-dimensional 5 x 5 risk matrix which is shown below in Table 4-3

Table 4-3: Risk Matrix

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Medium	Medium	High	Very High	Very High
Likely	Medium	Medium	High	High	Very High
Possible	Low	Medium	Medium	High	High
Unlikely	Very Low	Low	Medium	Medium	Medium
Very Unlikely	Very Low	Very Low	Low	Medium	Medium

4.4 Risk treatment

Risk treatment involves the selection of one or more options to modify risks. Following the analysis and evaluation of an identified risk, a treatment or control measure is selected with a view to reduce the likelihood and or consequence of the evaluated risk until the residual risk is acceptable.

The risk treatment process is cyclical in nature with the below steps:

- Assessment of the selected risk treatment
- Determining if the residual risk is acceptable,
- If not acceptable, select a revised risk treatment
- Assessment of the revised risk treatment

4.5 Monitor and review

In accordance with AS/NZS ISO 31000:2009 *Risk Management – Principles and Guidelines*, the risk management process will involve periodic checking and surveillance. This will be managed by the Project Manager and will involve design discipline leads as necessary. Informal reviews will occur prior to and during regular client progress meetings and formally prior the submission of design deliverables at key milestones, i.e. at the completion of the concept and detailed design stages for the various design disciplines.

5. SiDR workshop

5.1 Workshop overview

The focus of the SiDR workshop was to consider the impacts of the proposed design and identify potential hazards and risks that may require mitigation strategies to be documented for future phases of the project. The SiDR workshop also addressed construction, maintenance and operations related issues that were able to be identified from the concept design.

5.2 SiDR workshop details

The SiDR workshop was held on 17 June 2019. Attendees of the workshop are listed in Table 5 1.

Table 5-1: Safety in Design Workshop attendees

Name	Organisation	Project role
Roger Burra	NZTA	Project Manager (Consultant)
Eddie Anand	NZTA	Project Manager
Dandan Huang	NZTA	Project Engineer
Kirsten O'Donoghue	NZTA	Project Engineer – Road Safety
Andy Wright	Project Services Ltd	Construction and Constructability Expert
Nick Gluyas	Stantec	Design Manager
Keith Weale	Stantec	Design Lead and Lead Reviewer
Vinay Kumar	Stantec	Project Designer - Geometrics
Nigel Millar	Stantec	Project Engineer – Geotechnical
Seb Head	Stantec	Project Engineer – Drainage
Phil Peet	Stantec	Project Director/Project Technical Lead

5.3 SiDR assessment outcomes

The design team leaders identified risk events for their respective design discipline and discussed how best to manage these risks. Where possible, the design should reduce the likelihood of these risk events from occurring, along with their severity of impact.

Where the risk event cannot be completely or partially designed out, relevant actions are recorded to avoid, reduce or control the risk at the other stages for the life of the project. The responsibility for implementing any control measures during construction, operation and maintenance, and demolition will rest with the respective contractor or owner at the respective project phase.

A risk event is defined as a hazard that has the potential risk to cause damage to property or serious harm, injury or casualty to people associated with construction, operation and maintenance and demolition of the project, as well as the public interfacing with and around these operations.

The Safety in Design risks on the project that have been identified to have an extreme or high-risk rating are summarised in

Table 5-2.

A complete register recording the SiDR assessment outcomes is attached in Appendix A.

Table 5-2: Safey in Design risks on the project with an extreme or high rating

Risk Area	Risk Description
Steep / Unstable slopes	Slips, falls, rolling equipment
Artesian conditions	Known high-pressure underground aquifer in the area. Could result in unexpected high-pressure water 'explosion'
Bank/Slope Instability	Piling and heavy lifting (craning) may be required in the vicinity of the riverbank.
Underground - Watermain	Known high-pressure underground watermain in the area. Could result in unexpected high-pressure water 'explosion'
Separation between adjacent moving plant/machinery	Tight site and benching will limit available space to undertake work and puts workers near moving plant
Confined spaces	Stormwater works require the installation of a long, large diameter culvert at a relatively deep level - this could create a confined space and may lead to high velocity, high volume flows resulting in scour failures
Post tensioned reinforced concrete	Risk of strand failure
Falling from height and/or falling objects	Building of bridges and walls will require working at height and could result in falls and or falling objects
Lifting / Cranes / Working under suspended loads	Bridge and wall construction will require lifting of large prefabricated elements
Live Public Traffic (Highway/ Pedestrian/Cycleway)	Site is very tight and may necessitate complicated temporary traffic arrangements during construction
Maintenance Access (e.g. for cleaning, removal / replacement of plant)	Site is very tight and may restrict access or necessitate difficult/unexpected access and egress points
Maintenance of landscaping	Maintenance of landscaping may necessitate working at height in difficult to access areas (e.g. above retaining walls)
Existing Hazards	The construction phase will require the demolition of the existing Melling Bridge across Hutt River (which is a concrete structure with piles that terminate in an aquifer)
Complex construction	If a single span 220m arch bridge option is chosen for the main river bridge this would require specialist design and construction expertise
Maintenance Traffic Management requirements	Maintenance repairs to damaged flexible barrier requires maintenance personnel to work near live traffic

5.4 Future workshop needs

No further workshops will be carried out during the Detailed Business Case phase. However, any subsequent detailed design, pre-implementation and construction phases will need to review the SiD register as the project progresses and carry out additional workshops.

