**REPORT**

Tonkin+Taylor

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## Executive summary

This hydrogeological assessment evaluates the potential temporary and permanent groundwater related effects associated with the construction and future operation of the State Highway 1 North Canterbury – Woodend Bypass Project, an 11 km, four-lane grade-separated motorway extension from Belfast to Pegasus. This report sets out the hydrogeological assessment used to provide technical support to the SAR for the applications made by NZTA under the Fast-track Approvals Act 2024 (FTAA). The assessment assesses potential changes in groundwater levels, flow and quality that may affect groundwater receptors such as surface waters, wetlands and groundwater users.

The hydrogeological setting for the Project is characterised by shallow groundwater (typically within 2 m ground surface) of the predominantly Coastal Confined Gravel Aquifer defined in the Canterbury Land and Water Regional Plan (CLWRP).

The shallow groundwater aquifer is the main focus of the assessment. A sequence of confined aquifers underlie the shallow groundwater system. Shallow groundwater is likely to be hydraulically connected to this underlying deeper aquifer where confining layers (e.g. silt stratum) are thin and allow leakage between the two aquifers. Kaiapoi and Cam River/Ruataniwha are tidally influenced at the SH1 crossings and both Waihora and Taranaki Streams have losing reaches. The Quarry Lakes are directly connected with shallow groundwater and lake levels are maintained by groundwater throughflow. A number of wetlands are present within and near the Project Site.

There are many construction activities that have the potential to intercept groundwater. These include excavations for culverts, stormwater systems, utilities and shallow foundations. Some of these activities will require dewatering to allow construction and this will result in temporary localised changes in groundwater levels. Ground improvements will penetrate shallow groundwater and, in some places, the deeper semi-confined to confined aquifers and may cause overall changes to groundwater flow, level and quality. Changes to groundwater may also occur as a result of the Quarry Lake infilling, and proposed surface water take for construction purposes.

While the design is well advanced in terms of bulk and location, detailed design is ongoing. A conservative approach has been adopted in the assessment of groundwater related effects to allow for minor changes in design and construction approach. As site specific data on seasonal groundwater level variation is not yet available, the assessment has adopted a shallow groundwater level representative of winter conditions. Other examples of the conservative approach include assumption that earthworks may occur up to the designation boundary (unlikely in the majority of locations), and the adoption of a broad range of hydrogeological parameters.

The assessment has considered all possible groundwater related impacts of the Project, concluding that most present negligible effect on groundwater receptors. Temporary and permanent groundwater related effects on wetlands will result, and mitigation and offset recommendations to address these effects are provided in the Ecological Impact Assessment (Volume 3I).

Groundwater drawdown effects from dewatering for culvert installations near streams will be managed by discharge of dewatering back to the surface waters. Standard controls to manage turbidity effects in the discharge will be required.

At specific locations where piling and/or ground improvements are proposed temporary effects including the mixing of aquifers and impacts on groundwater quality may occur. These effects will be very localised and impacts to surface waters, wetlands and bore users is assessed as low/negligible.

The construction works include excavation at the Gladstone landfill.. The potential effects on groundwater receptors if excavation and dewatering were to occur will  pose a low level of effect

and controls will be provided in the Groundwater Management Plan (GMP) to manage disposal of dewatering discharge.

The construction storage areas (CSA) at Lineside interchange are within a community Drinking Water Protection Zone (cDWPZ) and appropriate environmental management controls will be put in place to control certain activities such as the storage of hazardous construction materials.

Permanent effects are assessed to be mostly negligible. Residual effects at a low scale of effect will remain on groundwater (mixing of aquifers) where ground improvements comprising stone columns exist at Williams Street interchange and Woodend Beach Road. These effects will be very localised and have a negligible effect on groundwater receptors.

Mitigation, management and monitoring requirements for groundwater related activities are proposed to be included in the Groundwater Management Plan; these are broadly standard controls and procedures similar to other infrastructure projects.

# Acronyms, terms and abbreviations

## Works definitions

| Acronym/Term | Description |
|---|---|
| **Early Works** | The Kaiapoi Bridge strengthening and quarry lakes partial reclamation authorised under CRC260612, CRC230304, CRC230305, CRC230306, CRC230307 and RC255072. |
| **Construction Works** | Those works necessary to construct and establish the Project, including:<br>• Bulk earthworks (including cut and fill activities);<br>• Ground improvement works;<br>• Establishment of bridges, culverts, drainage, stormwater treatment and disposal systems, noise mitigation features, and other structures;<br>• Temporary construction yards, buildings, and laydown areas;<br>• Temporary haul roads, access points, and traffic management;<br>• Temporary drainage and erosion and sediment control measures;<br>• Landscaping and planting;<br>• Pavements and surfacing;<br>• Road furniture and ancillary works; and<br>• Site reinstatement and rehabilitation activities. |
| **Operations and Maintenance Activities** | Those activities needed to ensure the completed Construction Works function effectively and safely on an ongoing basis. |

## General

| Acronym/Term | Description |
|---|---|
| **bgl** | Below Ground Level |
| **cDWPZ** | Community Drinking Water Protection Zone |
| **Designation** | As the context requires:-<br>• Existing: The designation for the Project and State Highway 1 in an operative version of the Waimakariri District Plan.<br>• Proposed: The existing designation inclusive of the alterations sought by the NZTA shown in Volume 2C (conditions) and Volume 4D (boundaries) of the SAR. |
| **ECan** | Environment Canterbury (Canterbury Regional Council) |
| **EcIA** | Ecological Impact Assessment |
| **GAZ** | Groundwater Allocation Zone |
| **km** | Kilometre |
| **L/s** | Litres per second |
| **LiDAR** | Light Detection and Ranging |
| **CLWRP** | Canterbury Land and Water Regional Plan (March 2025 version) |
| **FTAA** | Fast-track Approvals Act 2024 |
| **m** | Metre |
| **m RL** | Metres reduced level, levels reported in terms of NZVD 2016 |
| **NES-F** | Resource Management (National Environmental Standards for Freshwater) Regulations 2020 |
| **NPS-FM** | National Policy Statement for Freshwater Management 2020 (Amended January 2024) |

| Acronym/Term | Description |
|---|---|
| **NZGD** | New Zealand Geotechnical Database |
| **NZTA** | New Zealand Transport Agency Waka Kotahi |
| **NZVD 2016** | New Zealand Vertical Datum |
| **Project** | State Highway 1 Belfast to Pegasus Motorway and Woodend Bypass (the construction, operation, and maintenance thereof) |
| **Project Site (or Site)** | The land contained within the area delineated as "Project Site" in Volume 4C of the SAR |
| **RMA** | Resource Management Act 1991 |
| **SAR** | Substantive Application Report |
| **SH1** | State Highway 1 |
| **WDC** | Waimakariri District Council |

## Management Plans

| Acronym | Full management plan name |
|---|---|
| **CSMP** | Contaminated Sites Management Plan |
| **ESCMP** | Erosion and Sediment Control Management Plan |
| **GMP** | Groundwater Management Plan |

# 1 Introduction

## 1.1 Project overview

The New Zealand Transport Agency Waka Kotahi (**NZTA**) proposes to construct, operate, and maintain the State Highway 1 North Canterbury – Woodend Bypass Project (Belfast to Pegasus) (the **Project**). The Project will extend the State Highway 1 (**SH1**) Christchurch Northern Corridor between Belfast and Pegasus and spans a linear length of approximately 11 kilometres (**km**), commencing from approximately 600 metres (**m**) south of the Kaiapoi River Bridge and ending approximately 700 m north of the Pegasus/Ravenwood intersection. The Project includes upgrades to approximately 4 km of the existing SH1 and a new approximately 7 km bypass of Woodend township. Key features of the Project are shown in Figure 1.1.

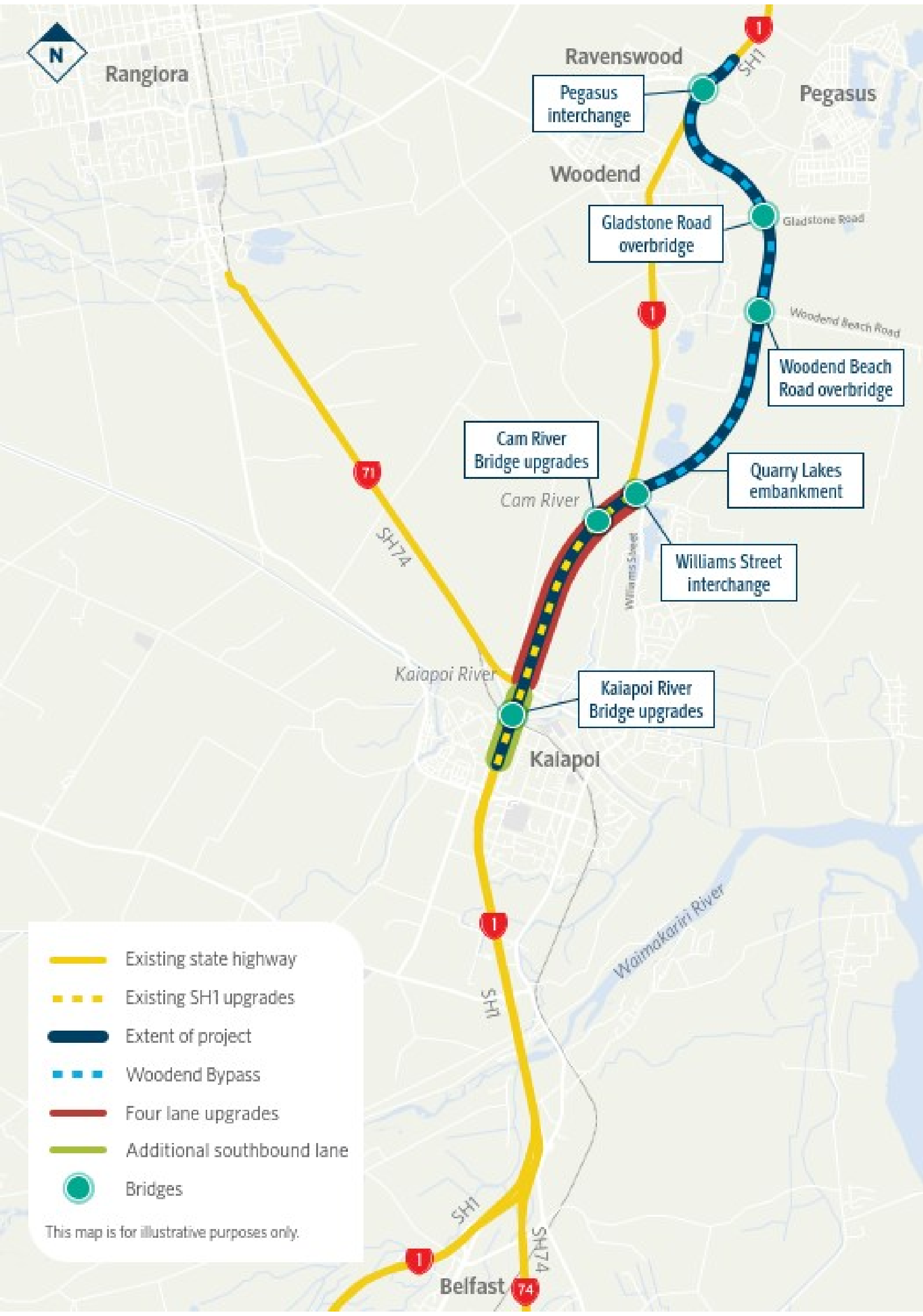


*Figure 1.1: Project Site and key works activity location.*

A comprehensive background and description of the Project is contained in the Substantive Application Report (Volume 2A) (SAR).

This report sets out the hydrogeological assessment used to provide technical support to the SAR for the applications made by NZTA under the Fast-track Approvals Act 2024 (FTAA).

While this is not a matter before the Environment Court, the authors of this report have each read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2023 ('Code'). The authors have each complied with the Code in the preparation of this report.

The data, information, facts and assumptions the authors have each considered as part of this report are set out in this report. The reasons for the conclusions of the report are also set out in this report. Unless stated otherwise, this report is within each of the authors' expertise and the authors have not omitted to consider material facts known to them that might alter or detract from the opinions expressed.

## 1.1 Purpose and content of this hydrogeological technical assessment

The purpose of this report is to assess the potential environmental effects of the Project on the groundwater regime. The Project area is located on relatively low-lying land with shallow groundwater. The bulk of the proposed works are above ground, raised on embankment and will not intercept groundwater. There will be specific construction activities such as shallow excavations for culverts and bridge foundations that will intercept the shallow unconfined groundwater. At some locations, deeper ground improvements could reach the deeper semi-confined and confined groundwater. Activities such as localised dewatering, excavations close to the groundwater table, infilling an artificial lake and piling have the potential to affect the groundwater regime. This hydrogeology assessment considers the effects on groundwater as well as surrounding groundwater user and surface waters; rivers, streams and wetlands.

The report provides the following content:

- Overview of the proposed activities at each new structure (main Project components), and site wide activities, where groundwater may be and/or will be encountered.
- Description of the environmental setting of the Project including an overview of the geology, hydrogeology and hydrology.
- Development of a hydrogeological conceptual model at key locations based on published literature and currently available data which is used to identify the groundwater regime including flow direction, water level and water quality.
- Identification of wetlands, groundwater users including community drinking water protection zones (cDWPZ) and surface waters where groundwater inflows support baseflows.
- Assessment of the activities at each new structure (and across the Project) in relation to shallow groundwater and how the activities have the potential to result in environmental effects from:
  - Temporary changes from the construction works.
  - Permanent changes from the road operation.
  - Provide recommendations for mitigation, management and monitoring.

This report relies on and uses information from assessments completed during the 2013-2015 designation process to identify and characterise the hydrogeological setting and the groundwater and surface water iterations. This report is also based on extensive investigations supporting the 30 % design phase including geotechnical and hydrogeological investigations along the alignment.

In addition, this report cross references other assessments included in Construction Methodology Statement (Volume 3A), Ecological Impact Assessment (Volume 3I) and the Stormwater and Flooding Assessment (Volume 3L).

## 1.2 Structure of this report

This technical assessment has been set out to provide a Project-wide overview of the proposed activity (Section 2). It subsequently identifies the key activities associated with the Project and describes how these activities could alter the existing groundwater environment (Section 3). A regional and local environmental setting is provided (Section 3).

The subsequent sections (Section 7 to 13) of the report cover each Project component as described in Section 2 with regard to the:

- Proposed activities.
- Environmental setting.
- Conceptual hydrogeological understanding.
- Assessment of effects on the environment including recommendations for mitigation.
- Summary and conclusion.

The report concludes with mitigation and management measures to ensure appropriate controls and management are in place for the proposed activity.

## 1.3 Limitations

Recommendations and opinions in this report are based on data from site investigations including groundwater level monitoring data.. The nature and continuity of subsoil away from the test locations are inferred and it must be appreciated that actual conditions could vary from the assumed model.

This report has been prepared on the basis of information provided by NZTA and others (not directly contracted by Tonkin & Taylor Ltd (T+T) for the work), including Environment Canterbury. T+T has not independently verified the provided information and has relied upon it being accurate and sufficient for use in preparing this report.

# 2 Description of proposed activity

The Project comprises a number of components. These activities are covered in the three sections, described below. Only detail relating to the hydrogeology effects is included. For a more comprehensive description for each Project component, these can be found in the SAR.

## 2.1 Project wide activities

Project wide activities relate to the general activities that occur along the entire alignment, either at frequent intervals or are those activities not tied to and covered in the specific Project components.

The Project wide activities that relate to groundwater include:

- Temporary construction yards and facilities.
- Stormwater infrastructure - swales, drains, culverts and stormwater detention and treatment facilities (not covered by below items).
- Shallow excavations for utilities, services, road features and street furniture.
- Decommissioning of existing bores within the designation.
- Water take for construction use e.g. dust suppression.

An overall summary of these activities is provided in Section 3.

## 2.2 Existing SH1 Upgrades

Upgrade of SH1 from approximately 600 m south of Kaiapoi River Bridge to the Cam River/Ruataniwha (a total distance of approximately 4 km), including:

- Additional southbound lane – Between approximately 600 m south of the Kaiapoi River Bridge to the bridge itself. Note: The southbound lane extends beyond the Project Site to approximately 200 m south of the Ohoka Road Overpass, but these works are beyond the scope of the Project.
- Kaiapoi River Bridge upgrades – Seismic strengthening and widening to provide additional southbound lane.
- Four-lane upgrades – Upgrade the SH1 carriageway from two lanes to four lanes from Lineside Road Overpass to the Cam River/Ruataniwha.

This section comprises widening of the existing SH1 at existing ground levels with minor excavation to remove topsoil. There are limited construction activities where groundwater is expected, these include:

- Installation of two culverts (ID:001-002) to replace existing culverts on SH1. Excavation into shallow groundwater and dewatering will be required to allow online installation.
- Stormwater treatment swales which extend each side, but within the road footprint/ alignment.
- Cut-off drains which extend each side and outside of the alignment.
- Other minor excavations may be required for installation of utilities.

The activities at Kaiapoi Bridge comprise the additional deck slab and associated surfacing and barriers with no inground works, therefore no assessment on groundwater effects is required.

## 2.3 Woodend Bypass

A new four-lane motorway, bypassing Woodend township from the Cam River/Ruataniwha to approximately 700 m north of the Pegasus/Ravenwood intersection (approximately 7 km), including:

- Cam River Bridge upgrades – A new bridge to the east of the current bridge (SH1 and southbound on ramp). These works integrate with the Williams Street interchange.
- Williams Street interchange – A new interchange and SH1 overbridge at the existing intersection of Williams Street and SH1.
- Quarry Lakes embankment and southern remnant lake infilling - A new tiered embankment through two artificial lakes (formed through quarrying), including dynamic compaction. The southern remnant lake created by the causeway will be filled and a wetland constructed in this area. Note: The initial (partial) reclamation is part of the Early Works consenting package.
- Woodend Beach Road overbridge – A new local road bridge over SH1, including a realignment of and upgrades to Woodend Beach Road.
- Gladstone Road overbridge – A new local road bridge over SH1, including upgrades to Gladstone Road.
- Pegasus interchange – Remove existing roundabout at the intersection of SH1 / Pegasus Boulevard / Bob Robertson Drive and replace with a new grade-separated diamond interchange overpass, including traffic signals and local road upgrades including connection of Garlick Street to SH1.

This 7 km section comprises construction of a new SH1 on a raised embankment with generally minor excavation to remove topsoil. Construction activities include:

- New bridge at Cam River/Ruataniwha to the east of the current bridge (SH1 and southbound on ramp).
- New grade-separated diamond interchange overpass at Williams Street interchange.
- Tiered embankment through two artificial lakes at Quarry Lakes.
- Two new local road bridges over SH1 at Woodend Beach Road and Gladstone Road.
- New grade-separated diamond interchange overpass, including traffic signals and local road upgrades at Pegasus interchange.
- Installation of 15 culverts (ID:003-017) including three major culverts conveying existing stream flows at McIntosh Drain, Waihora Stream and Taranaki Stream and minor culverts at other drainage crossings and points of overland flow paths. Excavation into shallow groundwater and dewatering will be required to allow culvert installations.
- Stormwater treatment swales which extend each side along significant lengths of the road alignment and within the road footprint.
- Cut-off drains which extend each side along significant lengths of the road alignment and outside of the road footprint.
- Stormwater bioretention basins at William Street interchange and Waihora Stream (Pegasus Interchange).
- Other minor excavations may be required for installation of utilities.

# 3 Assessment of effects considerations for the Project

## 3.1 Regulatory context

The Canterbury Land and Water Regional Plan (CLWRP) is the main statutory document relevant to this hydrogeology assessment. Reference to other relevant documents includes:

- National Policy Statement for Freshwater Management (NPS-FM 2020, as amended in October 2024) (Ministry for the Environment, 2024a) including the definition for natural inland wetland.
- Resource Management (National Environmental Standards for Freshwater) Regulations 2020 (NES-F) which includes specific rules and provisions regarding development works within, or within 100 m of identified natural inland wetlands.

A detailed assessment of the Project's regulatory status is provided in the SAR.

## 3.2 Overview

The Project has the potential to result in changes to the hydrogeological environment and may result in both positive and/or adverse effects, and temporary and/or permanent effects. The potential changes relating to groundwater considered are:

- Groundwater flow regime.
- Groundwater levels.
- Groundwater quality.

Changes to groundwater could have an effect on groundwater receptors. These include surface water, groundwater users reliant on bore water supplies, and groundwater dependant wetlands and springs. Details on the how groundwater reaches these receptors is described in Section 6.3.1.

The way that the groundwater environment can be changed by the Project is described below. All groundwater effects assessments are based on the 30 % detailed design; therefore a conservative approach has been adopted for these assessments. Each report section (6 to 13) describes the specifics and scale of the activities at each Project component, and the potential effects as a result of those activities in the area specific hydrogeological setting.

## 3.3 Earthworks

### 3.3.1 General work activities

Earthworks form a large part of the Construction Works. Typically, these works include the creation of haul roads and the raised road embankment. The construction activities are generally limited to within the proposed alignment, however for the proposes of this assessment, earthworks to the boundary of the designation have been allowed for to allow for conservativism in the assessments. The effect of the road embankment on the overall groundwater environment is described in the road operation (Section 3.9).

Some of the temporary excavation activities are expected to occur within 1 m of, and into shallow groundwater. Excavation of any confining layer is not anticipated due to the expected depth of the confining layer and the shallow nature of all of the excavations.

In most areas of the Project it is assessed that the potential for contaminants to be encountered during excavation activities is very low, with a correspondingly low risk of contaminants entering groundwater and altering groundwater quality. Where required further investigation is described in the relevant Project component section e.g. Gladstone Road.

### 3.3.2 Specific work activities

**Stockpiling** of material will occur along most of the alignment with the shallow excavations/removal of topsoil prior to the creation of the haul roads. In addition, temporary designated stockpile areas will be formed at key locations where larger volumes of fill are required for storage. Stockpiling could temporarily reduce the groundwater recharge in the local area of the stockpile. Establishment of erosion and sediment control measures will occur prior to any construction activities.

The construction of the **road embankments** could result in effects on groundwater with potential changes to the local regime; flow and groundwater level caused by the placement of the fill, resulting in consolidation of the aquifer matrix and reduction in groundwater recharge. This could have a temporary and/or permanent effect on nearby surface waters and groundwater dependent wetlands.