6. Recommendations

6.1 Current SiDR Conclusion

The introduction of the legislation obligations for Clients, Project Managers, Designers, and Contractors under existing legislation has led to a formalisation of roles and responsibilities for projects.

Stantec has followed safe design procedures for the Business Case phase of this project.

Design risks have been identified and recorded for the project and mitigating actions are proposed. Design notes have been placed on the construction issue drawings where applicable to highlight the design intent to the construction teams.

All parties involved in the project are responsible for workplace health and safety management.

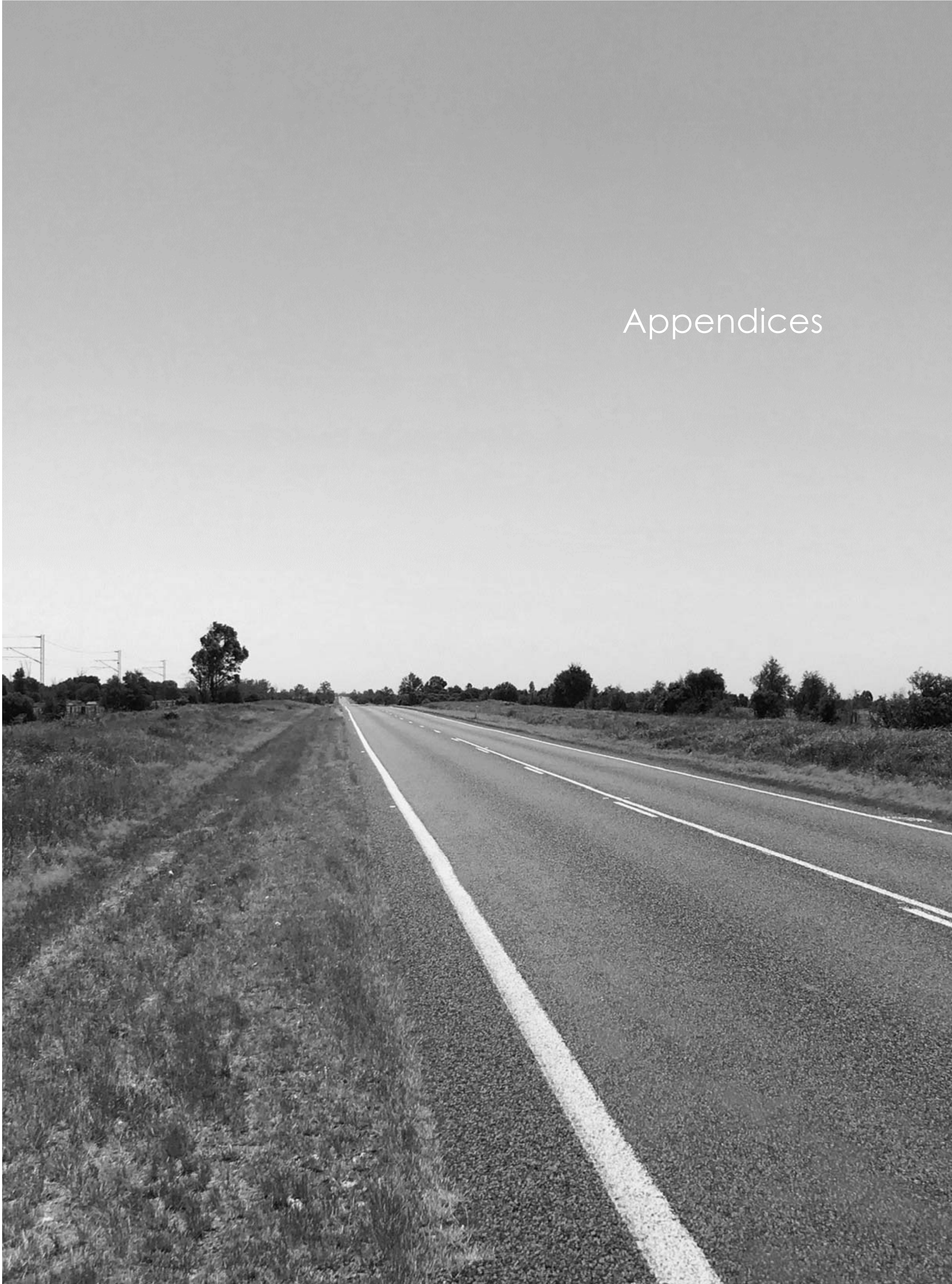
6.2 SiD for subsequent project phases

The detailed design team shall:

- Review and confirm the SiD factors identified as part of the Detailed Business Case phase.
- Identify other risk factors that may have arisen as a consequence of:
  - Further refinement of project
  - Changes to the scope of the project
  - Discussions/negotiations with stakeholders, etc.
- Assess the probability of occurrence of each of the risk factors now identified
- Delete previously identified risk factors which are no longer relevant. This may occur as a result of an event happening which makes the risk factor a constraint, or as a result of events being overcome by the passage of time, or as a result of the refined design eliminating the risk.
- Assign a likelihood of occurrence against each risk factor

In addition to on-going safety in design reviews, it is recommended that the project site be subject to a road safety audit to consider the issues relating to operational safety of the facility by all road users, including cyclists and pedestrians.