During the formation of the **haul roads**, excavation is expected to be more than 1 m above the local groundwater level along much of the alignment, however, there is the potential for excavation could occur within 1 m of the groundwater surface but not into the groundwater surface at some localised places. All excavations are relatively shallow and there will be no excavation of any confining layer.

Temporary effects will occur from the establishment of **Construction support areas** (CSAs) which include facilities, plant/material storage, and earthworks stockpiling. Site establishment activities for the CSAs will include site clearance, ground preparation, and establishing erosion and sediment control measures prior to any construction activities occurring. The CSAs will be disestablished prior to the road operation. Storage of hazardous construction materials (if any) will be limited and not within cDWPZ.

### 3.3.3 Mechanically Stabilised Earth (MSE) abutments

MSE abutments or walls are above ground features comprising hardfill reinforced by layers of geogrid. Foundations to MSE abutments are on shallow footings which required minimal excavation or on ground where in-ground improvements have already been made. Minimal interactions with groundwater are expected with this type of construction and if groundwater is encountered in excavations, no removal of groundwater is required.

## 3.4 Excavations for structures

### 3.4.1 Culvert installations

There are a number of culverts located throughout the Project. Some culverts will be constructed for flowing waterways and others will be constructed for dry overland flow paths. During the culvert installation works, excavation could occur within 1 m of the groundwater surface and where groundwater is encountered temporary dewatering is likely to be required to allow placement of the culvert in dry conditions. However, there will be no excavation of any confining layer during the excavations.

At major culvert excavations, dewatering is likely to be required for a maximum of 20 to 30 days and this would typically be achieved via local drawdown through well pointing and/or a sump pump in the trench base. The length of open trench at any one time and therefore the amount of pumping required will depend on the dimensions of the culvert and ground conditions. The dewatering activities will result in varying water discharge volumes, entrained with sediment that could alter the water quality at the point of discharge and the water volumes/flows into the receiving surface water.

Dewatering assessments have been undertaken for a selected range of excavation dimensions i.e. culvert sizes to assess the effects of dewatering. These are included in the appendices to this report.

The effects of dewatering include the lowering of the local groundwater level which could have an effect on nearby surface waters and groundwater dependent wetlands. The dewatering could also affect groundwater users as a result of temporary lowering of the groundwater levels and these considerations have been assessed.

The major culverts, identified as those which cross existing surface waters, will be constructed offline and there is the potential for minor groundwater diversion to occur as a result of the change in location and associated with the backfilling of the relocated culvert.

During road operation, there will be limited effects from the culvert installations because the culverts have either been installed to convey existing surface water flows or to provide a channel for existing overland flow paths where the Project creates a barrier to this natural flow path. There is the potential for minor groundwater diversion to occur as a result of the installed culvert due to the presence of any granular fill material/base course used during construction which could very locally divert the groundwater flows and these effects are considered.

### 3.4.2 Stormwater swales and cut-off drains

There will be shallow excavations for stormwater swales and cut-off drains adjacent to the Existing SH1 upgrades and Woodend Bypass.

The stormwater swales will be constructed in the road embankment above the existing ground level, therefore these excavations are expected to carry stormwater runoff from the road alignment and will not intercept groundwater.

Cutoff drains will be installed along a large part of the Project alignment. These drains are not designed to intercept groundwater. Their primary purpose is to intercept offsite flow and convey it to a discharge location. The cut-off drains will be less than 1 m depth and will be graded along their length, so initial excavations will be very shallow and gradually deepen to the discharge point. It is likely that most of these excavations will be dry. The deepest part of the excavation will be at the point of discharge into surface water channels where excavations could intercept groundwater, at these locations, the drains are often replicating the existing drainage. This can be resolved once inverts and/or depths are available for drain locations. Allowance should be made for locations where short-term dewatering may be required i.e. 1 – 2 days, to allow excavation and drain construction.

### 3.4.3 Utilities installations

Temporary construction works include excavations for service relocations and new service installations. The depth of the service trenches will vary depending on the location and the type of services being laid. The service trenches are typically 0.6 m - 2.0 m wide and 0.8 m - 1.5 m deep, therefore, excavation could occur within 1 m of the groundwater surface at many locations. There will be no excavation into any confining layer due to the shallow depth of the excavations.

Where groundwater is expected to be intercepted, temporary dewatering may be required for several days to allow trench bedding material and services to be laid and backfilled in a dry trench. The length of the open trench at any one time, and therefore the amount of and duration of dewatering required will depend on the type of service being relayed or installed. Polyethylene (PE) pipes can be completed in short runs, whereas power cables require longer lengths to be installed at once.

It is anticipated that dewatering would typically be achieved via local drawdown through well pointing and/or a sump pump in the trench base during working hours.

## 3.5 Ground improvements

Ground improvements will be completed on all five new bridges to ensure the ground has sufficient bearing to support the bridge abutment. Ground improvements will be specific to each bridge and comprise from reinforced undercuts, stone columns and installation of displacement rigid inclusions such as Continuous Flight Auger or Displacement Piles. Ground improvement design and construction is individual to each bridge abutment and is described in the Construction Methodology Statement (Volume 3A). These in-ground works vary in depth and will penetrate the shallow unconfined aquifer and at some locations, could penetrate the deeper confined aquifer. A description of the proposed ground improvement at each location, including extent and depth, is provided in the relevant sections of this technical assessment.

**Stone columns**, also known as rammed aggregate piers, are constructed in situ by ground displacement using a vibroflot or displacement probe. The target depth of the hole is a soil profile of a suitable bearing capacity. Once the excavation is complete, the hole is filled with stones as the probe is lifted gradually from the hole. The diameter and spacing of the stone columns is variable and results in a strengthened soil profile. No groundwater removal occurs during these temporary works. The resulting ground improvement area is likely to have a slightly higher permeability than prior to the improvement due to the filling with stones. There is also the potential to mix groundwater between aquifers.

**Rigid inclusions** are also constructed in situ by ground displacement typically using an auger, driven into the ground. The drilled hole is filled with concrete via a tremie as the auger is lifted gradually from the hole. This method allows reinforcement of weak or compressible soils, transferring structural loads to deeper soils as described in the construction methodology (Volume3A). These can be effective at shallower depths than piles, depending on the diameter and spacing of the rigid inclusions. No groundwater removal occurs during these temporary works. The resulting ground improvement area is likely to have a slightly lower permeability than prior to the improvement due to the filling with concrete meaning that locally, groundwater levels may temporarily increase. There is also the potential to mix groundwater between aquifers, although this risk is much lower than that of stone columns. Minor temporary changes in groundwater quality due to the placement of concrete could occur.

It is possible to combine the **Stone columns** and **Rigid inclusions** methods where required, depending on the ground conditions. This could comprise the top part of the ground improvement being stone columns, founded on lower part of comprising concrete. With care and monitoring this method could reduce the likelihood of mixing groundwater between aquifers.

## 3.6 Piling

Deep bored piles, also known as drilled shafts, will be used for ground improvement at Cam River Bridge. The method of installation comprises bore drilling through a cased hole, and placement of reinforced concrete. Shallow groundwater will be intercepted by the piling and it is possible that excavation into a confining layer could occur. Therefore, there is the potential to temporarily mix groundwater between aquifers during the construction period and before placement of concrete. Minor changes in groundwater quality due to the placement of concrete could occur.

## 3.7 Dynamic compaction

Dynamic compaction is a ground improvement technique that will be used to densify the loose granular fill at for the embankment over the Quarry Lakes. The impact of the dynamic compaction transmits high-energy waves through the fill to compact it and improve geotechnical properties. The dynamic compaction will occur above the lake level. Dynamic compaction is anticipated to comprise a 30-tonne weight lifted to a height of up to 30 m and dropped on the embankment. It is estimated that the depth of the compaction will reach a depth of approximately 10 m, therefore the compaction effects will reach the natural soil profile below the lake floor.

## 3.8 Decommissioning of existing bores

There are 16 existing bores within the designation. Prior to the construction works commencing, NZTA will have taken ownership of these bores through the land acquisition process. These bores will be decommissioned during the construction works because the road will either be located directly on top of these bores or the bores will be likely damaged during the construction works. Bores will be decommissioned in accordance with ECan Guidelines[1] with bore casing removed prior to filling and sealing of the bore (where practical) by NZTA and in advance of the Construction Works in each area.

## 3.9 Road operation

The presence of the **road embankments** could result in effects on groundwater with potential changes to the local regime.

The placement of the road embankment will locally reduce the groundwater recharge in the area of the road by limiting rainfall recharge to the underlying shallow aquifer. Reduction in recharge could reduce groundwater levels in the shallow aquifer. Depending on the ground conditions, potential consolidation caused by the road embankment onto the shallow soils could occur and result in changes to the groundwater flow by altering the permeability of the shallow unconfined aquifer matrix. The potential surcharge effect from the road embankment is considered in Section 7.4.3.

## 3.10 Potential mitigation of effects

Management and mitigation options may be required where effects are considered greater than a low effect. Full detail is provided later in this report. As an overview, these effects on groundwater may include changes to:

- Level;
- Quality;
- Flow; and/or
- Water budget (allocation).

Standard management procedures and mitigation options have been considered to reduce potential effects and these include:

- Groundwater or surface water recharge to reduce effects of stream depletion and groundwater drawdown.
- Modification of activities e.g. based on scale and/or duration to reduce level of potential effects.
- Monitoring to inform work practices.
- Treatment to allow water modified by contaminants such as total suspended sediments (TSS) to be disposed to ground post-treatment.

[1] Environment Canterbury: Canterbury Land and Water Regional Plan.

# 4 Regional environmental setting

## 4.1 Site context/topography

The Project lies within 2.5 km of Pegasus Bay on lower-lying parts of the Canterbury Plains from Kaiapoi north to Pegasus. It is located on flat to gently undulating topography. The groundwater (water table) is shallow with many shallow channels across the area draining into local streams and rivers. The low-lying nature of the area contributes to potential for high levels of flooding inundation. From these Coastal Plains, the landform gradually gains in elevation, towards the foothills of the Southern Alps which are located 70km to the west of the alignment. The Project Site is shown in the Site Plan and Environmental Features (Volume 4C).

## 4.2 Geology

The geology of the wider Canterbury Plains and Christchurch area comprises interbedded alluvial gravels and finer sediments deposited during past glacial and inter-glacial periods. The Canterbury Plains have typically been deposited in fluvial environments[2]. Nearer the coastal margins, the geology includes finer sediments associated with marine depositional environments.

The published geology for the Project area[3] describes the near surface soils as alluvial silt, sand and gravel. Figure 4.1 shows the Project alignment superimposed onto the mapped geomorphological units. Holocene dune sand described as coastal wind-blown sand of the Christchurch Formation (shown in green) are generally linear features, formed parallel to the coastline. These extend in a north-south orientation from Kaiapoi (Pines Beach) to beyond Pegasus to the north.

These deposits are bounded by Holocene river deposits (shown in yellow) to the east, which comprise variably sorted gravel, sand, silt and clay mixtures. At the north end of the Project, a river channel extending west to east (labelled ‘ya2’ and ‘ya3’ in Figure 4.1) is present. This channel was a former flood channel of the Ashley River/Rakahuri and in this area, a gravel layer is often observed in the top 3 m – 4 m of the soil profile. Raised river channel sediments are shown adjacent to this channel where the soil profile is expected to comprise silts and sands.

Specific site investigations have been completed and these are described in Section 5, with further reporting in Appendix B.

[2] Brown, L.J. 2001: Canterbury groundwater. Chapter 23 in Groundwaters of New Zealand. Eds: M.R. Rosen & P.A. White. 24 p.

[3] Forsyth, P.J.; Barrell, D.J.A.; Jongens, R. (compilers) 2008. Geology of the Christchurch area (external link). Institute of Geological & Nuclear Sciences 1:250 000 geological map 16. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Limited. 67 p. + 1 sheet.

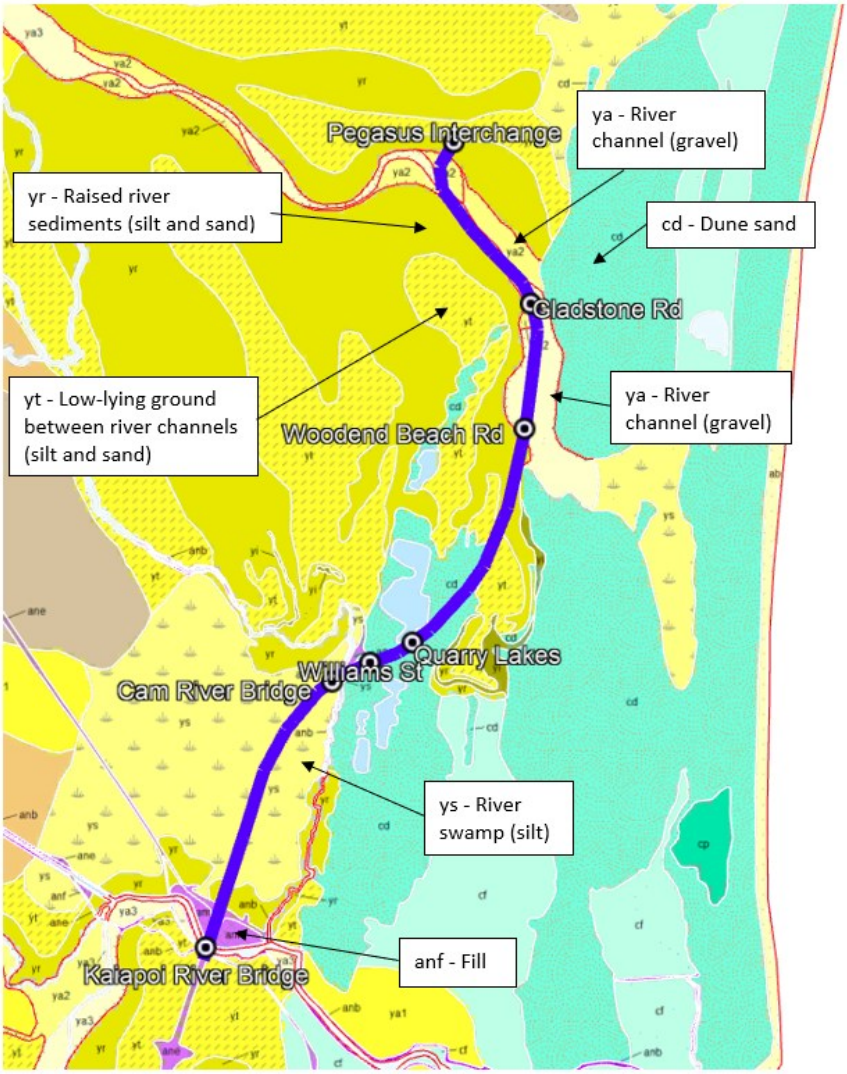


*Figure 4.1: Surface geology and geomorphological units[3] of the Project area.*

## 4.3 Hydrogeology

### 4.3.1 Overview

Within the Project area, the underlying geology comprises a series of unconfined to confined aquifers composed of Holocene glacial outwash deposits with gravels forming the main aquifer matrix. These aquifers are confined by finer sediments which progressively thin inland from the coast. At the coastal region, which includes the Project area, the finer sediments comprising sand, silt and peat deposits, have been deposited by marine transgressions during the interglacial periods. These sediments interfinger with the gravel deposits, derived from the alpine rivers and the deposition of the fluvio-glacial fans associated with the debris of successive glaciations[4].

[4] Brown, L.J. 2001: Canterbury groundwater. Chapter 23 in Groundwaters of New Zealand. Eds: M.R. Rosen & P.A. White. 24 p.

A schematic image of the aquifer systems on the Canterbury Plains in relation to regional groundwater conditions is presented by ECan[5] and has been reproduced in Figure 4.2. Whilst this figure is centred on Christchurch, the hydrogeological setting is also representative of the Project area.

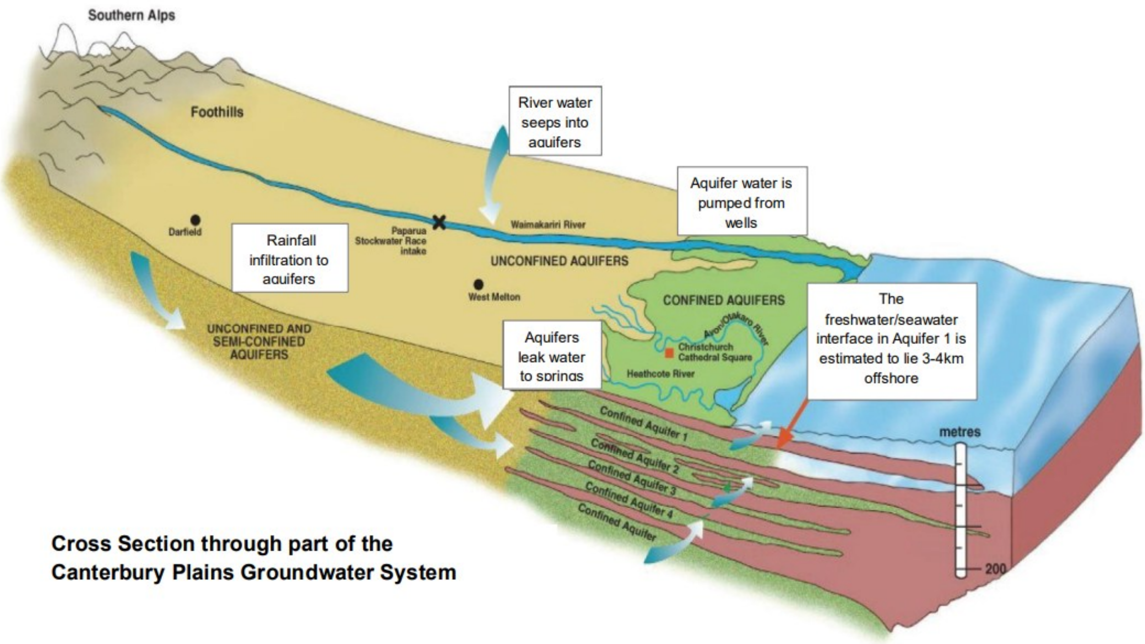


*Figure 4.2: Illustration of the aquifer systems beneath the Canterbury Plains (Source: Weeber, 2008[5]).*

#### 4.3.1.1 Groundwater flow

Regionally, the groundwater flow direction within the gravel aquifers is generally east, towards the coast. However, groundwater flow directions vary from southeasterly to northeasterly across the Project alignment (i.e. between the Ashley River/Rakahuri and Waimakariri River). These changes in flow direction relate to the piezometric contours where flow is perpendicular to groundwater contours[6]. These flow directions are shown on the regional piezometric contour plan in Figure 4.3. The groundwater hydraulic gradient[6] near the coast as approximately 0.0007 m/m. The hydraulic gradient steepens inland.

#### 4.3.1.2 Aquifer recharge and discharge

At regional scale, recharge to the aquifers occurs through leakage from the Ashley River/Rakahuri and the Waimakariri River, and through infiltration of rainfall to the plains, where the aquifers are unconfined. Recharge to the confined aquifers also occurs through leakage from overlying aquifers.

Groundwater discharge occurs by vertical flow, either downwards or upwards between aquifers and horizontally towards the coast within aquifers. Discharge also occurs at spring-fed streams which often rise along the margins of the coastal confined aquifer system, and within the coastal marine area (through flow and offshore leakage).

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[5] Weeber, 2008. Christchurch Groundwater Protection: A hydrogeological basis for zone boundaries, Variation 6 to the Proposed Natural Resources Regional Plan. Environment Canterbury. Report No. U08/21. ISBN 978-1-86937-802-8, 60 p.
[6] PDP (2013) NZTA Woodend Corridor Investigation - Groundwater Assessment, prepared for MWH New Zealand Ltd.

### 4.3.2 Coastal confined aquifer system

As a result of the fluvial and marine depositional processes, the Plains are divided into the 'Inland Plains' where the aquifers are predominantly unconfined and 'Coastal Plains' where there are a series of deep confined aquifers. Most of the Project overlies the mapped coastal confined gravel aquifer system, shown in Figure 4.3.

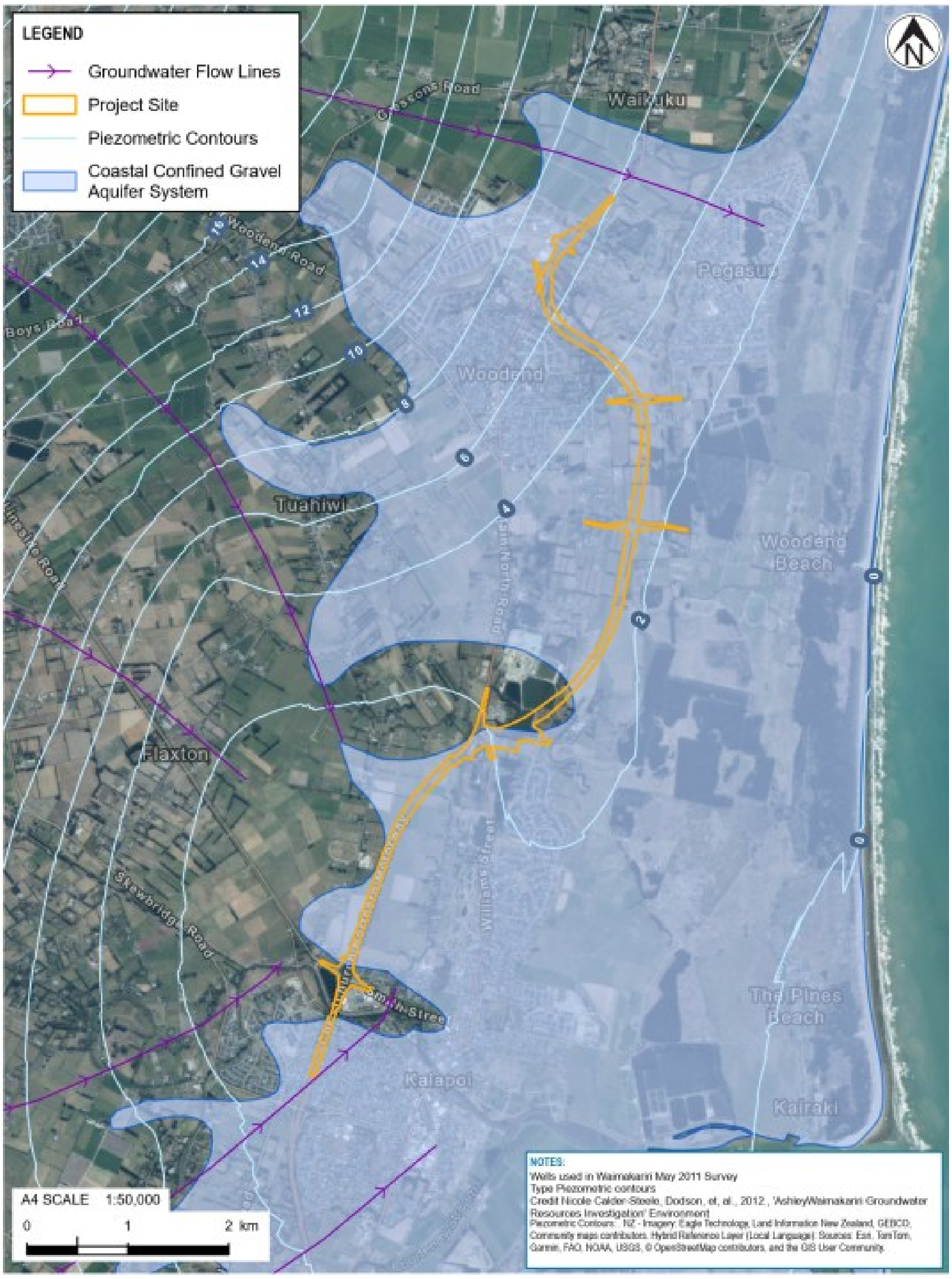


*Figure 4.3: Extent of Coastal Confined Aquifer (blue shading) for the Project. ECan piezometric contours[7] are shown and assumed as similar for unconfined and shallow confined groundwater. Source: ECan[8].*

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[7] ECan, Waimakariri shallow groundwater - piezometric contours (May 2011).

[8] Confined Coastal Gravel Aquifer System - Canterbury Maps Open data https://opendata.canterburymaps.govt.nz/datasets/2a4820ab58ad43baa10969187e567e69_6/explore?location=-43.432442%2C171.833250%2C7.45.

The transition into the unconfined and semiconfined aquifer system to the west coincides with the mapping of progressive thinning of the postglacial and interglacial finer grained sediments[2]. The western edge of the mapped coastal confined gravel aquifer system is delineated by the line where sediments of the uppermost overlying confining layer are three metres thick[5]. Two localised areas are mapped west of the coastal confined gravel aquifer system in the vicinity of Lineside Road (Kaiapoi River) intersection, and north of the Williams Street (Pineacres) intersection and Quarry Lakes[9].

#### 4.3.2.1 Shallow unconfined aquifer

The Project interacts primarily with shallow groundwater of the unconfined aquifer across the Project area with shallow excavations within the unconfined aquifer (where groundwater is encountered). This report section provides an overview on the shallow groundwater with more detail and a hydrogeological conceptual model summary provided for each project component at specific locations in Sections 7 to 13.

The unconfined aquifer generally comprises interbedded sediments of the Springston and Christchurch Formations across a wide area. Recharge of the shallow aquifer is via rainfall and, on a regional scale, from surface water losses, such as the Ashley River/Rakahuri, across the wider catchment area. At a local scale in the vicinity of the Project alignment, groundwater flow directions are expected to vary and be influenced by surface waters where groundwater is hydraulically connected to surface water.

Groundwater horizontal hydraulic gradients vary across the Project alignment. These gradients are steeper in the north and shallower in the south of the project (refer to Figure 4.3). They also steepen inland from the coast. On a local scale the gradients in the unconfined aquifer may steepen where groundwater discharges to streams and rivers are observed. The presence of lakes is also expected to affect hydraulic gradients.

Lake levels in the vicinity of the alignment are generally expected to be supported by groundwater which may occur as throughflow (e.g. groundwater flowing towards the coast may flow through a lake). The combined effect of throughflow, rainfall, and evaporation at the lakes will affect the hydraulic gradients in the vicinity of the lakes. For example, the presence of the Quarry Lakes is an area where downstream groundwater levels are slightly raised, with a corresponding reduction in hydraulic gradient (further discussed in Section 10).

Not all reaches of the surface waters intersect the unconfined aquifer. The Project area includes surface waters that have been modified by previous developments such as at Ravenswood where both Taranaki Stream and Waihora Stream have gaining reaches (described below with groundwater seepages) and neutral/losing reaches. Waihora Stream channel continues as an overland flow path toward Gladstone Road where the groundwater surface becomes deeper and where groundwater flow is away from the surface water.

All of the local surface waters are (and were for Waihora Stream) spring fed streams. These streams rise on the inland plains in areas at or near the boundary between the unconfined and semi-confined aquifers near or along the western margin of the coastal confined aquifer occurs. Other springs, separate from surface waters are present in the wider area. Only one spring is recorded in the Project area. During extensive ecological assessments[10] to identify natural inland wetlands along the

[9] PDP Memorandum. Dated 1 November 2024. To New Zealand Transport Agency (Waka Kotahi). Re. NZTA Woodend Corridor Investigation – Groundwater Assessment Update.
[10] T+T Ecologists during July 2025 site visit at approximately NZTM 1573 312 E 5204 576 N.

alignment, only one spring was observed at a constructed pond/depression, following the heavy rainfall in late April 2025 near the proposed Williams Street interchange[11].

Groundwater dependent wetlands have formed at places where the groundwater surface is exposed and/or where groundwater is very close to the surface. Further information on wetlands is described in Section 4.4.2. However, no visible springs were seen.

#### 4.3.2.1.1 Groundwater and surface water interactions

As part of previous investigations[12] stream bed surveys completed at Cam River/Ruataniwha, Waihora Stream and Taranaki Stream have identified groundwater seepages, inferred to be from shallow groundwater, that contribute to stream baseflows. The results and reporting for these investigations are included in Appendix D.

**Cam River/Ruataniwha**

As part of the groundwater-surface water interaction investigations[12], shallow groundwater at a standpipe, screened within the hyporheic[13] zone beneath the riverbed confirmed direct hydraulic connection with the groundwater and gaining conditions for most of the tidal cycle[12]. The shallow groundwater monitoring over eight tidal cycles showed a groundwater level response of approximately 0.1 m over a tidal variation of approximately 1.2 m.

Groundwater seepage testing[12] in the riverbed, where the substrate is described as silt and clay, indicates small volumes of seepage at the investigation locations ranging between $6.1 \times 10^{-6}$ L/s/m$^2$ to $1.2 \times 10^{-5}$ L/s/m$^2$.

The extent of the tidal fluctuations on shallow groundwater at Cam River bridge will be confirmed during the continuous groundwater level monitoring at the recently installed piezometers (monitoring wells).

**Waihora Stream**

The hydrological setting of Waihora Stream is complex and a summary of the hydrology is described in Section 4.4.1. Waihora Stream headwaters are/were originally spring fed from gravel strata, estimated to be at depths greater than 10 m bgl, where a gravel has been identified through local site investigations. However, the headwaters of Waihora Stream are within 6 m of Taranaki Stream and piped connection between the two surface waters has been established[14]. Further investigations[12] have identified the stream bed is composed of either silt or gravel substrate and has a width of 2 - 5 m wide and a depth range between 0.5 - 0.7 m. Water quality analysis shows a similar ionic composition to Taranaki Stream, which is now better understood since the recent confirmation of the connecting pipe with Taranaki Stream.

Measured stream flows at one location approximately 200 m downstream of SH1 varied between approximately 1.5 L/s during summer and 20 L/s during autumn. At the time of assessment, the piped connection between these two surface waters was unknown. Therefore, it is not possible to determine the groundwater inputs to Waihora Stream based on this flow monitoring and there is uncertainty on the permanent contribution to baseflows from groundwater.

However, conceptually it is considered that baseflow in Waihora Stream is at least part maintained by groundwater inflows and with intersection of the shallow groundwater[12]. The presence of

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[11] Located at 565 Williams Street between the Cam River/Ruataniwha and the proposed Williams Street interchange.
[12] PDP (May 2025) Groundwater – Surface water interactions along proposed Belfast to Pegasus Woodend Bypass alignment. Prepared for NZTA/Waka Kotahi.
[13] The hyporheic zone is the region beneath and alongside the bed of a stream or river where the stream water and groundwater mix.
[14] T+T site investigations during ecology fieldwork.

wetlands is indicative of the areas where shallow groundwater could be intercepted by the riverbed. Beyond 0.8 km (from the headwaters) stream flows go to ground. The extent of the losing reach has not been confirmed, but it is understood[12] to vary seasonally. The southeastern most wetland in the Waihora wetland complex; WC_W1_NPSFM is the most downstream point on Waihora Stream where surface water is observed.

**Taranaki Stream**

The groundwater-surface water interaction investigations[12] have identified the stream bed is composed of either silt or gravel substrate and has a width of 2 - 5 m wide and a depth range between 0.5 - 0.7 m. Measured stream flows varied between approximately 113 L/s to 125 L/s during summer and 85 L/s – 100 L/s during autumn. Between the gauging sites[12], there is either a surface water loss to groundwater is identified during the summer monitoring, and a neutral loss during autumn monitoring.

Water quality analysis comparing upstream and downstream water sampled identified no difference in water chemistry indicating limited groundwater inflows. This in combination with the shallow groundwater monitoring in the stream bed indicates that there is most likely to be no direct hydraulic connection with the groundwater and potentially losing conditions in this stream reach. This conclusion corresponds with site investigation data where groundwater strikes and reported groundwater levels in two boreholes close to Taranaki Stream measured 3 m bgl.

#### 4.3.2.1.2 Groundwater levels

The depth to groundwater across the Project area is shallow, with levels typically less than 2 m bgl reflected by the low elevation, topography, extensive surface water drainage network (originally installed to control and lower shallow groundwater) and the proximity to the coast where shallow groundwater is at sea level.

Long term groundwater monitoring data is available at bores located close to at Lineside interchange, Kaiapoi. Based on the range of groundwater levels recorded at bore M35/0724, measured between 1960 and 2025, the seasonal variation in shallow groundwater levels is approximately 0.6 m with a water level typically between 1.5 m bgl and 2 m bgl. There are only two occasions when groundwater levels 'spiked' to 0.8 m bgl and 1.2 m bgl over this monitoring duration.

Another bore, BW24/0523, approximately 300 m south of Kaiapoi River and east of the designation, measured between 2016 and 2023 shows a similar range in water levels and seasonal variation with three occasions where groundwater spiked close to surface, as shown in Figure 4.4.

Recent investigations have confirmed the depth to groundwater is variable across the Project area ranging between typically 0.5 m to 2.5 m depth with some discrete locations having water levels at > 3 m bgl. Further information is included in Section 5 and groundwater level monitoring records are provided in Appendix C.

Due to the low-lying area and shallow depth to groundwater, hydraulic gradients across the area are small, estimated[12] to be approximately 0.0007 m and this is reflected in the small variation in groundwater levels.

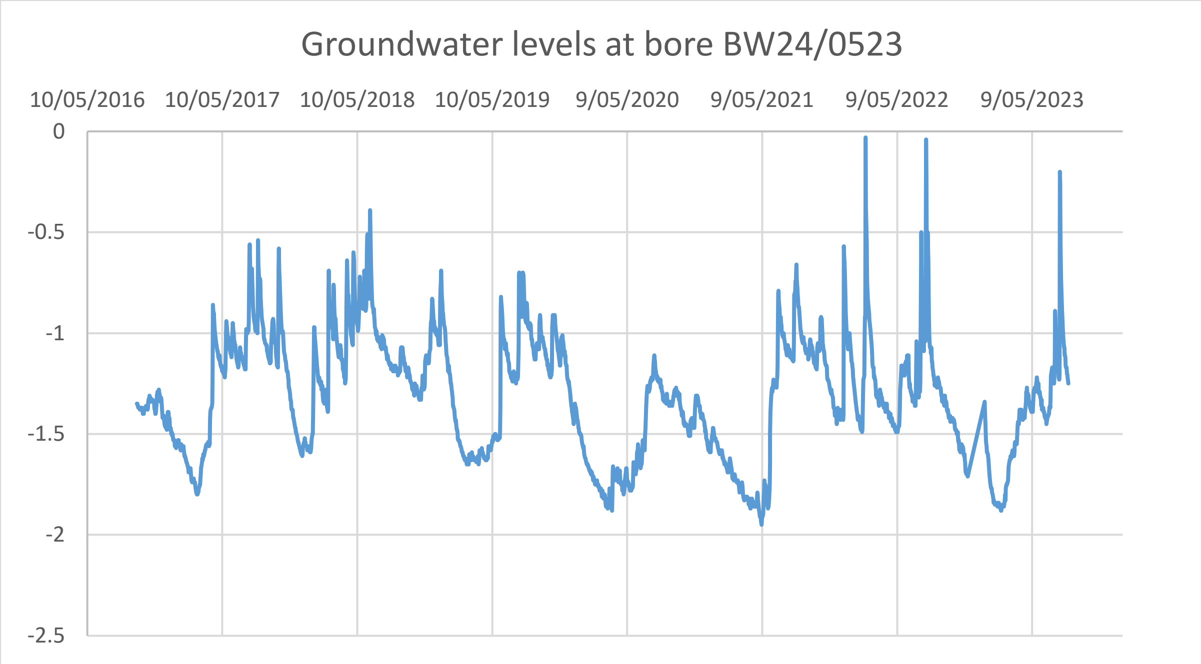


*Figure 4.4: Groundwater levels in shallow monitoring well (6 m deep) at Otaki Street, Kaiapoi.*

#### 4.3.2.1.3 Shallow groundwater quality

The latest annual groundwater quality survey[15] for Canterbury (September to December 2023) included sampling at 349 monitoring wells. Most groundwater samples were collected from the upper part of the regional groundwater system (< 40 m bgl) i.e. shallow unconfined aquifer and upper confined aquifers. There were 32 wells sampled in the Waimakariri CWMS zone, nine of which are deeper than 40 m.

Key water quality parameters analysed are compared with the health-based Drinking Water Standards for New Zealand[16] (DWSNZ) maximum acceptable values (MAV) for nitrate-nitrogen, manganese and arsenic. The aesthetic-based DWSNZ aesthetic value (AV) parameters include pH, manganese, iron, hardness (measured as $CaCo_3$), ammonia-nitrogen, chloride, sodium and sulphate.

The general groundwater quality for the Waimakariri CWMS zone water samples is summarised as follows:

- No wells were reported to exceed the DWSNZ MAV for nitrate-nitrogen, manganese and arsenic.
- Three wells had exceedances for *E. coli*.
- Parameters; pH, manganese, iron and aluminium were reported to be elevated above their respective AVs in up to six wells (only one well for aluminium).

For the Canterbury region as a whole, in areas where shallow groundwater is likely to be connected to surface water:

- 61 % of samples (83/135) had nitrate-nitrogen concentrations > 2.4 mg/L, potentially contributing to lowland rivers exceeding the National Bottom Line concentration.
- 15 % of wells (20) had dissolved reactive phosphorus (DRP) concentrations > 0.018 mg/L, which may lead to D band classification for DRP in lowland rivers.

[15] ECan, 2023. Annual Groundwater Quality Survey 2023.
[16] Water Services (Drinking Water Standards for New Zealand) Regulations 2022.

#### 4.3.2.1.4 Saline intrusion

Saline intrusion occurs when groundwater in an aquifer near the coast, which is hydraulically connected to the ocean, is replaced by saltwater from the ocean, causing the saltwater wedge (saltwater/freshwater interface) to move inland. There are two main processes that increase the risk of saline intrusion:

- A rise in the sea water level at the coastline; and/or
- A lowering of the fresh groundwater hydraulic gradient (flatter).

A lower/flatter freshwater hydraulic gradient can be caused by factors such as reduced rainfall recharge and/or groundwater abstraction.

The proposed Project activities are unlikely to induce saline intrusion, as groundwater abstraction is not proposed and any changes in groundwater levels such as from dewatering due to the Project activities will be temporary. In addition, the distance from coastline is greater than the likely effect of saline intrusion.

Saline intrusion indicator parameter concentrations (chloride and electrical conductivity) are measured in samples taken from local shallow monitoring wells[17] (depth range of approximately 10 m to 16 m). In these wells, chloride concentrations are typically less than 100 mg/L and electrical conductivity (EC) is typically less than 25 mS/m[17].

EC in freshwater is typically less than 15 mS/m and EC values of between 15 to 25 mS/m are considered moderate values, indicating the presence of salts leached from the land surface or the aquifer material[17]. For chloride, fresh water generally has chloride concentrations less than 100 mg/L, significantly less than the 19,000 mg/L for sea water[17]. On this basis, it is considered that shallow groundwater at these wells is unlikely to be currently influenced by seawater.

### 4.3.2.2 Deeper confined aquifer

The deeper confined aquifer system extends to depths of greater than 100 m. The upper four gravel aquifers of the confined system are known (from the top down) as the Riccarton, Linwood, Burwood and Wainoni Aquifers, these are summarised in Table 4.1.

**Table 4.1: Summary of typical aquifer depths and thickness[18]**

| Aquifer no. | Aquifer name | Top of aquifer (m bgl) | Thickness (m)* | Overlying Aquitard |
|---|---|---|---|---|
| 1 | Riccarton Gravel (Burham Gravel) | 10 -20 | 20 | Christchurch and Springston Formation |
| 2 | Linwood Gravel | 30 – 50**<br>55-60 | 30 | Bromley Formation |
| 3 | Burwood Gravel | 110 | 15 | Heathcote Formation |
| 4 | Wainoni Gravel | 125 | 10-12 | Shirley Formation |
| 5 | Un-named | Up to 150 | >220 | |

* Reported thickness in this table is the maximum thickness recorded.

** Based on aquifers in the Kaiapoi – Ohapuku area (PDP report) & recent investigations.

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17 Land Air Water Aotearoa. Groundwater Quality: https://www.lawa.org.nz/explore-data/groundwater-quality.

18 Based on review of readily available ECan data and descriptions provided in various published reports and maps referenced in this report and including Canterbury Regional Council, 1997. Groundwater: Christchurch West Melton. Report 97(12).

This nomenclature is based on the confined aquifers beneath Christchurch, therefore north of the city and within the Project area where the upper confining layers can be less distinct, the Riccarton aquifer is often referred to as the Burnham gravel/aquifer[19]. The Burnham Formation is widespread to the west of the Project area and becomes the thick, deep unconfined aquifer which extends across the Inland Plains.

The depth to the top of the aquifers can be variable, particularly where the thinning of the Coastal confined aquifer occurs to the west of the Project area. The Riccarton/Burnham Gravel is relatively shallow in some areas and the overlying confining layer is occasionally absent and/or very thin. This means the Burnham aquifer is often semi-confined becoming locally confined where thicker aquitards exist.

Two investigation bores, at Pegasus reached Aquifer 2 (Linwood Gravel) at 30 m depth. A thick 6 m thick silt stratum was noted to separate Aquifer 1 and Aquifer 2. Further details on the conceptual model at Pegasus are described in Section 13.

Typically, piezometric pressures in the confined aquifers increase with depth and progressively toward the coast. The deep groundwater sources in the coastal confined aquifer, such as the WDC public water supply bores at Gladstone Road, are often artesian with pressure heads at or above ground level. During investigations, artesian groundwater levels were encountered during the drilling of some bores through the semi-confining to confining layer and into the Riccarton/Burnham Gravel. No flowing artesian conditions were encountered although upward flows occur (artesian pressures).

Based on the shallower depth of the Riccarton/Burnham Gravel in the Project area, most of the ground improvements will reach the confined aquifers, these are described in Sections 8, 9, 13.

### 4.3.3 Groundwater allocation zones

The Project alignment extends across the Eyre Groundwater Allocation Zone (GAZ), the Cust GAZ and the Ashley GAZ. These GAZ's lie in the Waimakariri Canterbury Water Management Strategy (CWMS) Zone. There is currently groundwater allocation available in each of these GAZ as shown in Table 4.2.

**Table 4.2: Current groundwater allocation within the Project area**

| Zone | Allocated volume (m3/annum) | Amount available for allocation (m3/annum) & % of unallocated volume |
|---|---|---|
| Eyre GAZ | 99,070,000 | 1,925,788 (3 %) |
| Cust GAZ | 20,130,000 | 3,445,470 (18 %) |
| Ashley GAZ | 15,400,000 | 1,342,155 (9 %) |

## 4.4 Hydrology

### 4.4.1 Surface water

The Project extends across five surface water catchments and five surface waters, as shown on Figure 4.5. These are summarised in Table 4.3 in the order in which the catchment is crossed by the Project (south to north). Details on each surface water are described in the following sections.

[19] L. J. Brown , D. D. Wilson , N. T. Moar & D. C. Mildenhall (1988) Stratigraphy of the late Quaternary deposits of the northern Canterbury Plains, New Zealand, New Zealand Journal of Geology and Geophysics, 31:3, 305-335.