Appendices



Appendix A Safety in Design Register

Client Name	NZTA	Location	Wellington
Project Name	SH2 Melling Interchange	Date	Monday, June 17, 2019
Project Number	310201126	Project Component	All
SID Facilitator	Nick Gluyas	Design Stage	DBC

SID Review Team

Name	Company	Name	Company
Roger Burra	NZTA	Nick Gluyas	Stantec
Eddie Anand	NZTA	Keith Weale	Stantec
Dandan Huang	NZTA	Vinay Kumar	Stantec
Kirsten O'Donoghue	NZTA	Nigel Millar	Stantec
Andy Wright	Project Services Ltd	Seb Head	Stantec
Phil Peet	Stantec		

PRELIMINARY HAZARD IDENTIFICATION						RISK ASSESSMENT			PROPOSED MITIGATION		RESIDUAL RISK ASSESSMENT				HANDOVER			
Ref	Area / Activity	Hazard Category	Hazard Sub Category	Nature of hazard	Possible effect of hazard	Consequence	Likelihood	Assessed Risk	Proposed Treatment / Remedial Action	Hierarchy of Control	Consequence	Likelihood	Assessed Risk	Nature of Residual Risk	Phase Affected	Status	Remarks	Owner
1	General / Whole Site	Ground_Stability	Steep / Unstable Slopes	S ips falls rolling equipment	Broken limbs crush injuries	Catastrophic	Possible	H	Design to consider the angle of slopes and ensure steep slopes are either maintenance free (or have all protection mitigation - e g fencing)	Isolate	Moderate	Very Unlikely	L	Slip or fall would be limited due to designed (shallow) slope and fall protection mitigation	Maintenance	Active		
2	General / Whole Site	Working_Near_Water	Artesian Conditions	Known high pressure underground aquifer in the area Could result in unexpected high pressure water 'explosion'	Flying debris Broken limbs	Major	Likely	H	Geotechnical investigation to identify location and depth of aquifer design to consider pile construction technique (i e design for the potential breaching of the aquifer) Design to earn from past bridge pile construction in the area Construction safe work methodology to assume aquifer may be ruptured and pre-plan for that eventuality (e g have Plan B's prepared) Construction sequencing to start with piles on land and work towards the river	Isolate	Minor	Likely	M	Construction methodology will be based on an assumption that the aquifer will be ruptured with all required safety controls in place	Construction	Active		
3	General / Whole Site	Working_Near_Water	Flood Plains / Risk of Flooding	Hutt River and side valleys are known to flood	Instability drowning injury from dislodged material/plant etc	Catastrophic	Possible	H	Warning system is in place or Hutt River Flood Contractor to have weather monitoring and flood warning (side valleys) in place and a pre approved emergency plan for securing the works and eaving the site before the lood event occurs	Isolate	Moderate	Very Unlikely	L	Unsecured material or plant may cause damage to the works or 3rd party assets but should not harm individuals if they have been evacuated from site	Construction	Active		
4	General / Whole Site	Working_Near_Water	Bank/Slope Instability	Piling and heavy lifting (craning) may be required in the vicinity of the river bank	Instability toppling cranes crush injuries drowning	Catastrophic	Possible	H	Design to avoid placing cranes near the edge of the river bank (e g use a bigger crane from further away or use a different method) Where crane platforms cannot be avoided undertake appropriate temporary works design to engineer a stable platform	Control (Engineering)	Moderate	Very Unlikely	L	Little residual risk of topping assuming temporary works considers all uses and loading needs of the lifting platform (and the crane lifting capacity is not exceeded)	Construction	Active		
5	General / Whole Site	Working_Near_Water	Work over Water	Building a bridge over the Hutt River will necessitate working over water	Falling into the river drowning	Catastrophic	Unlikely	M	Contractor to adopt construction sequence (including suitable temporary works) that minimises the amount of working above water Design to maximise the use of pre fab elements to reduce the need to physically work over water Pre fab elements to maximise use of safety eatures (e g incorporated anchor points fitting of safety barriers before craning into place) Safe work method to be developed for working above water Emergency response plan (for falls into water) - e g recovery boat Personnel working above water to wear personal lotation device	Isolate	Moderate	Very Unlikely	L	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		