**Table 4.3: Summary details of surface waters and catchments**

| Surface water catchment[20] | Surface water allocation zone[20] (SWAZ) | Surface water | Description of surface water |
|---|---|---|---|
| Kaiapoi River catchment | Kaiapoi River | Kaiapoi River | Permanent water, tidal |
| Cam River/Ruataniwha catchment | Cam River/Ruataniwha | Cam River/Ruataniwha | Permanent water, tidal |
| Waimakariri River catchment | Waimakariri River | McIntosh Drain | Intermittent to permanent water |
| Saltwater Creek catchment | Saltwater Creek | McIntosh Drain | |
| | Taranaki Creek | Waihora Stream | Ephemeral in northern part & intermittent becoming dry channel to the south. |
| Taranaki Creek catchment | Taranaki Creek | Taranaki Stream | Permanent water |

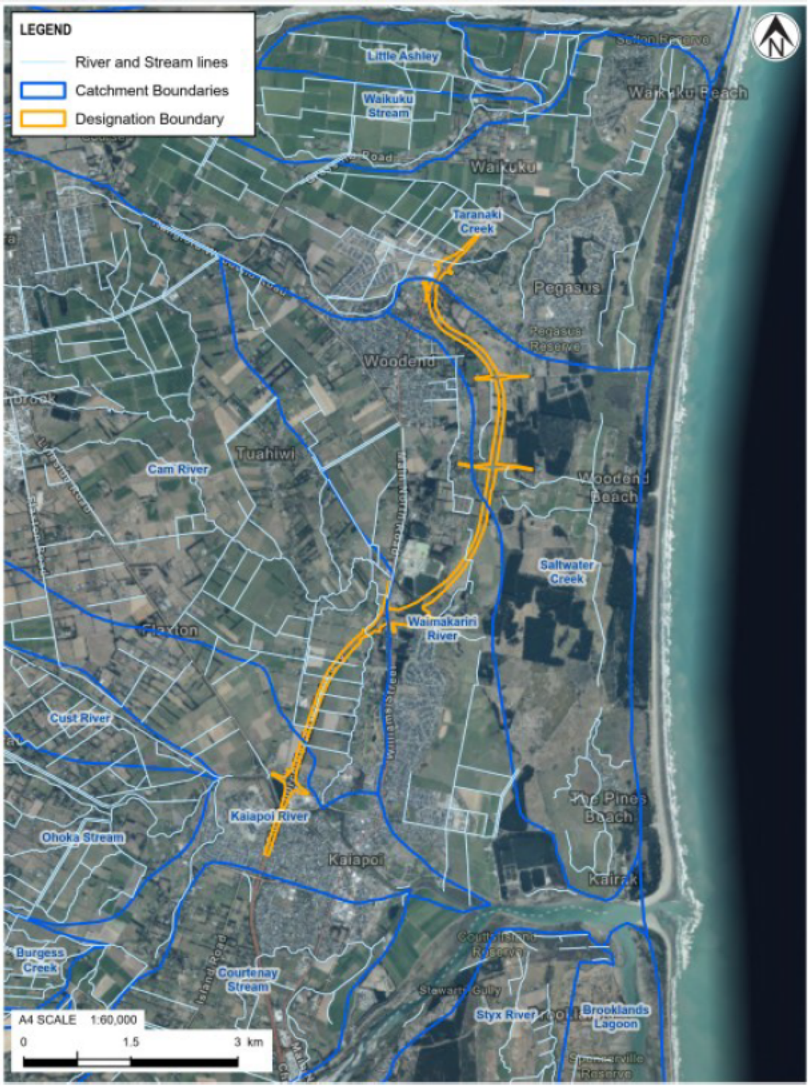


*Figure 4.5: Surface water catchment areas and surface waters along the alignment. Source: ECan.*

[20] ECan, Canterbury Maps: https://mapviewer.canterburymaps.govt.nz/. Accessed April 2025.

#### 4.4.1.1 Kaiapoi River

The Kaiapoi River is a spring-fed river flowing through the intensified farmland on the inland plains north of the Waimakariri River. Tributaries of the Cust, Ohoka and Silverstream rivers feed into the Kaiapoi River. At SH1 the Kaiapoi River is approximately 40 m wide and is bound by stop banks. The riverbed is comprised of soft-bottomed substrate, most likely silt and clay. At SH1, the river is tidally influenced, being approximately 4 km upstream of the coastal marine area boundary.

#### 4.4.1.2 Cam River/Ruataniwha

The Cam River/Ruataniwha is spring fed by tributaries that rise on the inland Canterbury Plains from the area around Rangiora and Southbrook. The Project crosses and is close to the lower reaches of the Cam River/Ruataniwha, where the river is tidal and relatively wide (approximately 20 m). The Cam River/Ruataniwha confluences with the Kaiapoi River approximately 600 m east of the Kaiapoi Bridge and southern end of the Project.

The groundwater-surface water interaction investigations[12] have identified the Cam River/Ruataniwha at approximately 300 m downstream of the SH1 crossing to have a tidal range of at least 1.2 m. Shallow groundwater is discharging into the Cam River/Ruataniwha through the riverbed via direct hydraulic connection/intersection with the shallow groundwater/water table, but the groundwater inflows are identified as minor and are not a dominant contributor to the river flow.

#### 4.4.1.3 McIntosh Drain

McIntosh Drain is an intermittent to permanent modified natural watercourse that has historically been straightened to accommodate the agricultural land uses within the adjacent area. The drain channel is restricted, having been cut below ground level typically 1 m below the surround farmland.

The drain bed, where observed at the proposed SH1 crossing, has a fine sediment substrate (silt) and this is expected to be typical along much of the drain length, although this is often masked by aquatic vegetation. The water depth is shallow, and it has been identified to consist of slow shallow runs and pools (as described in the Ecological Impact Assessment (**EcIA**) (Volume 3I). The width of McIntosh Drain is typically 1 - 2 m, widening in areas where a change of direction occurs.

The Project crosses and is partially parallel to McIntosh Drain between Quarry Lakes and Fullers Road.

#### 4.4.1.4 Waihora Stream

Waihora Stream is an ephemeral to intermittent stream that has a relatively short length of approximately 1 km with no visible stream bed beyond this point. The hydrological setting of Waihora Stream is complex. Waihora Stream north of SH1 has been modified by the Ravenswood development with original flows north of the current headwaters diverted into the Taranaki Stream which generally flows from west to east.

The reach between the headwaters and SH1 is shallow, typically between 0.2 m to 0.3 m and has been partially reconstructed. The pipe connection between Taranaki Stream and Waihora Stream, as described in various Ravenswood development consent documents, has only been identified[21] in the stream bed at the headwaters of Waihora Stream. It is understood that flows in Taranaki Stream immediately downstream of Garlick Street bridge flow into Waihora Stream. Spring flows are also observed within Waihora Stream approximately 50 m downstream of the headwaters.

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[21] T+T Ecologists during July 2025 site visit at approximately NZTM 1573 312 E 5204 576 N.

The Waihora Stream catchment has been further modified by a recently constructed stormwater swale located approximately 10 m west of the Waihora Stream. This swale is at a higher elevation than Waihora Stream and falls to the north i.e. stormwater flows in the opposite direction to the Waihora Stream streamflow.

The stream flows in Waihora Stream flow south and pass under SH1 approximately 130 m downstream of the headwaters. The Project crosses Waihora Stream at SH1 and is close to and parallel to the Project designation along the southern reach of Waihora Stream.

#### 4.4.1.5 Taranaki Stream

Taranaki Stream is a perennial stream that has been significantly modified by the Ravenswood development. Taranaki Stream is crossed at Bob Roberston Drive and will be crossed by the road alignment at two locations. At Garlick Street, Taranaki Stream is within 6 m of Waihora Stream headwaters, and as described above, provides some flows to Waihora Stream.

The Taranaki Stream is a spring-fed stream with some spring sources identified approximately 2 km and 5 km upstream of Garlick Street. Groundwater inputs are also reported to occur from a shallow alluvial gravel fan, a remnant of Ashley River/Rakahuri flooding.

As described in Section 4.3.2.1.1, investigations identify[22] the stream reach in the vicinity of Pegasus interchange to have either a surface water loss to groundwater and/or a neutral loss, meaning the overall reach is likely to be losing water along this extent.

### 4.4.2 Wetlands

Wetland identification has been completed as part of the Ecological Impact Assessment (EcIA). The starting point of the wetlands being identified were to assess if they met the RMA wetland definition. Following this, the RMA wetlands were assessed to see if they met the NPSFM definition, and those that were not assessed to meet this definition, were assessed to determine if they met the definition of the CLWRP.

There are 23 wetlands, which have been identified within 100 m of the Project Site and 2 wetlands which are greater than 100 m from the Project Site but may be affected by the Project. A full description of the wetland assessments is provided in the EcIA (Volume 3E). Each wetland ID includes the identifier NPSFM, CLWRP and RMA which relates to the adopted hierarchical order of whether the wetland meets the definition of:

- A natural inland wetland (NIW) within the National Policy Statement for Freshwater (NPS-FM);
- Wetland in the Land and Water Regional Plan (CLWRP); or
- Wetland in the Resource Management Act (RMA) only.

In summary, the number of wetlands meeting each definition are 20 NPSFM, 3 CLWRP, 1 RMA and 1 not characterised, these are shown in the Site Plan and Environmental Features (Volume 4C) and tabulated on Table 4.4.These are described in the individual Project components in sections 7 to 13.

[22] Upstream gauging site 270 m upstream of Garlick St and downstream gauging site 270 m downstream of existing SH1 crossing.

**Table 4.4: Summary of wetlands within Project designation**

| Wetland ID | Catchment mapped (see Appendix H ) | Assessment considerations and relevant comments |
|---|---|---|
| **Cam River/Ruataniwha wetlands** | | |
| CR_W1_NPSFM | Yes | Yes |
| CR_W2_NPSFM | Yes | Yes |
| **Quarry lakes wetlands** | | |
| QP_W1_NPSFM | Yes | |
| QP_W2_LWRP | No | Yes (for water take from lake), wetland catchment is same as wetland extent. |
| QP_W3_LWRP | No | Yes (for water take from lake), wetland catchment is same as wetland extent. |
| QP_W4_NPSFM | Yes | Yes |
| BR_W1_NPSFM | Yes | Yes |
| BR_W2_NPSFM | Yes | Yes |
| BR_W3_NPSFM | Yes | Yes |
| BR_W4_NPSFM | Yes | Yes |
| **Farm Area wetlands** | | |
| FA_W1_NPSFM | Yes | Yes |
| FA_W2_NPSFM | Yes | Yes |
| **Fullers Road wetland complex** | | |
| FR_W1_NPSFM | Yes | Yes |
| FR_W2_NPSFM | Yes | Yes |
| FR_W3_NPSFM | Yes | Yes |
| FR_W4_NPSFM | Yes | Yes |
| **Waihora wetland complex** | | |
| WC_W1_NPSFM | Yes | Yes |
| WC_W2_NPSFM | Yes | Yes |
| WC_W3_NPSFM | Yes | Yes |
| WC_W4_NPSFM | Yes | Yes |
| WC_W5_NPSFM | Yes | Yes |
| WC_W6_NPSFM | Yes | Yes |
| **Garlick Street wetlands** | | |
| GS_CW1_RMA | No | No (as stormwater basin) |
| GC_W1_LWRP | No | Yes |
| **Main North Road wetland** | | |
| GC_W2 | No | No (constructed wetland) |

### 4.4.3 Springs

One spring M35/7465 is identified on Canterbury Maps[23] within 400 m of the Project Site. The spring is categorised as a gravitational seepage and is located within woodland on a residential property at 171 Gladstone Road.

Stream flows on Waihora Stream appear to be in part spring fed, however the individual springs could not be determined during field work. No other springs were identified during the ecology fieldwork to identify and assess wetlands. i.e. at locations where springs are likely.

## 4.5 Climate

The climate of the Waimakariri District is broadly classified as a Temperate Oceanic Climate with the weather influenced by the presence of the Southern Alps and the ocean[24]. The district receives year-round precipitation with no strong seasonal trends. However, the coastal region, which includes the Project area, is warmer and drier than the inland plains[24].

An onsite rain gauge with telemetry has been constructed at approximately NZTM 1573558.9 E 5200314.2 N adjacent to monitoring piezometer BH_61 on NZTA property east of the Quarry Lakes. The collection of rainfall data commenced in September 2025.

In absence of site-specific rainfall data (during the preparation of this report), long-term rainfall data[25] has been collected from ECan climate station (ID: 324611) at Kainga Yard station located approximately 4.5 km south of Kaiapoi River. Average annual rainfall across the Project is calculated as 562 mm/year based on the data range for years 2000 to 2024. To support the assessments made in this technical report, an estimate of the average annual rainfall recharge of approximately 16 % is taken from a national model[26]. This equates to an estimated annual rainfall recharge of approximately 87 mm/year.

## 4.6 Surrounding groundwater users

### 4.6.1 Bores

A bore use survey was completed by PDP[27] in April 2025 for bores within 400 m of the Designation. A 400 m buffer was selected based on the original designation outcomes. This distance from the road alignment is considered appropriate due to the level of effect of the proposed activities on groundwater and the negligible effects on groundwater users. The scope of bore survey included:

- Obtaining bore and well data from Canterbury Maps/ ECan bore and wells database[28].
- 'Door knock' survey to confirm groundwater use and depth of abstraction for identified bores.

Within a 400 m buffer of the Project Site, there are 163 bores of which 99 of these bores have been confirmed as part of the door knock survey. This includes five additional bores identified during the bore survey that were not listed on the ECan database. The remaining 64 bores were all contacted during the bore survey, but the details of the bores were not confirmed by the bore owners. The

[23] Canterbury Maps Spring location layer.
[24] NIWA (May 2022) Waimakariri District Climate Change Scenario: Technical Report. Prepared for Waimakariri District Council. National Institute of Water & Atmospheric Research Ltd (NIWA), Wellington. Ref: WDC22301.
[25] Daily Rainfall totals from September 1999 to March 2025 at Kainga Yard station 324611. Data received 23 May 2025. Provided via email from Tony Gray, Environment Canterbury.
[26] Ministry for the Environment. Estimated Groundwater flux, 2019, Recharge. Mean annual values in mm/day.
[27] PDP (17/04/2024). Memorandum to New Zealand Transport Agency (NZTA): Results from Bore Use Survey along the proposed SH1 Belfast to Pegasus Motorway and Woodend Bypass alignment.
[28] Canterbury Maps – All bores and Wells data. April 2025.

bore locations (confirmed or otherwise) are shown in the Site Plan and Environmental Features (Volume 4C). Figures in more detail are also provided in each Project component is Sections 7 to 13.

Table 4.5 provides a summary of the bore survey results. Full details of each bore which includes location, bore depth, screen depth and water levels are provided in Appendix D and contained within the PDP report[27]. Bore use descriptions have been retained from the original PDP report and these are clarified below:

1 **Water supply purposes** are classified as those bores from which water is actively abstracted for a defined use such as domestic, community, public, or stock water supply, or irrigation.

2 **Other uses** are those bores either not used for any purpose or used for purposes that do not require water abstraction and supply such as water level observation or geotechnical purposes.

3 **Owner unsure if bore exists,** it is assumed (by T+T) that this statement means the bore is more than likely not to exist because the bore owner has not been aware of the bore.

**Table 4.5: Results of bore survey for all known bores within 400 m of the Designation[27]**

| Bore status | Bore use | Number of bores | Depth range (m bgl) |
|---|---|---|---|
| Exists | Water supply purposes[1] | 66 | 4.8[3]– 250.7 |
| | Other uses[2] | 14 | 3.2 – 193.6 |
| Unconfirmed | Bore details not confirmed by owner | 64 | 6.7-131.1 |
| Unsure | Owner unsure if bore exists[4] | 14 | 8.5-61.6 |
| Capped/sealed | n/a | 6 | 20.5-32.6 |

Note:

[1] Bore depth of 0 m excluded as likely incorrectly reported.

The range in reported bore depths is between approximately 4 m to 250 m. Most of the information on bore depths was obtained by PDP[27] from the ECan database, usually based on bore log records at the time of drilling rather than from bore owners during the 'door knock' survey. The bore depths correspond to a range of aquifers from which groundwater is being used (e.g. taken for water supplies or monitoring purposes). Specific details on public water supply (PWS) bores are provided below. Details of the potential effects on groundwater users are considered in Section 6.

### 4.6.2 Community drinking water protection zones

There are two Waimakariri District Council (WDC) community Drinking Water Protection Zones (cDWPZ) within 400 m of the Designation. These cDWPZs provide zoning around five public water supply (PWS) bores at Lineside and two PWS bores at Gladstone Road. An additional bore; M35/11911 is shown with a cDWPZ defined on Canterbury Maps, however, it is understood[29] that this bore does not provide water for PWS. Both water sources are the deep confined aquifer, as illustrated in Figure 4.6. An overview of the potential effects on drinking water supply source water is provided in Section 6 and further assessment of effects details are provided in Sections 7 and 12.

[29] WDC, Rangiora Water Supply Water Safety Plan (WSP): February 2018 (rev 1). TRIM No. 180213014155.

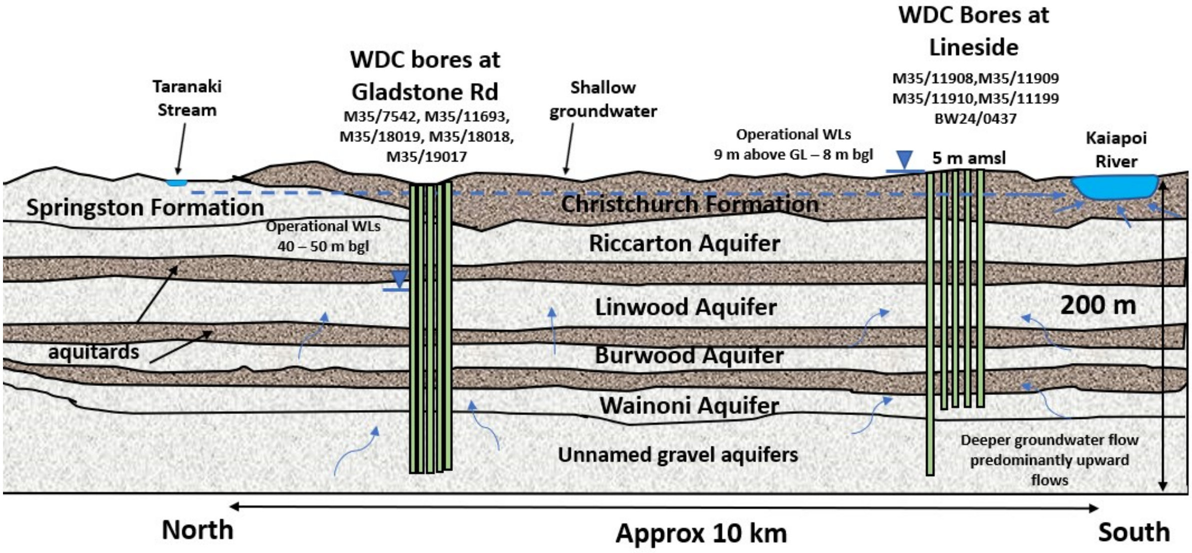



*Figure 4.6: WDC community public water supply bores at the Project in the Confined Coastal system. Source: T+T[29].*

Other cDWPZs considered are delineated around bores that are located up to 800 m from the designation. These are considered in the effects assessment, where construction activities may result in a groundwater effect. These cDWPZ are as follows:

- Woodend WDC cDWPZ for bore M35/0225, at depths between 19.7 m to 22.7 m bgl, identified to be screened within the confined Riccarton Aquifer, located approximately 800 m west of the designation.
- Woodend WDC cDWPZ for bore M35/10908 (Pegasus PWS bore) at depths between 142.8 m and 145.8 m bgl, screened within the deep confined aquifer (Wainoni or Aquifer 5), located approximately 500 m northeast of the designation on Boulevard Drive.
- Woodend WDC cDWPZ for bores M35/18019, M35/18018 and M35/18017 (EQ Wells 1, 2, & 3) at depths greater than 200 m, screened within the deep confined aquifer (Wainoni or Aquifer 5), located between approximately 160 m and 250 m east of the designation.
- Waikuku Village Subdivision cDWPZ for bore M35/7340, at depths between 21 m to 23 m bgl, identified to be screened within the confined Riccarton Aquifer, located approximately 600 m north of the northern-most end of the designation at Pegasus.

# 5 Site investigations

## 5.1 Overview

Geotechnical investigations have been undertaken for the Project over May to June 2025 and provide site specific data for this hydrogeological assessment. The investigation comprised numerous investigation types and locations. Details of the site investigations and summary of the ground conditions are described in Appendix B. The relevant investigations to characterise the hydrogeological conditions include:

- 72 machine drilled boreholes to a maximum depth of 40 m.
- 27 piezometer installations.
- 152 Cone Penetration Tests (CPTs) to a maximum depth of 20 m.
- 91 test pits to a maximum depth of 4 m.

Additional investigations have been undertaken in August/September 2025 in areas where site access was not available during the main investigation works, such as at Gladstone Road landfill.

Further data collection including groundwater level is also ongoing, through the use of telemetered water level monitoring devices installed in piezometers. This further data will be collected for up to 12 months and will be used to provide the baseline water level records for the Project. Groundwater level data collected to date is presented in Appendix C.

The following sections relate to hydrogeological information used to support this assessment.

## 5.2 Hydraulic conductivity testing

In-situ hydraulic conductivity testing, specifically slug tests, has been conducted on multiple piezometers installed along the Project alignment. These tests were undertaken to evaluate the hydraulic conductivity of subsurface materials encountered within the Project Site. The resulting data has been systematically collected and analysed to derive representative hydraulic conductivity values for the subsurface materials along the Project alignment. The derived values have been subsequently used to support further assessments of potential environmental impacts associated with activities during construction.

Details of the piezometers are presented on the investigation logs in Appendix B and summarised in Section 5.3.1.

Piezometer development records, field sheets, slug test methodology and results of analysing the test data are attached in Appendix E.

## 5.3 Groundwater monitoring

### 5.3.1 Piezometer details

Groundwater piezometers (monitoring wells) for the purposes of this hydrogeological assessment were installed in 23 of the boreholes at typical depth ranges of 3 m to 6 m to characterise the shallow groundwater. At some locations, the screen depths were adjusted to reflect the local ground conditions and resulted in a wider range of screen depths. Tabulated depths for the top of the screen location ranges from 1.9 to 12 m bgl. Piezometer locations are shown on Figure 1 in Appendix A and summary details of the piezometer installations are presented in Table 5.1. Piezometers shaded blue are those specifically for this hydrogeological assessment. Other piezometers form part of the investigations completed for geotechnical and contaminated land purposes. Installation records, shown on the borehole logs are attached in Appendix B.

Piezometers were installed to monitor shallow groundwater levels in the unconfined aquifer in areas where structures and/or excavations are proposed as well as in areas to generally characterise the depth to groundwater along the alignment.

Groundwater levels measured during the drilling of the boreholes are recorded on the borehole logs. Some groundwater level measurements recorded during drilling may not reflect levels of clean groundwater due to the method of drilling and use of water as a drilling fluid.

Following piezometer installation each well was developed (flushed) using a Supertwister brand pump to remove any residual silt from the groundwater and provide a good connection between the piezometer and the screened formation.