Client Name: NZTA
Project Name: SH2 Melling Interchange
Project Number: 310201126
SID Facilitator: [redacted] 9(2)(a)

Location: Wellington
Date: Monday, June 17, 2019
Project Component: All
Design Stage: DBC

SID Review Team

Name	Company	Name	Company
Roger Burra	NZTA	9(2)(a) [redacted]	Stantec
Eddie Anand	NZTA		Stantec
Dandan Huang	NZTA		Stantec
Kirsten O'Donoghue	NZTA		Stantec
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	Stantec		

6	General / Whole Site	Working_Conditions_or_Location	Seismic Activity	Site located on NZ main fault line	Collapse of works falls crush injuries	Catastrophic	Very Unlikely	M	Design (permanent and temporary works) to consider the impact of a design level earthquake during construction Construction work methods to consider the potential for an earthquake and include suitable controls emergency procedures etc	Control (Engineering)	Major	Very Unlikely	M	An earthquake event is impossible to predict or control Focus needs to be on managing the impact of any event through appropriate seismic design (permanent and temporary works) and ensuring construction methodologies consider the 'what if' scenario of an earthquake event	Construction	Active		
7	General / Whole Site	Existing_Services	Underground - Watermain	Known high pressure underground watermain in the area Could result in unexpected high pressure water 'explosion'	Flying debris Broken limbs	Major	Possible	H	Services investigation at detailed design stage to dentify location and depth of watermain design to consider relocation/isolation prior to construction works realigned watermain to be ocated in safe easily maintainable location (e g relatively shallow and clear of live traffic) construction methodology to include safe work method for working around the watermain (where required) - e g exclusion areas etc	Isolate	Minor	Unlikely	L	Residual risk largely managed	Construction	Active		
8	General / Whole Site	Existing_Services	Underground - Wastewater / Stormwater	Biological	Biological risk of coming into contact with untreated sewerage	Moderate	Possible	M	Services investigation at detailed design stage to dentify location and depth of sewer NZTA to discuss sewer location with Riverlink project to ascertain whether stop bank works will require the relocation of the sewer (which sits under the future stop bank alignment) If so NZTA should agree a suitable realignment with Riverlink that avoids both projects	Eliminate	Moderate	Very Unlikely	L	Residual risk largely managed as realigned service would be outside the impact area of the project	Construction	Active		
9	General / Whole Site	Proximity	Restricted Working Room / Access	Tight site and benching will limit available space to undertake work and puts workers in close proximity to moving plant	Hit/struck by moving plant	Catastrophic	Possible	H	Design to confirm (via constructability reviews) that there is at least one safe way of constructing the works given the tight working room (and communicate this methodology to contractors) Contractors to undertake detailed planning and sequencing of construction works ncluding haul routes equipment circulation traffic management planning pedestrian routes work exclusion zones and selecting plant that is suitable for the available work space Establish safe work methods for high risk activities such as reversing refuelling using technology (e g cameras slew locks etc) and spotters where appropriate	Control (Engineering)	Major	Unlikely	M	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		

Client Name	NZTA
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Dandan Huang	NZTA		Stantec
Kirsten O'Donoghue	NZTA		Stantec
[redacted] 9(2)(a)	Project Services Ltd		Stantec
	Stantec		