**Table 5.1: Borehole piezometer summary**

| Location | Borehole ID | TOC (m bgl) | Ground elevation RL (m) | Depth of piezometer screen (m bgl) | Initial GWL (m RL) | Initial GWL (m bgl) |
|---|---|---|---|---|---|---|
| Kaiapoi Bridge | BH_02 | 0.63 | 3.58 | 5-8 | 0.13 | 3.45 |
| | BH_48 | -0.12 | 2.43 | 3-6 | 0.12 | 2.31 |
| | BH_51 | 0.623 | 4.07 | 5-8 | 1.65 | 2.41 |
| Lineside to Cam | BH_52 | | 1.07 | 3-4.95 | 0.02 | |
| | BH_53 | | 0.980 | 1.9-4.9 | 0.01 | |
| Cam River Bridge | BH_54 | | 1.64 | 4-7 | 1.10 | 0.54 |
| | BH_55 | | 1.65 | 3-6 | 0.15 | 1.5 |
| Cam River/Ruataniwha to William St | BH_47 | 0.37 | 5.41 | 2-6 | 1.43 | 3.98 |
| | BH_57 | | 3.180 | 3-4.95 | 1.38 | 1.8 |
| William St | BH_07 | 0.63 | 2.33 | 6-8.5 | 0.98 | 1.34 |
| | BH_10 | 0.45 | 3.11 | 7.3-10.3 | -0.24 | 3.35 |
| Quarry lake | BH_58 | 0.77 | 4.19 | 11-14 | 3.47 | 0.72 |
| | BH_59 | 0.46 | 2.14 | 6-9 | 1.34 | 0.81 |
| | BH_60 | 0.47 | 1.34 | 12-15 | 1.33 | 0.01 |
| | BH_61 | 0.55 | 2.56 | 6-9 | 1.33 | 1.22 |
| | BH_62 | | 3.48 | 5-8 | 1.34 | 1.92 |
| McIntosh Drain | BH_63 | 0.56 | 2.98 | 3-6 | 1.49 | 1.49 |
| Woodend Beach Rd | BH_64 | | 4.73 | 5.6-7 | | |
| | BH_65 | 0.66 | 3.89 | 3-4.5 | 2.50 | 1.39 |
| Woodend Beach Rd to Gladstone Rd | BH_35 | | 4.91 | 2-6 | 2.99 | 1.915 |
| | BH_66 | | 5.08 | 3-6 | 3.12 | 1.96 |
| Gladstone Rd | BH_67 | | 6.71 | 3.5-4.5 | 3.94 | 2.775 |
| | BH_68 | | 6.16 | 3.5-6 | 0.01 | |
| Gladstone to Pegasus | BH_69 | | 5.52 | 3-6 | 0.01 | |
| Pegasus Approach | BH_29 | 0.35 | 9.30 | 6.5-7.5 | 8.06 | 1.24 |
| | BH_36 | | 10.34 | 1.7-4.7 | | |
| | BH_70 | 0.61 | 9.63 | 2.5-4.5 | 8.07 | 1.56 |

| Location | Borehole ID | TOC (m bgl) | Ground elevation RL (m) | Depth of piezometer screen (m bgl) | Initial GWL (m RL) | Initial GWL (m bgl) |
|---|---|---|---|---|---|---|
| Pegasus Interchange | BH_71 | 0.64 | 9.27 | 3-6 | 8.09 | 1.19 |
| | BH_73 | 0.66 | 8.76 | 3.7-6.7 | 6.36 | 2.40 |

Recent investigations have confirmed that the reported depth to groundwater is variable across the Project area, typically from ground level to 2.5 m depth with some discrete locations having water levels more than 3 m bgl. These levels reflect early winter groundwater levels and further increases in groundwater level may occur. Based on the long-term groundwater level monitoring at BW24/0523, groundwater levels typically peak between June and August. The tabulated groundwater levels may be reflective of a seasonal high, considering the effect of the heavy rainfall event of 30 April/ 01 May 2025, and will be confirmed by proposed ongoing monitoring (see following section).

### 5.3.2 Ongoing groundwater level monitoring

Non-vented electronic pressure transducers (MicroSensor Level Transmitters) have been installed in all of the monitoring wells so that groundwater level measurements, recorded at 15-minute intervals, can be collected over the monitoring period. This essentially continuous monitoring will allow records of fluctuations in groundwater levels (e.g. in response to rainfall) to be captured across all seasons at each monitoring well along the alignment. A barologger (Solinst Leveloggers®) has also been installed in piezometer BH_61 east of Quarry Lakes.

#### 5.3.2.1 Groundwater monitoring

Pre-construction monitoring at the network of shallow piezometers will be established along the Project alignment to address WDC designation conditions. Monitoring at these locations will allow the collection of baseline data on groundwater level.

Groundwater monitoring could continue as part of the construction monitoring to manage the low risk of changes to groundwater during specific activities; piling activities, ground improvements, quarry lake infilling and dynamic compaction during the construction works.

## 5.4 Groundwater surface modelling

A groundwater model has been developed by T+T to predict groundwater depth and level across the Project in advance of field data collection via telemetry. The T+T groundwater model uses data from recorded groundwater observations compiled from the NZGD and has been developed using a stepwise approach which included model building, local refinement of data and post-processing. The model estimates the 85$^{th}$ percentile groundwater levels (i.e. the groundwater level is below the modelled levels for 85 % of the time, and above this for 15 % of the time). This reflects the variation in groundwater levels during the year and is shown in Figure 5.1. The model is described in detail in Appendix F and provides a figure showing the modelled groundwater surface over the Project.

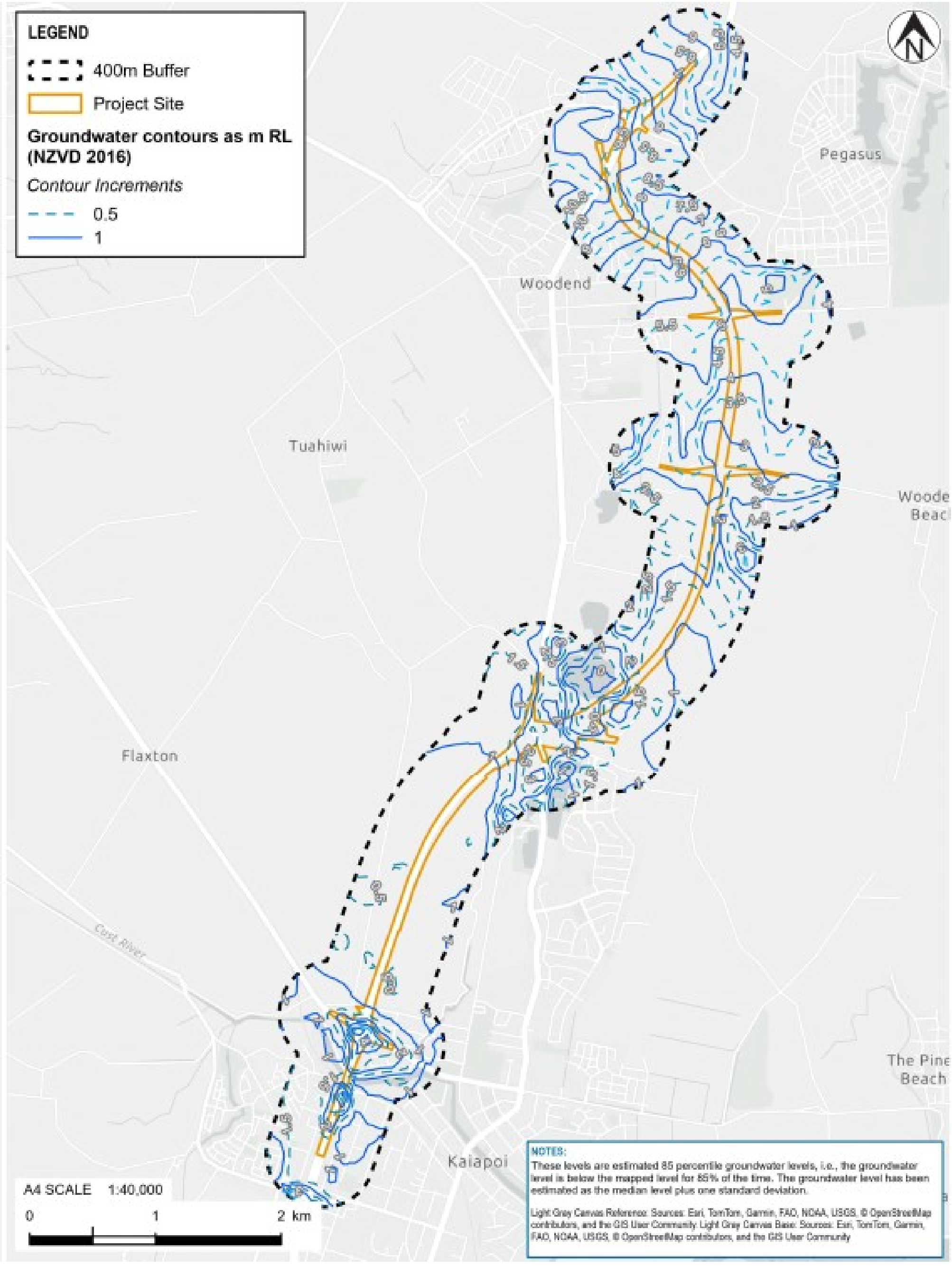



*Figure 5.1: Modelled 85th percentile groundwater levels.*

## 5.5 Groundwater quality

Groundwater samples have been collected from the five recently installed piezometers to assess the general groundwater quality in the vicinity at the following locations:

- Kaiapoi bridge BH_51.
- Quarry Lakes BH_58 and BH_59.
- Woodend Beach Road BH_65.
- Pegasus interchange BH_71.

The tabulated water quality results and laboratory transcripts are included in Appendix C.

the results show the overall groundwater quality is fairly consistent across the Project. Those parameters with exceedances against the ANZG guideline values (Appendix C) are also generally consistent with those identified as having high or increasing concentrations in groundwater in the 2023 annual groundwater quality survey for the Canterbury region (as described in Section 4.3.2.1.3). The general groundwater quality observations are noted include:

- pH in BH_58 has a higher pH unit than other water samples and this alkalinity is similar to the lake water pH.
- Zinc is not monitored in the groundwater quality survey[15], but exceeds the ANZG 95 % guideline value at BH_65 and BH_71. Zinc is a more typical urban land use contaminant.

As described in Section 4.3.2.1.4, electrical conductivity (EC) in conjunction with Cl concentrations in groundwater, can be used to indicate the potential for saline intrusion. Based on the concentrations of these indicator parameters in the groundwater sampled from the piezometers, it is unlikely that the shallow groundwater quality is being influenced by seawater in these areas. We note that BH_71 has slightly elevated EC and Cl concentrations, however we infer that BH_71 is not affected by saline intrusion because of its inland location.

Overall, it is likely that the shallow groundwater quality is indicative of the wider agricultural/ horticultural and urban land use in the groundwater catchment.

# 6 Project-wide items

## 6.1 Proposed activities

Some Project-wide activities will occur along the alignment which have the potential to result in effects on groundwater. Where these activities are not at a specific location, as described in Sections 7 to 13, these are included in this section. Overall, these activities include:

- Installation of culverts.
- Shallow excavations for stormwater swales, cut-off drains and minor excavations for utilities.
- Shallow excavations for construction of the road.
- Earthworks and placement of road embankment.
- Decommissioning of bores.

Whilst the surface water take from the Quarry Lakes is for the Project-wide construction works, it is described in Section 10 along with other activities in and around the Quarry Lakes.

## 6.2 Summary of Project-wide conceptual hydrogeology model

The overall conceptual understanding of the hydrogeology for the Project is as follows:

- Shallow unconfined aquifer within the interbedded sediments in the Springston and Christchurch Formations with shallow groundwater levels.
- Shallow groundwater inflows contribute to some stream baseflows.
- Deeper confined aquifer separated by a confining layer of variable thickness across the area. The first confined aquifer is the Riccarton/Burnham Aquifer within gravel strata.
- Aquifer 2, confined aquifer of the Linwood Formation is also encountered by the investigations at approximately 30 m depth.

Full details on the Project hydrogeology are described in Section 4.

## 6.3 Project-wide groundwater quality considerations

Groundwater quality changes may occur with certain construction activities such as excavations, groundwater takes, and ground improvements. The effects on groundwater quality are evaluated as effects on groundwater receptors e.g. change in groundwater quality at boreholes or in surface water. The source-pathway-receptor (SPR) model is used to evaluate groundwater quality effects on receptors. The SPR model is a conceptual framework used to assess environmental risks by identifying and evaluating the potential for contaminants to impact sensitive receptors.

### 6.3.1 Source-pathway-receptor relationship

#### 6.3.1.1 Source

The source refers to the origin of contamination or the hazard. This may include point sources such as sediment laden discharges, spillage from concrete pours, fuel leaks from construction plant, or diffuse sources like agricultural runoff. Characterising the source involves identifying the type of contaminants, their concentrations, and the spatial and temporal extent of contamination.

#### 6.3.1.2 Pathway

The pathway is the route through which contaminants travel from the source to the receptor. In hydrogeological contexts, pathways typically include groundwater flow through aquifers or surface water movement. The integrity and characteristics of geological strata, hydraulic conductivity, and the presence of preferential flow paths (e.g., fractures or utility corridors) are critical factors influencing pathway viability.

#### 6.3.1.3 Receptor

The receptor is any entity that may be adversely affected by the contaminant. Receptors can include human populations (e.g., residents, construction workers), ecological systems (e.g., wetlands, aquatic habitats), and physical assets (e.g., water supply wells, infrastructure). The sensitivity and exposure potential of receptors are assessed to determine the level of risk posed by the contaminant.

#### 6.3.1.4 Contaminant linkage

A complete SPR linkage exists only when all three components the source-pathway-receptor relationship are present and connected. If any component is absent or interrupted (e.g., no viable pathway or receptor), the risk is considered incomplete or negligible. The identification and evaluation of SPR linkages are essential for implementing risk mitigation strategies.

An example of a SPR relationship for temporary works, specifically in relation to turbidity is:

- **Source**: Excavation, piling, leaching from concrete structures, or dewatering activities disturb sediments.
- **Pathway**: Suspended particles migrate via groundwater or surface water flow.
- **Receptor**: Wetlands, groundwater users, or sensitive habitats.

Management of this activity could include installation of silt curtains, staged excavation, and real-time turbidity monitoring to help break or control the pathway.

An example of a SPR relationship for permanent long-term effects, specifically in relation to stormwater discharges is:

- **Source**: Contaminated stormwater runoff.

- **Pathway**: Percolation through soil in the unsaturated zone, infiltration into underlying shallow groundwater or direct discharge into receiving surface waters.
- **Receptor**: Wetlands or surface water bodies.

Management of this activity could include the use of stormwater treatment systems such as infiltration basins and planted swales to minimise effects.

### 6.3.2 Groundwater quality issues

#### 6.3.2.1 Changes to groundwater quality from concrete ground improvements

Introducing concrete into groundwater can result in a pH increase (i.e. an increase in alkalinity) due to the leaching of hydroxide ions from the concrete[30]. This occurs because the hydration of Portland cement releases calcium hydroxide, which dissociates into calcium ions and hydroxide ions. The hydroxide ions cause increases in pH and can create elevated alkalinity in water (pH > 7). Research under laboratory conditions[30] shows the greatest change in pH occurs soon after placement, prior to curing, with ongoing increases up to pH 11.5.

As concrete cures, groundwater (and surface water) in contact with it becomes alkaline[31]. Once cured, the leaching of hydroxide ions significantly reduces. Concrete interaction with water can lead to:

- Elevated pH levels in groundwater and surface water.
- Adverse effects on wetlands due to high alkalinity.
- Compositional changes in groundwater, including decreased ion concentrations[32].
- Increased dissolution of heavy metals[31] as a result of increased levels of pH, for example dissolved arsenic.

The amount of leaching from concrete and the extent of alkaline plume mobility in groundwater depends on:

- Concrete mixture, pile geometry, and volume[30].
- Aquifer matrix permeability and local hydraulic gradient.
- Dilution and dispersion processes in the aquifer.

Overall, it is identified that the impact of concrete on groundwater can be significant, but it is also likely to have only a localised effect. Monitoring undertaken by T+T at sites in Wellington[33] and Auckland[34], in silt aquifers and silt and sandy silt aquifers, showed the pH rose no more than 0.5 pH units in groundwater monitored in wells located 2 m and 30 m down gradient of in-situ mass stabilising ground improvements involving significant cement volumes.

#### 6.3.2.2 Changes to surface water quality from concrete ground improvements

For the Project, many of the ground improvement activities occur in close proximity to surface waters. These are likely to be the nearest ecological receptors for groundwater which provides stream baseflow. Increase in pH of river water due to elevated pH could have an adverse effect on

[30] Law, D. W. & Evans, J (May-June 2013) Technical paper – Title no. 110-M24. Effect of leaching on pH of surrounding water. Published in ACI Materials Journal.

[31] Tonkin +Taylor (October 2006). Proposed Piling at the Fitzgerald Bridge, Christchurch - Potential Adverse Effects on Groundwater and Surface water.

[32] Nilsson, A., C & Sandberg, B. (January 2017). Elevated pH values in groundwater – Observations from SKB investigations 1976-2014 and possible causes. Report R-16-04. Svensk Kärnbränslehantering AB (SKB).

[33] Tonkin +Taylor (May 2015) WGN150118: 270 High Street pH monitoring results.

[34] Tonkin +Taylor (November 2017) Site validation report - East2, 141 Pakenham Street West.

aquatic life[30]. The potential for the proposed Project ground improvements to result in an increase in pH of groundwater which may discharge to surface waters is considered in the hydrogeological assessments in the relevant sections.

ECan provides guidance on working with cement directly in surface water [35]. While works directly in surface water bodies is not proposed for the Project, it is expected that the Contractor will develop and follow similar procedures when working in groundwater and near surface water.

#### 6.3.2.3 Management, mitigation and controls

Examples of standard management controls on the potential groundwater effects for the installation of the piles and ground improvements could include:

- Site management and controls including practices to ensure no surface contaminants can enter the probe holes during installation.
- Drilling of the pile holes.
- Auger techniques to ensure installation of rigid inclusions.
- Management of confined aquifer and artesian pressures.
- Control of any bore flushing and management of the drilling fluids.
- Mixing and placement of the concrete.
- Control, collection and treatment of displaced water from the piles/ground improvements with protocols for correct disposal.
- Safe clean work practises, cleaning equipment in controlled areas away from surface waters.
- Erosion and sediment controls.

Such controls will be covered in the Groundwater Management Plan (**GMP**) and Erosion and Sediment Control Management Plan (**ESCMP**).

## 6.4 Hydrogeological effects assessment for Project-wide items

### 6.4.1 Overview

The proposed activities described in Section 6.1 have the potential to result in changes to the hydrogeological environment and may result in both positive and/or adverse effects, and temporary and/or permanent effects. These activities are summarised in Table 6.1 and where the activity has the potential to affect groundwater, this effect has been assessed in in Sections 6.4.2 and 6.4.3. A summary of the effects including the scale of effect is included in Section 6.5.

**Table 6.1: Summary of proposed activities at for the Project-wide activities**

| Proposed activities | Activity has potential to affect groundwater: | | |
|---|---|---|---|
| | Level | Quality | Flow |
| Temporary activities during construction | | | |
| Embankment construction | Yes | No | Yes |
| Culvert installation | Yes | Yes | Yes |
| Shallow excavations | No | Yes | No |
| Bore decommissioning | No | No | No |

35 https://esccanterbury.co.nz/project/other-waterway-tasks/.

| Proposed activities | Activity has potential to affect groundwater: | | |
|---|---|---|---|
| Permanent activities during operation | | | |
| Road embankments | No | No | No |
| Stormwater discharges | Yes | Yes | No |

### 6.4.2 Temporary effects

#### 6.4.2.1 Culvert installations

McIntosh Drain culvert (ID:005) is the only major culvert not included with the other Project components. The new culvert will be installed immediately north of the existing McIntosh Drain channel. The construction work will be offline, i.e. the existing drain will continue to operate while this drain is completed. Additional excavation will be completed to remove soft soils below the culvert invert depth. The key details of this excavation are shown in Table 6.2.

**Table 6.2: Excavation dimensions for culvert installations at McIntosh Drain**

| Culvert ID | Surface water | Width (m) | Length (m) | Excavation depth range (m bgl) | | Excavation Base (m RL) |
|---|---|---|---|---|---|---|
| Culvert ID005 | McIntosh Drain | 5 | 50 | 3 | 3.1 | -1.1 |

Based on the recorded depth to groundwater in local test pits of approximately 1.6 to 2.9 m bgl (0.3 m to -1.8 m RL) and based on the water levels in the existing McIntosh Drain, shallow groundwater will be encountered during the excavation and dewatering will be required.

##### 6.4.2.1.1 Effects on groundwater

An assessment on the dewatering effects is included in Appendix G which includes a list of assumptions used to make this assessment. The results of this assessment are presented in Table 6.3. The calculated results show maximum assessed effects based on a conservative groundwater level, the indicative excavation dimensions and anticipated dewatering duration (assumed as up to 30 days).

**Table 6.3: Maximum assessed drawdown effect from dewatering at culvert ID005**

| Culvert ID | Drawdown within excavation(s) (m) | Radius of drawdown extent (m) |
|---|---|---|
| Culvert ID005 | 2.6 | 180 |

Note: Radius of drawdown is from the centre of the excavation.

The radius of drawdown extent is limited to local distances from the excavation and the maximum predicted distance from the centre of the excavation where dewatering occurs to where the amount of drawdown is estimated to be nil/less than measurable.

The dewatering assessment assumes laterally extensive, homogenous deposits with the maximum radial extent uniform in each direction. In reality, these radial drawdown effects will vary in each direction due to the heterogenous nature of the shallow sediments, where variability in the lateral continuity and the permeabilities of the sediments exist. This means the amount of local drawdown on the shallow groundwater (unconfined aquifer) beyond the immediate excavation could be smaller than predicted.

#### 6.4.2.1.2 Effects on ground settlements

Dewatering also has the potential to trigger ground settlements at the surface (see Appendix G). Settlement may occur in response to volumetric loss of soils during pumping resulting in the mobilisation of fines, lateral movement of excavation walls resulting in mechanical settlement, and changes in effective stress imposed on the underlying soils resulting in consolidation settlement. The effects are all permanent and localised to within the radius of drawdown extent. Volumetric loss is estimated to be within the order of 2 times the excavation depth beyond the edge of the excavation wall. This can be caused by excessive pumping and/or inappropriate screen sizing on dewatering devices.