10	General / Whole Site	Proximity	Separation between adjacent moving plant/machinery	Tight site and benching will limit available space to undertake work and puts workers in close proximity to moving plant	Hit/struck by moving plant	Catastrophic	Possible	H	Undertake detailed planning and sequencing of construction works ncluding haul routes equipment circulation traffic management planning pedestrian routes work exclusion zones and selecting plant that is suitable for the available work space Establish safe work methods for high risk activities such as reversing refuelling using technology (e g cameras slew locks etc) and spotters where appropriate	Control (Engineering)	Major	Unlikely	M	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
11	General / Whole Site	Confined_Spaces	Excavations / Tunnels / Trenches	Trench collapse during construction	Asphyxiation drowning	Catastrophic	Possible	H	Design to consider space required (working room) to nstall trench shields and where this is not possible/practical consider trenchless methods (e g pipe jacking)	Isolate	Moderate	Very Unlikely	L	Potential for collapse mitigated where shields are employed	Construction	Active		
12	General / Whole Site	Confined_Spaces	Manholes	Stormwater works require the installation of a long large diameter culvert at a relatively deep level	Asphyxiation drowning	Catastrophic	Possible	H	ocked manholes to restrict access to planned events with appropriate equipment Manholes to exclude rungs so A-Frames are needed along with appropriate breathing apparatus Manholes to be ocated in berm areas and not in live traffic lanes	Isolate	Moderate	Very Unlikely	L	Potential for asphyxiation/drowning mitigated by planned access	Maintenance	Active		
13	General / Whole Site	Confined_Spaces	Pipes	Stormwater works require the installation of a long large diameter culvert at a relatively deep level - this could create a confined space and may lead to high velocity high volume flows resulting in scour failures	Asphyxiation drowning collapse	Catastrophic	Possible	H	Design to consider staged construction of the new culvert Design to also consider likely storm event lows (and velocities) potential for scour and the value of providing a stilling/detention basin within the system Access nto the new system to be restricted to planned activities Appropriate venting to be provided where this is helpful Design to consider upgrade to ntake on Harbour View Road and the outflow into the river corridor to improve evel of service reduce maintenance intervals and mprove security	Isolate	Moderate	Very Unlikely	L	Potential for asphyxiation/drowning mitigated by planned access	Maintenance	Active		
14	General / Whole Site	Hazardous_Construction	Temporary works (e g propping jacking bracing)	Potential collapse during construction	Crush injuries	Catastrophic	Possible	H	Undertake appropriate design for all temporary works giving consideration to all potential loading situations (e g including wind and seismic)	Control (Engineering)	Moderate	Very Unlikely	L	Residual risk largely managed assuming temporary works design is adequate	Construction	Active		
15	General / Whole Site	Hazardous_Construction	Heavy lifting	Dropped loads toppled cranes	Crush injuries	Catastrophic	Possible	H	Undertake appropriate design for all lifting works giving consideration to all potential loading situations (e g including wind and seismic) Ensure appropriate exclusion zones are used under loads	Control (Engineering)	Moderate	Very Unlikely	L	Residual risk largely managed assuming lift planning is adequate	Construction	Active		
16	General / Whole Site	Hazardous_Construction	Pressure systems (e g concrete pumping)	Pressure hose failures	Flying debris Broken limbs	Catastrophic	Possible	H	Plan all pumping activities and use appropriate safe work methods Ensure all pumping equipment (pipes pumps connections) are well maintained	Control (Engineering)	Moderate	Very Unlikely	L	If pumping equipment is well maintained and appropriate safe working methods adopted then the residual risk is minimal	Construction	Active		

Client Name	NZTA	Location	Wellington
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SID Facilitator	9(2)(a) [redacted]	Design Stage	DBC

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9(2)(a) [redacted]	Project Services Ltd		Stantec
	Stantec		

17	General / Whole Site	Hazardous_Construction	Working around mobile plant	Tight site and benching will limit available space to undertake work and puts workers in close proximity to moving plant	Hit/struck by moving plant	Catastrophic	Possible	H	Undertake detailed planning and sequencing of construction works ncluding haul routes equipment circulation traffic management planning pedestrian routes work exclusion zones and selecting plant that is suitable for the available work space Establish safe work methods for high risk activities such as reversing refuelling using technology (e g cameras slew locks etc) and spotters where appropriate	Control (Engineering)	Major	Unlikely	M	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
18	General / Whole Site	Hazardous_Construction	Post tensioned reinforced concrete	Risk of strand failure	Flying debris Broken limbs decapitation amputation	Catastrophic	Possible	H	Plan all post tensioning activities and use appropriate safe work methods (e g exclusion zones)	Control (Engineering)	Major	Unlikely	M	If jacking equipment is well maintained and appropriate safe working methods adopted then the residual risk is minimal				
19	General / Whole Site	Hazardous_Construction	Construction programming / sequencing	Tight site and benching will limit available space to undertake work and puts workers in close proximity to moving plant	Hit/struck by moving plant	Catastrophic	Possible	H	Undertake detailed planning and sequencing of construction works ncluding haul routes equipment circulation traffic management planning pedestrian routes work exclusion zones and selecting plant that is suitable for the available work space	Control (Engineering)	Major	Unlikely	M	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
20	General / Whole Site	Working_at_Height	Falling Objects	Building of bridges and walls will require working at height and could result in falling objects	Hit/struck by falling object	Major	Possible	H	Ensure appropriate exclusion zones under working at height activities and fall/drop protection is used where required (e g netting etc)	Isolate	Minor	Unlikely	L	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
21	General / Whole Site	Working_at_Height	Lifting / Cranes / Working under suspended loads	Bridge and wall construction will require lifting of large prefabricated elements	Hit/struck by falling object	Catastrophic	Possible	H	Undertake appropriate design for all lifting works giving consideration to all potential loading situations (e g including wind and seismic) Ensure appropriate exclusion zones are used under loads	Isolate	Minor	Unlikely	L	Residual risk largely managed assuming lift planning is adequate	Construction	Active		
22	General / Whole Site	Working_at_Height	Falling from height	Bridge and wall construction will require working at height	Falls from height	Catastrophic	Possible	H	Contractor to adopt construction sequence (including suitable temporary works) that minimises the amount of working at height Design to maximise the use of pre ab elements to reduce the need to physically work at height Pre fab elements to maximise use of safety eatures (e g incorporated anchor points fitting of safety barriers before craning into place) Safe work method to be developed for working at height Personnel working at height to be suitably trained and wear fall restraints Emergency procedure to be developed and in place for recovery of anyone that alls in a restraint	Control (Engineering)	Moderate	Very Unlikely	L	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		

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SID Review Team

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23	General / Whole Site	Working_at_Height	Rope / Harness Work	Bridge construction may require rope and harness work	Falls from height	Catastrophic	Possible	H	Contractor to adopt construction sequence (including suitable temporary works) that minimises the amount of working at height Design to incorporate of safety eatures (e g integrated anchor points) for harness/rope work where this is unavoidable Safe work method to be developed for rope/harness work Personnel undertaking ropework to suitably trained and wearing fall restraints Emergency procedure to be developed and in place or recovery of anyone that alls in a restraint	Control (Engineering)	Moderate	Very Unlikely	L	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
24	General / Whole Site	Access_and_Traffic	Access and Egress from Site or Adjacent Properties	Site is very tight and may restrict access or necessitate difficult access and egress points	Traffic crashes due to unexpected movements	Major	Possible	H	Undertake detailed planning and sequencing of works for all site access points (SAPs) including haul routes equipment circulation traffic management planning worker pedestrian routes work exclusion zones and selecting plant that is suitable for the available work space Ensure access to private properties is clear and unambiguous	Control (Engineering)	Major	Unlikely	M	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
25	General / Whole Site	Access_and_Traffic	Traffic Management Requirements	Site is very tight and may necessitate complicated temporary traffic access and haul road arrangements	Traffic crashes	Major	Possible	H	As above Undertake detailed planning and sequencing of construction works including temporary traffic management planning suitable for the available work space	Control (Engineering)	Major	Unlikely	M	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
26	General / Whole Site	External_Interfaces	Live Public Traffic (Highway / Pedestrian / Cycleway)	Site is very tight and may necessitate complicated temporary traffic arrangements	Traffic crashes	Major	Possible	H	As above Undertake detailed planning and sequencing of construction works including temporary traffic management planning suitable for the available work space and the modes (e g inc peds and cyclists) that need to transition through the site	Control (Engineering)	Major	Unlikely	M	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
27	General / Whole Site	External_Interfaces	Live Rail	Construction requires the relocation of the train station and shortening of to line This may necessitate working alongside live rail operations	Struck by train derailment	Catastrophic	Possible	H	Undertake detailed planning and sequencing of construction works ncluding specific controls or working around/near the rail corridor Ensure adequate work space is reserved for all activities and all passing traffic (e g nc peds and cyclists) that need to transition through the site Designer to engage with KiwiRail to agree clearance envelopes and negotiate close of line periods for critical activities (i e eliminate the hazard if possible)	Control (Engineering)	Catastrophic	Unlikely	M	Train movements will still exist (i e the hazard will still exist) if a block of line cannot be agreed with KiwiRail however adequate controls and safe work methods are likely to be possible for the construction to progress in a safe manner (with live rail traffic) for all but the most critical rail corridor works (e g installation of new points cross overs ballast etc)	Construction	Active		
28	General / Whole Site	Design_Related	Unusual loadings (e g dynamic)	Bridge wall and culvert construction will require lifting of large prefabricated elements	Hit/struck by falling object	Catastrophic	Possible	H	Undertake appropriate design for all lifting works giving consideration to all potential loading situations (e g including dynamic wind and seismic) Ensure appropriate exclusion zones are used under loads	Isolate	Minor	Unlikely	L	Residual risk largely managed assuming lift planning is adequate	Construction	Active		

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29	General / Whole Site	Design_Related	Safety critical design sequencing	Tight site and benching will limit available space to undertake work and puts workers in close proximity to moving plant	Hit/struck by moving plant	Catastrophic	Possible	H	Undertake detailed planning and sequencing of construction works ncluding haul routes equipment circulation traffic management planning pedestrian routes work exclusion zones and selecting plant that is suitable for the available work space	Control (Engineering)	Major	Unlikely	M	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
30	General / Whole Site	Design_Related	Creation of Confined Spaces	Stormwater works require the installation of a long large diameter culvert at a relatively deep level (including deep manhole access points)	Asphyxiation drowning	Catastrophic	Possible	H	Design to consider access nto the culvert i e restrict unplanned access) and provide appropriate venting where this is helpful Design to consider locked manholes to restrict access to planned events with appropriate equipment Manholes to exclude rungs so A-Frames are needed along with appropriate breathing apparatus	Isolate	Moderate	Very Unlikely	L	Potential for asphyxiation/drowning largely mitigated by isolating hazard and restricting access	Maintenance	Active		
31	General / Whole Site	Design_Related	Heavy / Awkward Prefabricated Elements	Bridge wall and culvert construction will require lifting of large prefabricated elements	Hit/struck by falling object crush injuries	Catastrophic	Possible	H	Undertake appropriate design for all lifting works giving consideration to all potential loading situations (e g including dynamic wind and seismic) Ensure appropriate exclusion zones are used under and adjacent to loads	Isolate	Minor	Unlikely	L	Residual risk largely managed assuming lift planning is adequate	Construction	Active		
32	General / Whole Site	Maintenance_Refurbishment_Repair	Maintenance Access (e g for cleaning removal / replacement of plant)	Site is very tight and may restrict access or necessitate difficult/unexpected access and egress points	Traffic crashes due to unexpected movements	Major	Possible	H	Ensure final design includes access arrangements for a l uture routine (regular planned and periodic) maintenance activities and that maintenance SAPs and parking bays are located in ogical areas allow for the type and size of plant requiring access and can be accessed in a way that does not pose a hazard to passing traffic	Isolate	Moderate	Very Unlikely	L	Risk remains if there is failure to provide (design) for the maintenance access required and/or the maintenance accesses are not used/controlled in ine with the planned work methods	Maintenance	Active		
33	General / Whole Site	Maintenance_Refurbishment_Repair	Lighting (e g bulb replacement)	Lighting maintenance may necessitate working at height in difficult to access areas (e g above the bridge parapet over the Hutt River)	Falls from height dropped objects	Catastrophic	Possible	H	Designer to consider how bulbs will be maintained (e g use of scissor poles that allow bulbs to be brought to the ground and/or lights ntegrated into hand rails) and utilise LED bulbs that have long maintenance ntervals For design elements that cannot avoid maintenance at height then the designer should consider incorporating maintenance needs into the permanent works (e g anchor points etc) Maintenance activities that require working at height should be undertaken under an approved safe work method Personnel working at height should be suitably trained and wear all restraints (with an emergency recovery plan or anyone that falls in a restraint)	Control (Engineering)	Moderate	Very Unlikely	L	Risk remains if there is failure to adopt controls and follow planned work methods	Maintenance	Active		