Mechanical settlement may occur where inadequate shoring/support of excavation walls is adopted or where excavation batters are too steep. Similarly, the effect is likely to be localised to within the order of 2 times the excavation depth beyond the edge of the excavation wall.

Consolidation settlement occurs within soils in response to changes in effective stress but is more problematic in soils with a higher consolidation potential (e.g. soft soils comprising clay, silt, high organic content or peat). Dewatering results in an increase in the effective stress triggering an increase in porewater pressure within consolidation prone soils. As the porewater pressure dissipates, these soils consolidate resulting in irreversible settlement within the soils. Dissipation of porewater pressure within consolidation prone soils may not occur rapidly meaning settlement may take time to be realised. Triggering of consolidation settlement ceases once the groundwater levels return to pre-dewatered levels.

Appropriate management and construction methodologies, to be described in the GMP, can be implemented to reduce the effects of dewatering induced ground settlements. These include:

- Adoption of suitable pumping rates/screen sizing can be used to manage some volumetric loss.
- Battering or shoring of the excavation walls can be implemented to minimise mechanical settlements.

The temporary duration of the dewatering is not likely to provide sufficient time for porewater pressures within consolidation prone soils to dissipate, and this could result in appreciable ground settlement effects. Mitigation measures such as the discharge of groundwater to ground within the zone of influence of the groundwater drawdown reduces the net drawdown effect. This in turn reduces the change in effective stress and potential for consolidation settlement to be triggered.

In the event consolidation settlement were to occur, the hydraulic conductivity could be permanently reduced which could have an effect groundwater by reducing groundwater flow through the consolidated soils. However, the magnitude of settlement likely to be experienced over the short durations of the dewatering is small with the change in the hydraulic conductivity properties of the soils and groundwater flow assessed as low. While settlement effects are expected be permanent, the triggering is expected to only occur during construction and therefore have only been assessed under the temporary works effects only.

Other groundwater effects of culvert installation are described in the following sections.

#### 6.4.2.1.3 Effects on surface waters

Due to the location of the culvert, the dewatering could result in a high stream depletion effect on McIntosh Drain. However, the abstracted groundwater will be discharged back into McIntosh Drain just upstream of the affected reach after water treatment to remove sediment. Thus, the stream flows will be managed in a way that negates any depletion effects, and the effects will be low.

The volume and rate of discharge will be determined by the Contractor. However, the duration of the dewatering is likely to be less than 30 days. Due to the low flows in the McIntosh Drain, the discharge rate could be greater than the stream flows and this would need to be managed to ensure that flooding or erosion does not occur downstream.

The effects on other surface water features such as wetlands will be negligible. The closest wetland FA_W1_NPSFM is approximately 100 m west of McIntosh Drain crossing, as shown in Figure 6.1 and is not hydraulically connected with groundwater (described in Appendix H). Other wetlands of the Fullers Road complex are approximately 450 m to the northeast and east of McIntosh Drain beyond the conservatively assessed extent of drawdown effects.


*Figure 6.1: Existing wetland extent and defined catchment for FA_W1_NPSFM near to McIntosh drain.*

#### 6.4.2.1.4 Effects on other groundwater users

The nearest groundwater user to the culvert excavation is bore M35/5576 at 75 Barkers Road, approximately 350 m to the south beyond the assessed extent of drawdown effects. There is no cDWPZ within 1 km of the culvert excavation.

No well interference assessment using LWRP Schedule 12 (WQN10) well interference tool[36] has been completed for this assessment because the predicted drawdown effects from the dewatering assessment are calculated to only extend to 175 m from the excavation. For this reason, Schedule 12 assessments have not been completed for other dewatering assessments. Therefore, the effects on groundwater users from the potential dewatering activities is assessed as negligible.

[36] ECan. Well Interference Assessment: http://tools.ecan.govt.nz/wqn10/, Accessed 29 July 2025.

#### 6.4.2.1.5 Effects on groundwater quality

The effects on groundwater quality will be limited to increased sediment loading in the water at the base of the excavation at McIntosh Drain. Mobilisation of suspended sediment will be restricted and will be removed by the pumping of groundwater as part of the dewatering.

The Contaminated Land Investigation (Volume 3F) has not identified the local area in the vicinity of the excavation to be either contaminated or potentially contaminated land. This means there is limited potential for mobilisation of contaminants to occur as a result of the pumping i.e. inducing inward groundwater flows into the excavation thus mobilising potential contaminants, as described in Section 6.3.1. On this basis no other water quality effects on groundwater are predicted as a result of the pumping.

As discussed in Section 4.3.2.1.3, saline intrusion is unlikely at the Project site. Changes to the existing groundwater salinity at this location of the dewatering activities, and at other locations where dewatering could be undertaken at the Project site, is not expected to occur. The effect on groundwater salinity (including potential for saline intrusion) is therefore assessed as being less than measurable and negligible**.**

The overall effect on groundwater quality on identified receptors is assessed as negligible.

#### 6.4.2.1.6 Effects of discharge water quality at point of discharge

Dewatering will generate water to discharge. Total suspended solids (TSS) at the point of discharge will be managed by the Contractor through specification in the GMP with the intention of meeting the discharge water quality requirements.

As described above, the Contaminated Land Investigation (Volume 3F) has not identified the local area in the vicinity of the excavation to be contaminated or potentially contaminated land. Therefore, other water quality effects on the discharge are not expected and the water quality effects at the point of discharge will be negligible.

#### 6.4.2.2 Stormwater swales and cut-off drains

Most of the stormwater swales and bioretention devices will be constructed on the road embankment raised above the existing ground level. There will be no interception of shallow groundwater by swales and stormwater collection systems during construction.

Stormwater bio-retention and bio-infiltration basins will be installed in areas where groundwater is expected to be deeper than the invert level of the basins and excavations will be above the depth of shallow groundwater.

The primary purpose of the cut-off drains is to intercept surface water from off-site and prevent it entering the stormwater swales. The installation of the cut off drains has the potential to result in minor interception of shallow groundwater in one area being diverted locally to another location. It is expected that most of the cut off drains will not intercept groundwater. This is described in Section 3.4.

Based on the currently available groundwater level data, groundwater interception by cut off drains could occur in the areas of Cam River/Ruataniwha and McIntosh Drain where deeper excavations are anticipated. On a conceptual basis, the groundwater intercepted at these locations is likely to be the same groundwater that is ultimately discharging to the surface waters of Cam River/Ruataniwha and McIntosh Drain. The groundwater interception by the construction of the cut-off drains is assessed as a non-consumptive effect.

#### 6.4.2.3 Earthworks

##### 6.4.2.3.1 General excavation

As described in Section 3.2.1, extensive earthworks, predominantly as filling will be required to construct the road embankments and this could result in effects on groundwater with potential changes to the overall localised groundwater regime (e.g. quality, level and flow) which could have an effect on groundwater receptors.

Temporary activities include excavation over, within 1 m of, and potentially into shallow groundwater. There will be no excavation of any confining layer due to the depth of the confining layer being typically at depths greater than 15 m and due to the shallow nature of all of the excavations.

General excavation into groundwater for the construction of the road embankment is not expected. Other potential excavations into groundwater are covered in report sections describing the culvert installations and ground improvements.

In most areas of the Project, it is assessed that the potential for contaminants to be encountered during excavation activities in groundwater is very low, with a correspondingly low risk of contaminants entering groundwater and altering the groundwater quality. One area on the Project requires further investigation at Gladstone Road, and this is described in detail in Section 12.

Therefore, it is considered that the overall effects on groundwater from general excavation activities will be negligible and therefore the effect on groundwater receptors will be negligible.

##### 6.4.2.3.2 Filling

Temporary filling activities could result in effects on groundwater with potential changes to local groundwater recharge, levels and flows. The placement of fill and associated stockpiling of material will occur along most of the alignment with additional designated stockpile areas at key locations where larger temporary storage volumes are required.

Material storage and areas of filling, such as temporary haul roads will locally reduce the groundwater recharge in the area covered by the fill and stockpiles by limiting rainfall recharge to the underlying shallow aquifer. Reduction in recharge could reduce groundwater levels and consequently alter groundwater flows in the shallow aquifer.

It is considered that the reduction in surface area from these filling activities compared with the area of the groundwater catchments is very small and the reduction in recharge and therefore changes in groundwater levels will not likely be measurable. Rainfall onto the fill areas will either:

- Infiltrate through fill material (expected to be moderately permeable granular material) to reach the underlying natural deposits/vadose zone; and/or
- Be collected by the temporary erosion and sediment control measures installed for the construction, where stormwater will most likely be discharged to ground at adjacent locations to the construction sites and thus providing groundwater recharge.

Therefore, the effect on groundwater recharge and the overall groundwater regime from the filling activities will be negligible.

##### 6.4.2.3.3 Effect on wetlands

Direct effects on wetlands are identified where the placement of fill for the road embankment and associated stockpiling occurs within the wetland extents and catchment areas, thus reducing the amount of recharge and the size of the catchment area. These are effects are discussed in the relevant sections of this report (9 to 13).

#### 6.4.2.4 Other associated activities and effects

##### 6.4.2.4.1 Construction support areas

Temporary effects on groundwater from the establishment of CSAs is assessed as negligible considering controls likely to be implemented in the GMP. The potential effects caused by minor earthworks for site establishment are covered in the general excavation section. Storage of hazardous construction materials (if any) will be limited and will be managed following guidance in the GMP. Hazardous construction materials will not be stored in cDWPZ. Details of CSAs within cDWPZ are described in Section 7.4.2.3.

##### 6.4.2.4.2 Effects on groundwater users

As described in Section 4.6, there are 163 bores within 400 m of the Project Site. Groundwater users may be affected by the construction works activities.

Those bores less than 20 m deep are considered most likely to be intercepting the unconfined shallow aquifer. The bore survey identifies 50 bores recorded as shallower than approximately 20 m depth (where depths are recorded). These bores could be affected by the construction activities.

Bores greater than approximately 20 m depth are considered to target deeper groundwater within the confined aquifer system. There may be limited groundwater effects on these bores at specific locations where deeper piling works and ground improvements are proposed.

All existing bores considered to be potentially affected by the Project activities are included in the assessment of effects for each Project component in Sections 7 to 13.

##### 6.4.2.4.3 Effects on drinking water supply source water (cDWPZ)

As background, WDC will have prepared Source Water Risk Management Plans (SWRMPs) for each of its registered public water supplies. These SWRMPs will have been prepared in accordance with the requirements of the Water Services Act 2021[37] and each WDC PWS bore will have three Source Water Risk Management Areas (SWRMAs) delineated around each water supply. These SWRMAs are different to the CLWRP defined cDWPZs. In general, in accordance with the Ministry for the Environment (MfE) guidance[38], for groundwater sources, the three SWRMAs will comprise:

- SWRMA 1 - an immediate 5 m protection area around the wellhead or intake for groundwater sources to prevent direct contamination of the water source.
- SWRMA 2 - an intermediate protection area to reduce microbial contamination risks, based on 1 year groundwater travel times to the water supply.
- SWRMA 3 - a catchment area based on the entire up-gradient area of the catchment, to ensure long-term protection of the water source.

SWRMPs will contain risk assessments on potential sources of contamination based on current and historic land uses within the catchment and it is likely that consideration of existing activities from roads and road users would have been considered. However, it is unlikely that these plans would have considered the risks and environmental effects from a new road alignment.

Given the close proximity of the WDC PWS sources to the Project, and the regional groundwater flow direction, it is assumed that the project alignment sits within the SWRMA 2 and SWRMA 3 of

[37] Water Services Act 2021 No 36 (as at 03 September 2024), Public Act Contents – New Zealand Legislation

[38] Paddle Delamore Partners Ltd, 2018. Technical guidelines for drinking water source protection zones (No. C01671502). Prepared for the Ministry for the Environment. https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/technical-guidelines-for-delineating-drinking-water-source-protection-zones.pdf.

WDC drinking water supplies as identified in Section 4.6.2. Therefore, the actual and potential effect of Project activities on the WDC registered drinking water supplies are considered for the relevant Project components where cDWPZ exist in Sections 7 and 12.

#### 6.4.2.4.4 Bore decommissioning

The bore survey indicates there are 16 bores that are located within the designation and require decommissioning during construction of the road. These bores are summarised in Table 6.4 and are shown on figures in Section 7 to 13, where relevant. Prior to construction works commencing NZTA will take ownership of all these bores through its land acquisition process. Details on bore decommissioning are provided in Section 3.8. Bore decommissioning will be completed by backfilling with suitable material to ensure bores will be:

- Sealed to prevent vertical mixing of groundwater between aquifers.
- Permanently confine groundwater in the aquifer to the position that it originally occurred.
- Sealed to prevent any contaminants and surface water from entering the bore.

Details on the process for bore decommissioning will be detailed in the GMP prior to construction. These works are temporary and the overall effect on groundwater will be negligible.

**Table 6.4: Summary of bores requiring decommissioning during road construction**

| Bore ID | Depth (m bgl) | Address or Land Parcel | Bore use | Status* |
|---|---|---|---|---|
| M35/5603 | - | 1250 Main North Road | - | Unknown – 'not-used'. |
| M35/10715 | 6.7 | Existing SH1 road corridor | Monitoring | Unknown, mapped on road verge. Current bore owner developers; Templeton Group. |
| M35/17937 | 10.5 | 829289 | Monitoring | Active (exist, present) |
| M35/8899 | - | 146 Main North Road | Domestic Supply | Unknown - 'Active (exist, present)'. |
| M35/3075 | 22 | 130B Main North Road | Irrigation | Unknown – 'not-used'. Owned by NZTA. |
| M35/4455 | - | 160 Gladstone Road | - | Unknown – 'not-used'. |
| M35/0548 | 16.8 | 2 Fullers Road | Irrigation | Unknown - 'Active (exist, present)' . |
| M35/0478 | - | 1 Fullers Road | Domestic Supply | Unknown - 'Active (exist, present)'. |
| M35/18178 | 4.6 | 490610 | Monitoring | Active (exist, present). Owned by Readymix. |
| M35/18658 | 23.9 | Existing SH1 road corridor | Monitoring | Active (exist, present). Owned by NZTA. |
| M35/0505 | 131.1 | 264 Lees Road, Kaiapoi | - | Unknown – 'not-used'. |
| M35/0515 | 91.4 | 567 Williams St Kaiapoi | Domestic | Active (exist, present). |
| M35/17738 | 10.5 | Existing SH1 road corridor | Geotechnical / Geological Investigation | Unknown – 'not-used', mapped on road verge. Owned by NZTA. |
| M35/17737 | 14.0 | Existing SH1 road corridor | | |
| M35/0767 | 90.2 | Existing SH1 road corridor | - | |

| Bore ID | Depth (m bgl) | Address or Land Parcel | Bore use | Status* |
|---|---|---|---|---|
| M35/1797 | 88.7 | Existing SH1 road corridor | - | |

Note: * as defined by PDP. Unknown denotes bores not identifed by bore owner and PDP.

### 6.4.3 Permanent effects

#### 6.4.3.1 Road embankment

As described in Section 3.9, the road embankments could result in effects on groundwater with potential changes to the local regime.

The road embankments will locally reduce the groundwater recharge in the area covered by the embankment by limiting rainfall recharge to the underlying shallow aquifer. Reduction in recharge could reduce groundwater levels and consequently alter groundwater flows in the shallow aquifer.

It is considered that the reduction in surface area of the road embankments compared with the area of the groundwater catchments is small and the reduction in recharge, and therefore groundwater levels will not likely be measurable.

Rainfall onto the road embankment will be collected, as stormwater discharges by the constructed swales and bioretention basins. At most of the swale locations, the stormwater will be discharged into ground in the immediate vicinity of where the stormwater is collected and provide recharge to groundwater. At specific locations, stormwater will be conveyed to bioretention basins, thus providing groundwater recharge, albeit at a slightly different location but into the same shallow groundwater aquifer.

Therefore, the effect on groundwater levels from the road embankment will be negligible and therefore the effect on groundwater receptors will be negligible.

##### 6.4.3.1.1 Effect on groundwater flow

Depending on the ground conditions, potential consolidation caused by the road embankment onto the shallow soils could occur and result in changes to the groundwater flow by altering the permeability of the shallow unconfined aquifer matrix. The potential surcharge effect from the road embankment is limited to the road footprint width of approximately 40 m - 50 m and at the locations of overbridge embankments.

The shallow unconfined aquifer extends to depths to greater than 10 m where the confining layer is encountered. This means the potential barrier effects from the loading caused by the road embankment are not restricted by a shallower confining layer. However, the overall orientation of the road; south to north, generally crosses the groundwater flow paths from west to east and, potentially, there could be temporary groundwater mounding at the west side of the road embankment until porewater pressures have dissipated. Similarly, there could be down gradient effects on the east side of the road embankment, where shallow groundwater levels are slightly depressed by the restricted flow paths.

Based on the results of geotechnical investigations along the alignment, it is assessed that fill induced settlements will be limited to specific areas where compressible sediments exist at shallow depths. At these locations, ground improvements will be installed for the road foundation and thus the areas where most consolidation could occur will be mitigated (as reported in the Geotechnical Interpretative report[39]). Therefore, whilst there is the potential for this to occur, the magnitude of these effects is considered to be small and most likely unnoticeable on the groundwater

[39] T+T (August 2025) Geotechnical Interpretative Report.

environment. The overall effect on the groundwater environment from the road embankment during operation will be negligible and therefore the effect on groundwater receptors will be negligible.

#### 6.4.3.2 Stormwater retention and drainage

Generally there will be no interception of shallow groundwater by swales, basins, and proprietary devices with the exception of bioretention devices which will have underdrains as required. The operation of stormwater swales and basins will predominantly result in stormwater soakage to ground at the point of collection. At some locations, there will be minor changes to the discharge point, resulting in minor changes to the timing and amount of recharge to ground from the stormwater discharge e.g. as a result stormwater flowing to a low point in a swale.

At stormwater bio-retention and bio-infiltration basins, stormwater will be collected from wider areas. Stormwater will be retained in basins prior to discharge either to groundwater or surface water. These discharges will provide groundwater recharge and potentially will balance or result in a minor reduction in groundwater recharge. The overall changes in recharge are likely to be a non-measurable effect on groundwater levels and therefore a negligible effect on groundwater levels and flows.

The potential changes to groundwater quality could include elevated metals, nutrients and total petroleum hydrocarbons (TPH) in stormwater derived from road activities. The swales and bioretention basins will be lined with an infiltration media and planted, therefore sediment entrained in stormwater (TSS) will be collected and treated via the retention and infiltration processes. The expected efficacy of contaminant removal, described in the Stormwater and Flooding Assessment (Volume 3L) shows treatment efficiency, although has limited description on the existing or proposed stormwater quality. The stormwater treatment devices will be constructed in accordance with the NZTA guidelines.

Dissolved contaminants could enter the vadose zone and reach shallow groundwater. Some contaminants will be dispersed and diluted upon entering into and mixing with groundwater. The overall changes in groundwater quality are likely to be very localised at the points of discharge and are expected to have a non-measurable effect on groundwater quality further away from the point of discharge. The underlying ground conditions, comprising interbedded sediments are likely to retard stormwater contaminants through processes such as absorption and degradation, therefore, the stormwater discharges are likely to have a low effect on groundwater.

The overall effect on the groundwater environment and groundwater receptors from the operation of the stormwater system is assessed as low.

## 6.5 Summary of effects

A summary of the temporary and permanent effects on groundwater from the Project-wide activities, principally road embankment, culvert installation and stormwater drainage are provided in Table 6.5 and Table 6.6. Mitigation to reduce/minimise these effects is provided where the scale of effect is greater than ‘low’.

**Table 6.5: Temporary groundwater effects from Project-wide activities**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Culvert installation | Stream depletion | Low | - | - |
| | Well interference | Negligible | - | - |
| | Groundwater quality on receptors | Negligible | - | - |
| | Ground settlement | Low | - | - |
| Construction of stormwater drainage | Overall groundwater | Low | - | - |
| Earthworks | Overall groundwater | Negligible | - | - |
| Construction storage area | Groundwater quality on cDWPZ | Negligible | - | - |

**Table 6.6: Permanent groundwater effects from Project-wide activities**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Road embankment | Overall groundwater | Negligible | - | - |
| Stormwater drainage | Overall groundwater | Low | - | - |

# 7 Existing SH1 upgrades

## 7.1 Proposed activities

As described in Section 2.2, the proposed key activities relating to the hydrogeology effects at this location are limited and comprise:

- Installation of a culverts to replace existing culverts across SH1.
- Shallow excavations for stormwater swales, cut-off drains and minor excavations for utilities.
- Shallow excavations for construction of the road.

## 7.2 Environmental setting

### 7.2.1 Site location and general description

The area of the existing SH1 upgrades extends 4 km, starting south of the Kaiapoi River at Ohoka overpass to Cam River/Ruataniwha, as shown on Figure 7.1. At Kaiapoi, SH1 crosses the tidally influenced Kaiapoi River, and passes beside a commercial area (known as Waimak Junction) at Lineside where WDC's public water supply bores for the Rangiora water supply is located. Residential properties lie to the south of Kaiapoi River and to the north of Lineside. Beyond this and to the north, the area comprises rural farmland each side of the existing SH1. This area is low-lying, typically at 1 m RL, rising to 2 m RL toward Cam River/Ruataniwha. Land on the eastern side of SH1 is crossed by multiple drainage channels which discharge east into Cam River/Ruataniwha. These drains diverge from two crossing points beneath SH1 from the west. The existing SH1 upgrades discussed here do not include works at the Cam River/Ruataniwha.