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34	General / Whole Site	Landscaping	Maintenance of landscaping	Maintenance of landscaping may necessitate working at height in difficult to access areas (e g above retaining walls)	Falls from height dropped objects	Catastrophic	Possible	H	Designer to consider how andscape will be maintained (e g use of appropriate landscaping or various scenarios (e g hard no maintenance andscaping on steep slopes low maintenance shrubs and ground cover on moderate slopes grasses restricted to flat areas that are easy and safe to access) Design to ncorporate safety elements nto the permanent works where maintenance activities at height cannot be avoided (e g fall anchor points fall fencing at the top of retaining walls to protecting drop offs) Maintenance activities that require working at height should be undertaken under an approved safe work method Personnel working at height should be suitably trained and wear all restraints (with an emergency recovery plan or anyone that falls in a restraint)	Control (Engineering)	Moderate	Very Unlikely	L	Risk remains if there is failure to adopt controls and follow planned work methods	Maintenance	Active		
35	General / Whole Site	Demolition	Existing Hazards	The construction phase will require the demolition of the existing Melling Bridge across Hutt River (which is a concrete structure with piles that terminate in an aquifer)	Hit/struck by falling object crush injuries struck by debris	Major	Possible	H	Undertake detailed planning and sequencing of the demolition works ncluding specific controls or working around/near the demolition area Ensure adequate work space and exclusion zones are reserved for all activities and all passing traffic (e g nc peds and cyclists) that need to transition through the site Designer to undertake adequate temporary works design (e g temporary works/propping) Contractor to develop safe work methods and use appropriate plant to allow the demolition to progress in a safe manner	Isolate	Moderate	Very Unlikely	L	The unpredictability of demolition will still exist (i e the hazard) however adequate design (e g temporary works/propping) demolition controls (exclusion zones) safe work methods and appropriate plant are available to allow the demolition to progress in a safe manner	Demolition	Active		
36	General / Whole Site	Demolition	Future Hazards	The construction of the new river bridge interchange bridge and retaining walls has the potential to introduce new infrastructure that is difficult to deconstruct in the future (e g post tensioned elements)	Hit/struck by falling objects crush injuries struck by debris	Major	Possible	H	The detailed design phase should consider the future demolition hazards of the structures being designed/built Where the potential demolition of the uture structure is deemed to create a unique or difficult demo ition challenge then the designer should consider the specific conditions (and controls) that would be required to safely demolish the infrastructure For example that there is adequate work space exclusion zones temporary work methods (e g propping options) safe work methods and appropriate plant to allow the demolition to progress in a safe manner	Isolate	Moderate	Unlikely	M	The unpredictability of future demolition will still exist (i e the hazard) however adequate consideration of demolition during the design of that infrastructure would allow demolition to progress in a safe manner	Demolition	Active		