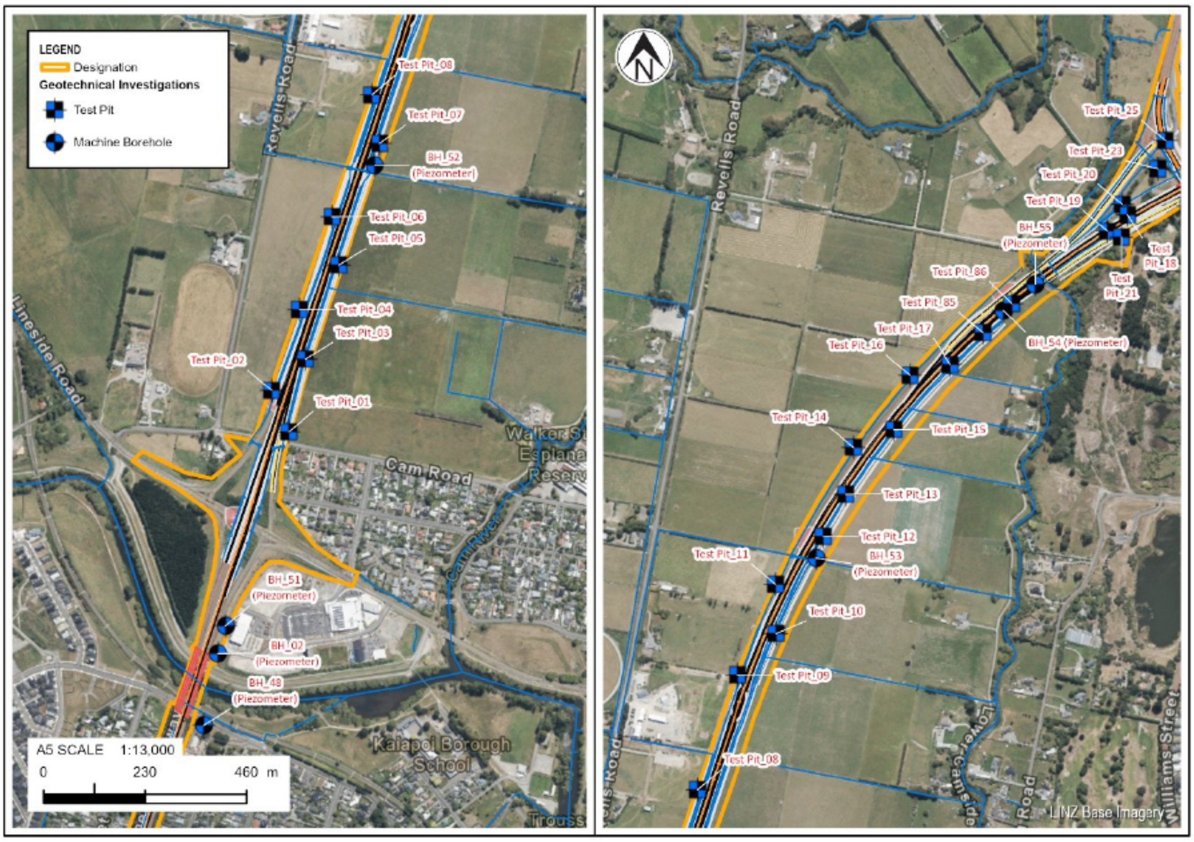



*Figure 7.1: General layout of existing SH1 upgrades and investigation locations (boreholes and test pits).*

### 7.2.2 Geology and hydrogeology

Table 7.1 provides a summary of the local geology. A schematic geological and hydrogeological section is presented in Figure 7.3.

**Table 7.1: Summary of local geology and hydrogeology at existing SH1 upgrade section**

| Geology & Hydrogeology | | Details |
|---|---|---|
| Published geology[3] | • Holocene river alluvial deposits. | • Predominantly soft silts shown as river swamp[3]. |
| Site specific investigations | • Interbedded sediments of sand/ gravelly sand to depths from 0.5 m – 3.6 m bgl.<br>• Deeper gravel sequence confirmed from depths from 2.7 to 20.1 m bgl. | • Based on piezos BH_02, BH_48, BH_51.<br>• See Figure 7.1. |
| Depth to shallow groundwater | At Kaiapoi/Lineside<br>• Range approx. 0.1 m to 0.2 m RL (2.3 to 3.9 m bgl). | • Based on piezos BH_02, BH_48, BH_51.<br>• Test pits TP_01 to TP_04.<br>• Figure 7.1. |
| | At Lineside to Cam River/Ruataniwha<br>• Range approx. 0.3 m to -1.0 m RL (0.6 m to 2.0 m bgl). | • Test pits TP_05 to TP_16.<br>• See Figure 7.1. |
| | • Coastal Confined Aquifer System. | • See Figure 3.3. |

| Geology & Hydrogeology | | Details |
|---|---|---|
| Identified aquifer system[1] | • Unconfined /Semi-confined Aquifer System. | • Identified between Kaiapoi River and Lineside intersection. |
| Groundwater flow direction | At Kaiapoi/Lineside:<br>• Toward northeast[40]. | • Variable flow directions, perpendicular to groundwater contours along a short distance.<br>• See Figure 3.3. |
| | At Lineside to Cam River/Ruataniwha:<br>• Toward southeast to south-southeast[40]. | |
| Groundwater quality | • Groundwater sample collected from monitoring wells; BH_51. | • See Section 5.5 & results in Appendix C<br>• Groundwater quality reflects the natural expected groundwater conditions. |
| Additional data | • CDWPZ for bores M35/11199, M35/11908, M35/11909, M35/11910 & BW24/0437 at Waimak Junction (Lineside). | • WDC public water supply bore depths 152 m to 193.6 m.<br>• Confined aquifer.<br>• See Figure 7.2. |

Note: 1. As defined on the LWRP planning maps.

### 7.2.3 Hydrology

Two surface waters are in the immediate vicinity of the existing SH1 upgrade section. Table 7.2 provides a summary of these and other nearby water features. Full descriptions of the wetlands are in Appendix H.

**Table 7.2: Summary of nearby water features to existing SH1 upgrade section**

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| Surface water catchments | • Kaiapoi River | • n/a | • As defined on Canterbury Maps[20].<br>• See Figure 4.5. |
| | • Cam River/Ruataniwha | • n/a | |
| Surface waters | • Kaiapoi River | • Crossed by SH1 | • See Figure 7.4. |
| | • Rossiters Drain | • Crossed by SH1 | • Not identified as 'RMA river'. |
| | • Wilsons Drain | • Crossed by SH1 | • Identified as 'RMA River – modified natural stream'. |
| | • Cam River/Ruataniwha | • 50 m NE | • Nominal distance |
| Wetlands | • None | • n/a | • n/a |
| Springs | • None identified | • n/a | • n/a |

It is noted that both the Kaiapoi River and Cam River/Ruataniwha have been modified during construction of the Northern Motorway in the late 1960s.

### 7.2.4 Surrounding groundwater users

Details of the bore survey are described in Section 4.6. Bores included in Table 7.3 are all of those bores within 400 m of the designation boundary for the existing SH1 upgrade and Figure 7.2 shows the area where most bores occur at Lineside, including bores with cDWPZ. The Site Plan and

[40] ECan Waimakariri shallow groundwater - piezometric contours (May 2011).

Environmental Features (Volume 4C) include all of the bores located in the existing SH1 upgrade area.

**Table 7.3: Results of bore survey for all known bores[27] within 400 m of the designation for the existing SH1 upgrade**

| Bore status | Bore use | Number of bores | Depth range (m) |
|---|---|---|---|
| Confirmed as present | Water supply purposes | 15 | 8 - 93.3 |
| | Other uses | 2 | 4 - 23.9 |
| Unconfirmed | Bore details not confirmed by owner | 7 | 19 - 131.1 |
| Unsure | Owner unsure if bore exists | 2 | 17.2 - 18.3 |
| Capped/sealed | n/a | 0 | - |

Notes: Details of bore use are provided in Section 4.6.1.

Table 7.4 provides details of those bores that may be affected by the temporary and permanent activities associated with the Project. Due to the nature of the proposed activities, there will be limited effects on the surrounding bore users and only bores with the potential to take water from the shallow unconfined groundwater within 10 m of the surface are included. These bores are considered to have most potential to be affected by activities such as short-term dewatering activities. Consideration of the PWS bores in included in the following Section 7.4.2.1. The effects on bores within the alignment are not considered because these will be decommissioned, as described in Section 6.4.2.4.


*Figure 7.2: All known bores within 400 m of the Designation surrounding Lineside interchange (source: modified from PDP Bore Use Survey[27].*

**Table 7.4: Bores within 400 m of the designation for the existing SH1 upgrade that may be affected by the Project**

| Bore use | Number of bores | Comments |
|---|---|---|
| Shallow bores[1] (0 m - 10 m depth) for water supply purposes | 3 | 2 of these bores are unknown and may be deeper than 10 m. |
| Community drinking water bores | 6[2] | n/a |
| Bores within alignment requiring decommissioning | 4 | Owned by NZTA |

Notes:

[1] Water supply purposes are classified as those bores from which water is actively abstracted for a defined use such as domestic, stock water supply or irrigation. Community drinking water bores are listed separately.

[2] ECan identify 6 WDC PWS bores, but it is understood that there are 5 WDC PWS bores (WDC, Rangiora Water Supply Water Safety Plan (WSP): February 2018 (rev 1). TRIM No. 180213014155).

#### 7.2.4.1 Community drinking water supplies

There are five public water supply bores (known as the Rangiora public water supply (PWS) bores) close to the road alignment at Lineside interchange. These PWS bores take groundwater from a very deep confined aquifers, and it is considered that there is very limited hydraulic connection to the surface and shallow groundwater due to the thick sequence of overlying strata (including confining layers of low permeability material), and generally upward vertical hydraulic pressures in the artesian confined aquifer.

Whilst the identified aquifer system as defined on the CLWRP planning maps shows these PWS bores to be within the unconfined /semi-confined aquifer system, it is interpreted that the PWS bores take groundwater from a confined aquifer system. This is shown on the schematic conceptual hydrogeology model in Figure 7.3 in Section 7.3.

The key details of these WDC owned bores[41] are:

- Smith Street Well 1 (M35/11199), screen depth between 147.7 m and 149.7 m, located 380 m east of the designation.
- Smith Street Well 2 (M35/11908), screen depth between 150 m and 153 m, located 12 m east of the designation.
- Smith Street Well 3 (M35/11910), screen depth between 149 m and 152 m, located 200 m east of the designation.
- Smith Street Well 4 (M35/11909), screen depth between 147.5 m and 150.5 m, located 6 m east of the designation.
- Smith Street Well 5 (BW24/0437), screen depth between 191.6 m and 193.6 m, located 3 m south of the designation (on Smith Street).

The cDWPZ around three bores; M35/11908, M35/11909 and BW24/0437 extend into and across the designation at Kaiapoi bridge and Lineside interchange. The two other public water supply bores; M35/11910 and M35/11199 and their respective cDWPZs are located further away (approximately 100 m and 250 m) to the east, as shown in Figure 7.2. A sixth bore; M35/11911 is shown on Canterbury Maps at a similar location to bore BW24/0437 with the cDWPZ overlapping the cDWPZ for bore BW24/0437. It is understood that this bore is not in use and is not included in the details above. However, since the cDWPZ for bore M35/11911 coincides with the other cDWPZ, any potential effects are also considered in this assessment.

[41] ECan, borelogs for M35/7542, M35/11693.

## 7.3 Localised conceptual hydrogeology model

In summary, the hydrogeological conceptual model for the SH1 upgrades comprises:

- Shallow groundwater close to surface.
- Unconfined (water table) aquifer within alluvial deposits predominantly comprising silt and sand to shallow depths of approximately up to 4 m underlain by thick gravel sequence.
- Groundwater within the shallow aquifer is recorded to vary between approximately 0.6 m and 4 m bgl (0.1 m and 1 m RL).
- Locally, shallow groundwater discharges to drains which extend between Lineside and Cam River/Ruataniwha and these drain into Cam River/Ruataniwha to the east. Shallow groundwater provides minor inflows to the Cam River/Ruataniwha.
- At SH1 bridge over Kaiapoi River, it is not known how much groundwater contribution to river flows occur in this reach. However, the predominant flow volumes are controlled by tidal effects.
- Aquifer 1 of the confined aquifer system is inferred to be semi-confined to confined at Kaiapoi bridge, overlain by a thin organic silt layer as shown in Figure 7.3.
- The area of Waimak Junction, the area is mapped as the ‘Unconfined /Semi-confined Aquifer System’. The remaining area of the existing SH1 upgrade is identified as the coastal confined aquifer system.
- Based on the local geology observed in the PWS bore logs and the recorded groundwater levels (reported as flowing artesian at the time of drilling), abstraction at these bores is from the deep confined gravel/sand aquifers characteristic of the coastal confined aquifer system.

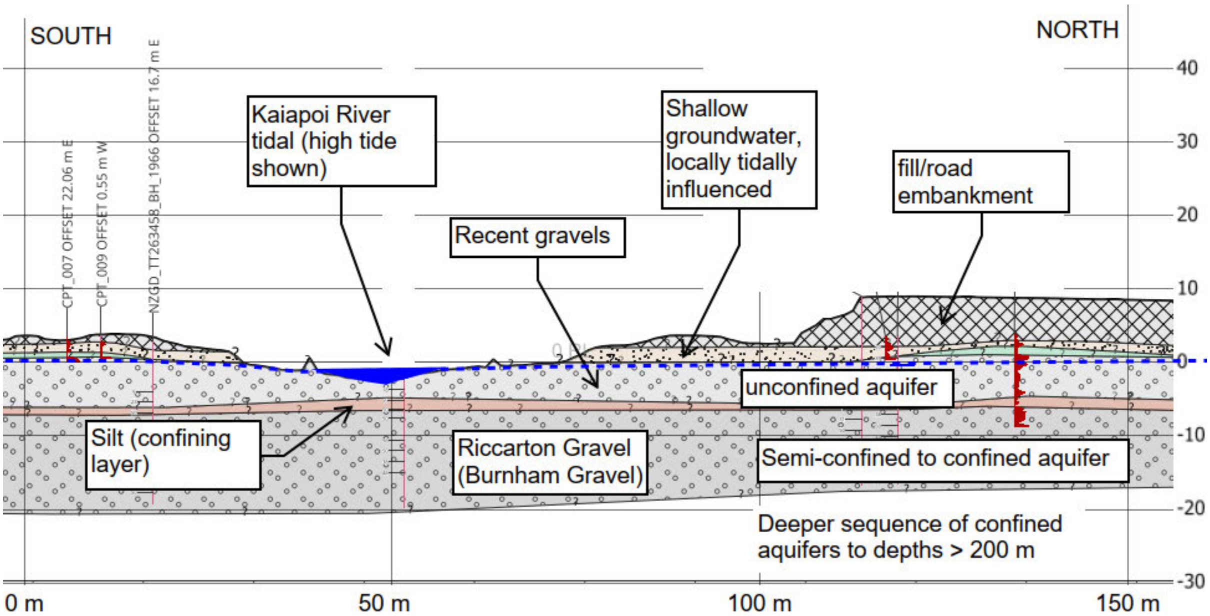



*Figure 7.3: Conceptual hydrogeological model - schematic sketch based on specific site investigation information at Kaiapoi River (based on information contained in Appendix B).*

## 7.4 Hydrogeological effects assessment for existing SH1 Upgrades

### 7.4.1 Overview

The proposed activities are summarised in Table 7.5 and the assessment of effects from these activities on groundwater are provided in Sections 7.4.2 and 7.4.3. A summary of the effects including the scale of effect is included in Section 7.5.

**Table 7.5: Summary of proposed activities at for the existing SH1 upgrades**

| Proposed activities | Activity has potential to affect groundwater: | | |
|---|---|---|---|
| | Level | Quality | Flow |
| Temporary activities during construction | | | |
| Culvert installation | Yes | Yes | Yes |
| Shallow excavations | No | Yes | No |
| Permanent activities during operation | | | |
| Road upgrade | No | No | No |
| Stormwater discharge | Yes | Yes | No |

### 7.4.2 Temporary effects

#### 7.4.2.1 Culvert installations

Two culverts will be installed in the vicinity of the existing SH1 upgrade. The key excavation details for each culvert are shown in Table 7.6.

**Table 7.6: Excavation dimensions for culvert installations on the existing SH1 upgrade**

| Culvert ID | Surface water | Width (m) | Length (m) | Depth range (m bgl) | | Excavation Base (m RL) |
|---|---|---|---|---|---|---|
| Culvert ID001 | Rossiters Drain | 2.3 | 45 | 1.1 | 1.5 | -1.5 |
| Culvert ID002 | Wilsons Drain | 2.3 | 45 | 1.3 | 2.0 | -1.6 |

Based on the depth to groundwater of approximately 1 m bgl (0 m RL) in these areas shallow groundwater will be encountered during the some of the culvert excavations and dewatering will be required.

An assessment on the dewatering effects is included in Appendix G which includes a list of assumptions used to make this assessment. The results for maximum assessed effects are presented in Table 7.7 and the general conclusions are the same as described in the Project-wide items in Section 6.4.2.1. For that reason, these points are summarised below:

- Results are based on a conservative groundwater level, indicative excavation dimensions and anticipated dewatering duration.
- Radial drawdown effects from the dewatering are limited to local distances from the excavation.
- The maximum predicted distance from the centre of the excavation to where the amount of drawdown is estimated to be nil/less than measurable is 110 m.

- Groundwater induced settlement effects are localised to near the excavation and are able to be mitigated thorough construction methodologies.

**Table 7.7: Maximum assessed drawdown effect from dewatering at culvert ID001 & ID002**

| Culvert ID | Drawdown within excavation(s) (m) | Radius of drawdown extent (m) |
|---|---|---|
| Culvert ID001 | 1.6 | 110 |
| Culvert ID002 | 1.6 | 110 |

The groundwater effects for culvert installation are described in the following sections.

#### 7.4.2.1.1 Effects on surface waters

The dewatering will result in direct stream depletion effect on Rossiters and Wilsons Drains during the culvert installations because the works will be completed online. However, the abstracted groundwater will be discharged back into the drains just upstream of the affected reach after water treatment to remove sediment. Thus, the stream flows will be manged in a way that negate any of the depletion effects and the overall effects will be low.

Given the radial drawdown effects of the dewatering are likely to be limited to a very local distance from the excavation of approximately 110 m, there will be no effects on other surface water features such the Cam River/Ruataniwha.

The volume and rate of discharge will be determined by the Contractor. However, the duration of the dewatering is likely to be less than 30 days. Due to the low flows in each drain, the discharge rate could be greater than the stream flows and this would need to be managed to ensure that flooding does not occur downstream.

#### 7.4.2.1.2 Effects on other groundwater users

The nearest shallow groundwater user to the culvert excavations is bore M35/0531 at approximately 350 m to the northwest from culvert; 001 and approximately 500 m to southeast from culvert; 002. The closest cDWPZ is approximately 800 m south of the closest culvert excavations. Given these are beyond the radius of drawdown extent the overall effects on groundwater users from the dewatering activities is negligible.

#### 7.4.2.1.3 Effects on groundwater quality

The effects on groundwater quality will be limited to increased sediment loading in the water at the base of each excavation. Mobilisation of suspended sediment will be restricted and will be removed by the pumping of groundwater as part of the dewatering.

There will be no other water quality effect on groundwater as a result of the pumping. The Contaminated Land Investigation (Volume 3F) has not identified the local area in the vicinity of the excavation to be contaminated or potentially contaminated land. This means there is limited potential for mobilisation of contaminants to occur as a result of the pumping i.e. inducing inward groundwater flows into the excavation thus mobilising potential contaminants, as described in Section 6.3.1.

Overall, the effects on groundwater quality will be negligible and therefore the effect on groundwater receptors will be negligible.

#### 7.4.2.1.4 Effects of discharge water quality at point of discharge

Dewatering will generate water to discharge. TSS at the point of discharge will be managed by the Contractor through specification in the GMP with the intention of meeting the discharge water quality requirements.

As described above, the Contaminated Land Investigation (Volume 3F) has not identified the local area in the vicinity of the excavation to be contaminated or potentially contaminated land. Therefore, other water quality effects on the discharge are not expected and the water quality effects at the point of discharge will be negligible.

### 7.4.2.2 Earthworks

Minor, shallow excavation activities will occur for the SH1 upgrades including road footprint excavations. The general conclusions are the same as described in the Project-wide items in Section 6.4.2.3. For that reason, these points are summarised below:

- Excavations (excluding the culverts as described above) are expected to be within 1 m above the local groundwater level.
- There will be no excavation of any confining layer.
- shallow excavations for construction of stormwater swales and cut-off drains are likely to be dry and only the short deepest part of the excavation could encounter groundwater.

The temporary earthworks are expected to have negligible effects on shallow groundwater receptors and in particular, groundwater quality.

### 7.4.2.3 Effects on drinking water supply source water (cDWPZ)

As described in Section 6.4.2.4.3, given the close proximity of the WDC Rangiora PWS bore sources to the Project, and the regional groundwater flow direction, it is assumed that the project alignment sits within the SWRMA 2 and SWRMA 3. Based on the SPR model described in Section 6.3.1, the actual and potential effect of the Project activities on the source of the registered drinking water supplies are considered. The details of the PWS bore sources are described in Section 7.2.4.1 with the water source from very deep (> 147 m). The water quality within the deep confined aquifer is unlikely to be directly influenced by other general surface activities from the Project. One specific activity is described below.

A CSA will be located near Kaiapoi Bridge in a cDWPZ and within 15 m of a PWS bore. Whilst the LWRP planning maps shows this cDWPZ to be within the unconfined /semi-confined aquifer system, it is interpreted that the hydrogeological setting is more characteristic of a confined aquifer system (Section 7.3).

Appropriate environmental management controls need to be put in place within the CSA around certain possible activities such as the storage of hazardous construction materials will not occur within the cDWPZ. Activities within the CSA will be managed by the Contractor through specification in the GMP mitigating the potential effects. Overall, the effects of the activities at the CSA on groundwater are considered to be negligible.

WDC also have other deep PWS bore sources near to the Project, known as the Kaiapoi supply. The WDC Kaiapoi PWS bores are located between approximately 500 m and 1.1 km east of the Project designation. Whilst the cDWPZs are at distances greater than 385 m from the Project, it is likely that the SWRMA 2 and SWRMA 3 for these bore sources are crossed by the Project and therefore noted here. Based on the negligible effects identified at PWS bores closer to the project, the water quality at the Kaiapoi PWS bore sources, identified at depths greater than 90 m[42], are unlikely to be influenced by the project activities, and the effects on these other local drinking water supply source waters is assessed as negligible.

### 7.4.3 Permanent effects

#### 7.4.3.1 Road embankment

As described in Section 3.9, the road embankments could result in effects on groundwater with potential changes to the local regime. The overall effects are the same as described in the Project-wide items in Section 6.4.3.1 and there are no location specific groundwater effects at this location. The overall effect on the groundwater environment from the road upgrade is negligible and therefore the effect on groundwater receptors will be negligible.