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37	Bridges	Maintenance_Refurbishment_Repair	Maintenance Access (e g for cleaning removal / replacement of plant)	Both bridges (especially any single span arch option chosen for the river crossing) will require routine inspection and maintenance which may necessitate working at height	Falls from height	Catastrophic	Possible	H	Maintenance Contractor to adopt safe work method for nspections and regular maintenance (including suitable temporary works) Design to maximise the use of pre fab elements that maximise use of safety eatures (e g incorporated anchor points fitting of safety barriers for maintenance activities) Safe work method to be developed for working at height Personnel working at height to be suitably trained and wear fall restraints Emergency procedure to be developed and in place for recovery of anyone that alls in a restraint	Control (Engineering)	Moderate	Very Unlikely	L	Risk remains if there is failure to adopt controls and follow planned work methods	Maintenance	Active		
38	Bridges	Competence	Complex construction	If a single span 220m arch bridge option is chosen for the main river bridge this would require specialist design and construction expertise	Incomplete design detailing in combination with an inexperienced construction contractor could result in unforeseen H&S risks i e 'you don't know what you don't know')	Catastrophic	Possible	H	Client to ensure that should a unique complex bridge solution be adopted (e g single span arch) that suitably experienced designers and contractors amiliar with the type bridge being built are utilised on the project and that suitable H&S controls are put in place	Control (Engineering)	Moderate	Unlikely	M	Risk remains if there is failure to adopt controls and utilise expertise familiar with the infrastructure being designed/built	Construction	Active		
39	Bridges	Utility Services	Maintenance Access	The existing Melling Bridge carries a number of uti ity services Any new bridge will need to incorporate the relocation of these services which will require maintenance This may create confined spaces or necessitate working at height	Asphyxiation drowning falls from height	Catastrophic	Possible	H	Services design to consider maintenance requirements and eliminate hazards where possible Where high risk activities cannot be avoided (confined spaces working at height etc) then safe work methods/processes to be put in place and uncontrolled/unplanned access restricted	Isolate	Moderate	Unlikely	M	Risk remains if services design cannot eliminate maintenance risks and/or there is failure to adopt the prescribed controls	Maintenance	Active		
40	River Bridge	Maintenance_Refurbishment_Repair	Maintenance Access (e g for cleaning removal / replacement of plant)	The bridge across the river will require maintenance (bearing replacement painting joint replacement scour protection etc) This may necessitate working in confined spaces working at height working in difficult to access locations or working with hazardous materials	Asphyxiation drowning falls from height toxicity crush injuries	Catastrophic	Possible	H	Design to consider maintenance requirements and eliminate hazards where possible - e g eliminate bearings and oints where possible/practical provide safe jacking points where bearings are needed design scour protection that avoids the need for diving nspections use non toxic materials provide flat areas where scaffold platforms/cherry pickers are required for access Where high risk activities cannot be avoided (confined spaces working at height etc) then safe work methods/processes/training to be provided	Isolate	Moderate	Unlikely	M	Risk remains if design does not eliminate maintenance risks and/or there is failure to adopt the prescribed controls	Maintenance	Active		

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41	Interchange Bridge	Working_at_Height	Falling from height	Bridge construction may require working at height possibly above live traffic	Falls from height struck by vehicle	Catastrophic	Possible	H	Design to restrict nterchange span to less than 35m to allow the construction of a single span (Super Tee or Steel) bridge avoiding the need to construct a central reserve bridge pier Contractor to adopt construction sequence (including suitable temporary works) that minimises the amount of working at height Design to maximise the use of pre ab elements to reduce the need to physically work at height Pre fab elements to maximise use of safety eatures (e g incorporated anchor points fitting of safety barriers before craning into place) Safe work method to be developed for working at height Personnel working at height to be suitably trained and wear fall restraints Emergency procedure to be developed and in place for recovery of anyone that alls in a restraint Exclusion zones to be provided below all heavy lifts and underneath all working at height activities	Control (Engineering)	Moderate	Very Unlikely	L	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
42	Retaining Walls	Working_at_Height	Falling from height	Wall construction may require working at height possibly adjacent to traffic	Falls from height struck by vehicle	Catastrophic	Possible	H	Design to consider wall construction methodologies that are based on 'top down' or 'bottom up from behind the wall' construction strategies where falls from height are protected or minimised Contractor to adopt construction sequence (including suitable temporary works) that minimises the amount of working at height Design to maximise the use of pre ab elements to reduce the need to physically work at height Pre fab elements to maximise use of safety eatures (e g incorporated anchor points fitting of safety barriers before craning into place) Safe work method to be developed for working at height Personnel working at height to be suitably trained and wear fall restraints Emergency procedure to be developed and in place for recovery of anyone that alls in a restraint Exclusion zones to be provided below all heavy lifts and underneath all working at height activities	Control (Engineering)	Moderate	Very Unlikely	L	Risk remains if there is failure to adopt controls and follow planned work methods	Construction	Active		
43	Central Reserve Safety Barrier	Access_and_Traffic	Traffic Management Requirements	Maintenance repairs to damaged flexible barrier requires maintenance personnel to work near live traffic	Struck by passing vehicle	Catastrophic	Possible	H	Design to consider (and balance) the merits of using rigid (concrete) barriers in ocations where the cross section is narrow and maintenance access will be difficult (e g under the nterchange bridge) Where flexible barriers are used then a safe repair methodology should be developed (pre-planned) such that it is ready when routine or emergency repairs are required	Substitute	Moderate	Very Unlikely	L	Risk remains if barrier is installed that requires maintenance and there is failure to adopt safe TTM controls	Maintenance	Active		
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