#### 7.4.3.2 Stormwater retention and drainage

The effects from the stormwater swales and bioretention devices located on the SH1 upgrades on groundwater are described in the Project wide items (Section 6.3.4). The overall effect on the groundwater environment from the stormwater swales and drainage is assessed as negligible.

## 7.5 Summary of effects

A summary of the temporary and permanent effects on groundwater from the SH1 upgrades, principally comprising road widening, culvert installation and stormwater drainage are provided in Table 7.8 and Table 7.9. Mitigation to reduce/minimise these effects is provided where the scale of effect is greater than 'low'.

**Table 7.8: Temporary groundwater effects from activities for the SH1 upgrades**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Culvert installation | Stream depletion (on drains) | Low | - | - |
| | Well interference | Negligible | - | - |
| | Groundwater quality on receptors | Negligible | - | - |
| Shallow excavations | Overall groundwater | Negligible | - | - |
| Construction storage areas | Groundwater quality on cDWPZ | Negligible | - | - |

**Table 7.9: Permanent groundwater effects from activities for the SH1 upgrades**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Road upgrade | Overall groundwater | Negligible | - | - |
| Stormwater drainage | Overall groundwater | Low | - | - |

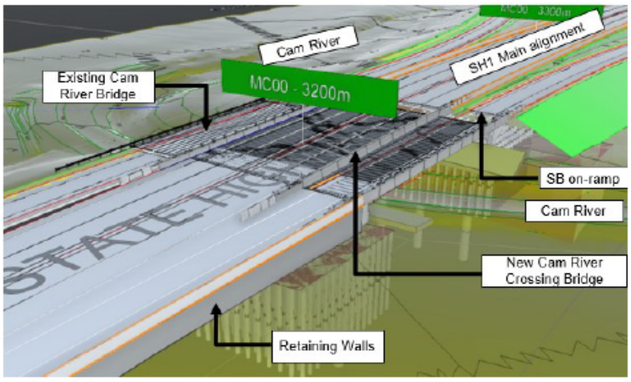
[42] ECan Canterbury Maps – bore and wells layer.

# 8 Cam River Bridge upgrades

## 8.1 Proposed activities

A new bridge at Cam River/Ruataniwha comprises a single discrete structure constructed on concrete piled foundations, carrying the four-lane main alignment and one southbound on-ramp, details are summarised in Table 8.1. It will be constructed adjacent to the existing Cam River bridge and will require a temporary road diversion during construction. The new bridge will have approach embankments leading up to the bridge from either side with the northern embankment leading on to the Williams Street crossing (see Section 9).

**Table 8.1: Summary details of Cam River/Ruataniwha new bridge structure**

| Details | |
|---|---|
| Figure |  |
| Surface water crossing | • Cam River/Ruataniwha. |
| Total bridge structural footprint | • 29 m x 22 m. |
| Foundations | • Piled foundations (1.5 m diameter, 14 m deep).<br>• 3 m long settlement slabs behind abutments. |
| Ground improvement | • Rigid inclusions (510 mm diameter, 1.5 m centres, 11 m long).<br>• Ground improvement footprint approx. 60 m (along the riverbank) x 20 m (wide) on both sides. |
| Approaches | • Embankments with 112 m retaining wall on east side south of bridge. |

The proposed key activities relating to the hydrogeology effects at this location comprise:

- Piled foundations to 14 m depth.
- Ground improvements to 11 m depth along Cam River/Ruataniwha banks.
- Embankments for leading to the bridge and raised SH1 and for retaining wall.

## 8.2 Environmental setting

### 8.2.1 Site location and general description

Cam River/Ruataniwha is crossed by the existing SH1 road bridge with SH1 being parallel to Cam River/Ruataniwha on the northern side, as shown in Figure 9.1 (in Section 9). The river is flanked by mature willows along the eastern banks with open farmland on the western banks. South of the bridge, the area is low-lying rural farmland, typically at 2 m RL. North of the bridge, the existing SH1 sits on a raised embankment at 5 m RL with ground either side of the embankment falling to approximately 1 m to 2 m RL.

### 8.2.2 Geology and hydrogeology

Table 8.2 provides a summary of the local geology. A schematic geological and hydrogeological section is presented in Figure 8.1.

**Table 8.2: Summary of local geology and hydrogeology at Cam River Bridge**

| Geology & Hydrogeology | | Details |
|---|---|---|
| Published geology[3] | • Holocene river alluvial deposits. | • Predominantly soft silts shown as river swamp[3]. |
| Site specific investigations | • Interbedded sediments of silt and fine to coarse sand to depths from 0.5 m – 8.5 & 9.5 m bgl.<br>• Deeper gravel sequence confirmed from depths from 8.5 to 29 m bgl.<br>• Variable thickness (up to 2 m) silt stratum at approximately 20 m bgl. | • Based on range of investigations including boreholes BH_04, BH_05 & piezometers BH_55, BH_54.<br>• BH_55, gravel to 29 m bgl & interbedded sand/gravel sequence to 40 m bgl.<br>• See Figure 8.1 for locations. |
| Depth to shallow groundwater | • Range 0.41 m to 1.06 m RL (0.58 m to 1.24 m bgl). | • Based on piezometers BH_55, BH_54.<br>• See Figure 8.1. |
| Identified aquifer system[1] | • Coastal Confined Aquifer System. | • See Figure 3.3. |
| Groundwater flow direction | • Toward east-southeast[40]. | • See Figure 3.3. |

Note: 1. As defined on the LWRP planning maps.

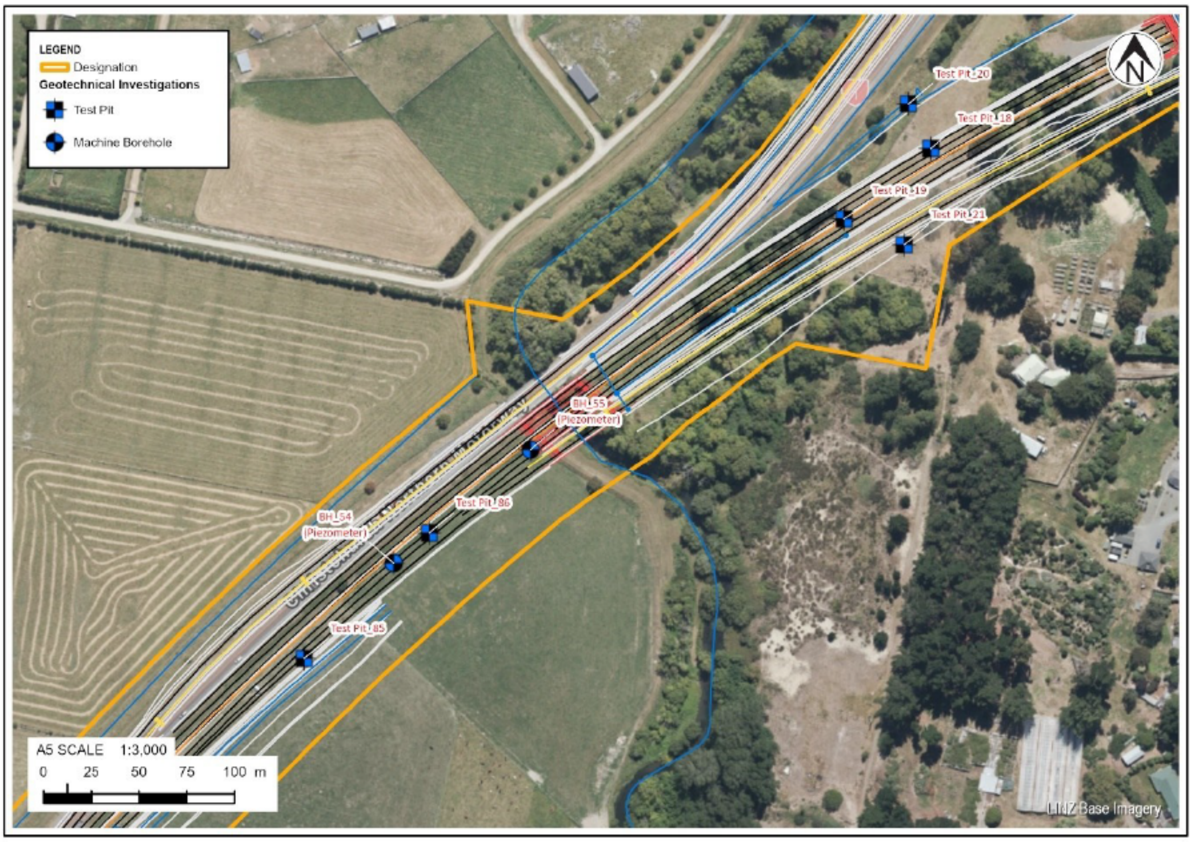



*Figure 8.1: Locations of monitoring wells, test pits, and surface waters in the vicinity of Cam River bridge.*

### 8.2.3 Hydrology

The Cam River/Ruataniwha is the only surface water at this road section. Table 8.3 provides a summary of the nearby water features. Whilst wetlands are noted in this table, the assessed effects are covered in Section 9 William Street interchange.

**Table 8.3: Summary of nearby water features to Cam River bridge**

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| Surface water catchment | • Cam River/Ruataniwha | • n/a | • As defined on Canterbury Maps[20].<br>• See Figure 4.5. |
| Surface waters | • Cam River/Ruataniwha | • Crosses SH1 | • Nearest surface water. |
| Wetlands | • CR_W1_NPSFM | • 20 m SW | • A very small (c.0.03 ha) area of wetland.<br>• Small wetland directly connected with Cam River/Ruataniwha at high tide.<br>• see Wetland assessment in Appendix H.<br>• See Figure 9.2 (in the next section). |
| | • CR_W2_NPSFM | • Mostly within designation | • A small (c.0.33 ha) wetland located within a paleo-channel of the Cam River/Ruataniwha. |

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| | | | • Receives water via overland flow from the surrounding catchment, high tide from the Cam River/Ruataniwha.<br>• Hydraulic connection with groundwater, no standing water visible.<br>• See Figure 9.2 (in the next section). |
| Springs | • None | • n/a | • n/a |

### 8.2.4 Surrounding groundwater users

Details of the bore survey are described in Section 4.6. Bores included in Table 8.4 are all of those bores within 400 m of the designation boundary surrounding Cam River bridge as shown in Figure 8.2.

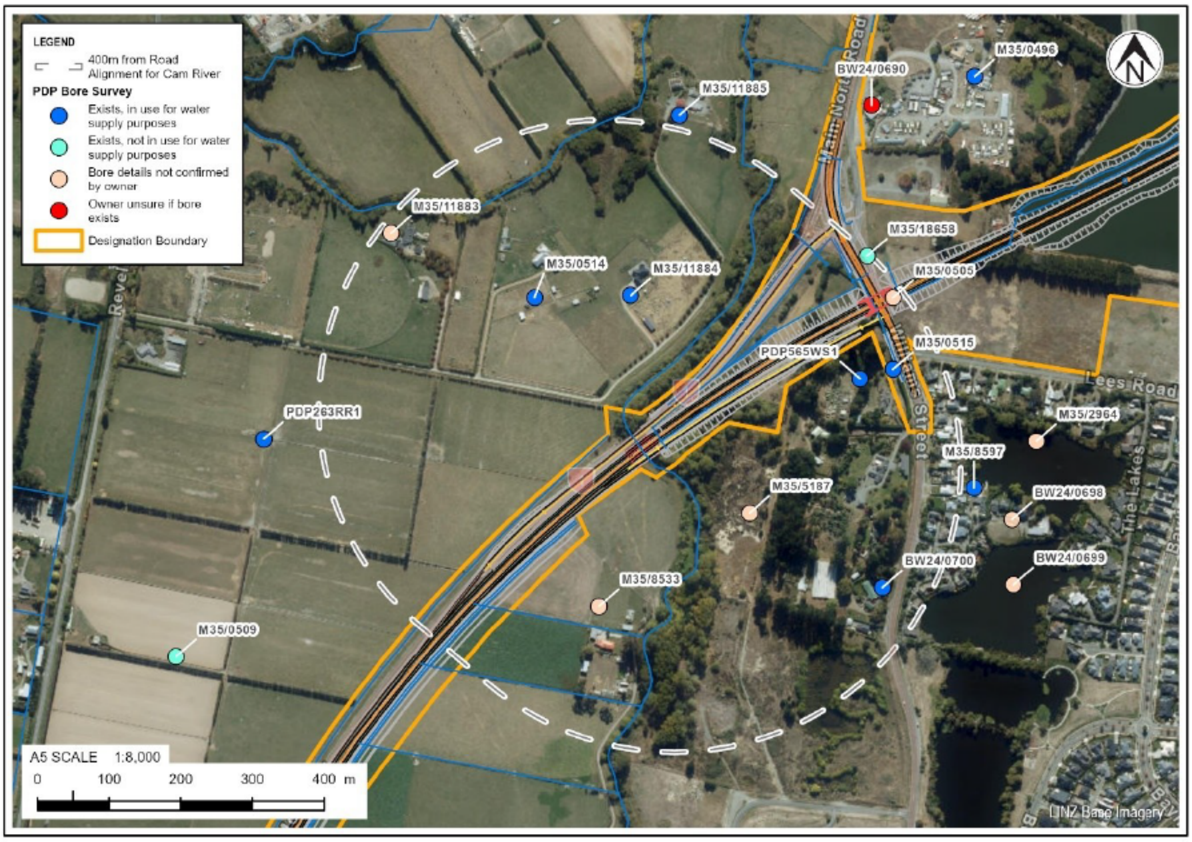



*Figure 8.2: All known bores within 400 m of the Project Site surrounding Cam River bridge (source: modified from PDP Bore Use Survey[27].*

**Table 8.4: Results of bore survey for all known bores[27] within 400 m of the designation at Cam River bridge**

| Bore status | Bore use | Number of bores | Depth range (m) |
|---|---|---|---|
| Confirmed as present | Water supply purposes | 5 | 62 - 91.4 |
| | Other uses | 1 | 23.9 |
| Unconfirmed | Bore details not confirmed by owner | 4 | 19 - 92 |

Notes: Details of bore use are provided in Section 4.6.1.

Table 8.5 provides details of those bores that may be affected by the temporary and permanent activities associated with the Project. Due to the nature of the proposed activities, there will be limited effects on the surrounding bore users and only bores with the potential to take water from the shallow unconfined and semi-confined groundwater within 20 m of the surface are included. This selected depth is to include consideration of the potential effects from the piling activities and ground improvements.

**Table 8.5: Bores within 400 m of the designation at Cam River bridge that may be affected by the Project**

| Bore use | Number of bores | Comments |
|---|---|---|
| Shallow bores[1] (0 m - 20 m depth) for water supply purposes | 3 | Includes 2 bore unknown depth |
| Community drinking water bores | 0 | n/a |
| Bores within alignment requiring decommissioning | 0 | n/a |

Notes:

[1] Water supply purposes are classified as those bores from which water is actively abstracted for a defined use such as domestic, stock water supply or irrigation. Community drinking water bores are listed separately.

[2] None of these bores are listed as shallow bores for water supply purposes.

## 8.3 Localised conceptual hydrogeology model

In summary, the hydrogeological conceptual model for the site comprises:

- An unconfined (water table) aquifer within alluvial deposits predominantly comprising silt and sand to approximately 8.5 m to 9.5 m depth underlain by thick gravel sequence.
- Groundwater within the shallow aquifer is recorded to vary between approximately 0.6 m and 1 m bgl (0.4 m and 1 m RL).
- Shallow groundwater has a limited hydraulic connection with the tidally influenced Cam River/Ruataniwha. In places, the Cam River/Ruataniwha is expected to intersect the shallow groundwater/water table.
- However, as described in section 4.4.1.2., contributions from groundwater inflows (300 m downstream of Cam River bridge) are minor and shallow groundwater is not a dominant contributor to river flows.
- The Riccarton Gravel (Burnham Formation) is considered to be relatively shallow and likely to be a semi-confined aquifer at depths of approximately 9 m bgl
- A thin likely confining layer, recorded in the four site investigation bore logs (each side of the river and existing bridge) potentially forms the aquitard to the underlying Linwood Gravel aquifer. This aquifer is considered to be confined.

Figure 8.3 shows the developed conceptual hydrogeological model for the Cam River/Ruataniwha with indicative depths of the piles and ground improvement works.

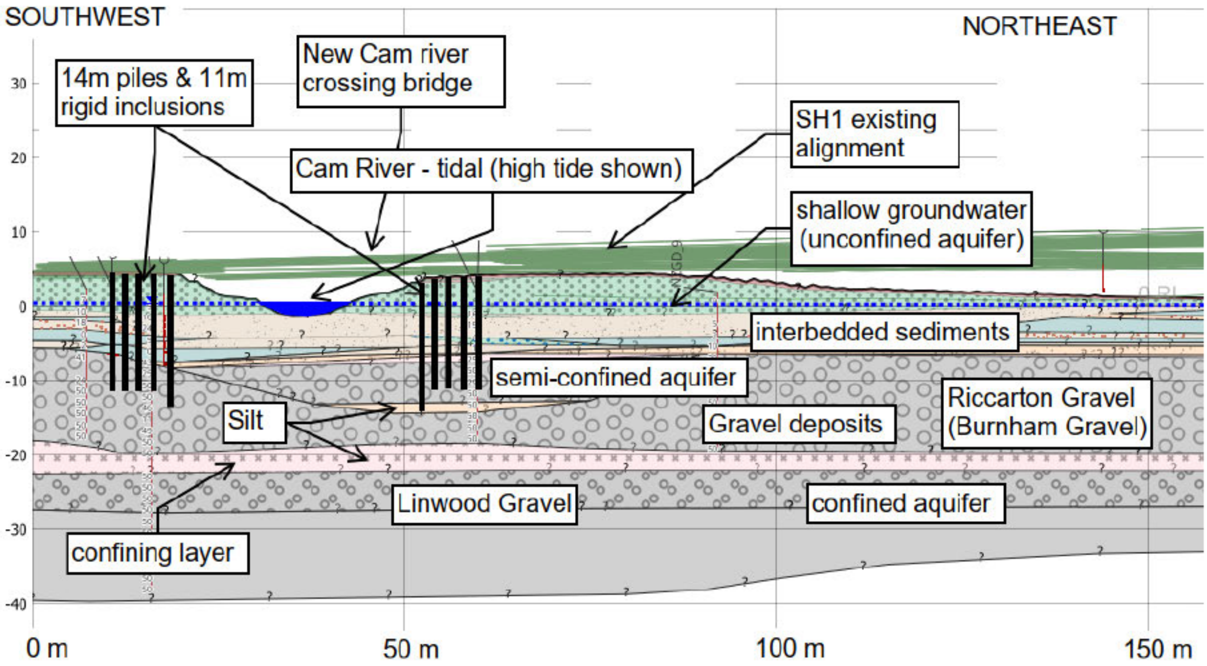



*Figure 8.3: Conceptual hydrogeological model - schematic sketch based on specific site investigation information at Cam River/Ruataniwha (based on information contained in Appendix B).*

## 8.4 Hydrogeological effects assessment for Cam River Bridge upgrades

### 8.4.1 Overview

The proposed activities are summarised in Table 8.6 and the assessment of effects from these activities on groundwater are provided in sections 8.4.2 and 8.4.3. A summary of the effects including the scale of effect is included in Section 8.5.

**Table 8.6: Summary of proposed activities at Cam River Bridge**

| Proposed activities | Activity has potential to affect groundwater: | | |
|---|---|---|---|
| | Level | Quality | Flow |
| Temporary activities during construction | | | |
| Ground improvements rigid inclusions | Yes | Yes | Yes |
| Foundations piling | Yes | Yes | Yes |
| Embankment construction | Yes | No | Yes |
| Shallow excavations | No | Yes | No |
| Permanent activities during operation | | | |
| Ground improvements & piles | No | No | No |
| Road embankment | No | No | No |
| Stormwater discharges | Yes | Yes | No |

### 8.4.2 Temporary effects

#### 8.4.2.1 Earthworks

##### 8.4.2.1.1 Effects on groundwater

Minor, shallow excavation activities will occur for the formation of the road embankment. The general conclusions are the same as described in the Project-wide items in Section 6.4.2.3. For that reason, these points are summarised below:

- Excavations will be within 1 m of the local unconfined groundwater level. If groundwater is encountered, these excavations will not require dewatering as placement of the backfill material can be completed in a wet excavation.
- Shallow excavations for the cut-off drain adjacent to the west side of the existing SH1, south of the river could intercept shallow groundwater when completed close to the river.
- There will be no excavation of any confining layer (piling and ground improvement works will occur into the confining layer and these activities are described in the following section).
- Recent site investigations have encountered natural ground conditions and the Contaminated Land Investigation (Volume 3F) has not identified the local area in the vicinity of the excavation to be contaminated or potentially contaminated land. The potential for contaminants to be encountered from the excavation activities in this area is very low, with a correspondingly low risk of contaminants entering groundwater, as described in Section 6.3.1.

The temporary earthworks in the vicinity of Cam River bridge are expected to have negligible effects on shallow groundwater receptors.

#### 8.4.2.2 Piling & ground improvements

##### 8.4.2.2.1 Effects on groundwater

For the purposes of this hydrogeological assessment, piling activities for bridge foundations and installation of rigid inclusions for ground improvements are considered to result in similar types of effects, although the scale of effect may differ due to the differing installation methods and the size of footprint at different locations. Installation of rigid inclusions (11 m depth) and piles (14 m depth) will intercept the shallow unconfined groundwater and reach the semi-confined groundwater of the Riccarton/Burnham aquifer over a relatively large footprint at each side of the Cam River/Ruataniwha.

**Mixing of groundwater from different aquifers**

There is the potential for mixing of groundwater from different aquifers, e.g. between the unconfined and confined aquifer during piling activities and installation of rigid inclusions because the pile and rigid inclusions depths extend into the semi-confined aquifer (as shown in Figure 8.3).

There are some factors that will reduce the potential for mixing of groundwater from different aquifers and these are related to the typical method of construction which is expected to be followed by the Contractor:

- Casing (for piles) and installation method (for rigid inclusions) will limit the potential for pathways to be created between different aquifers:
  - Piles will be fully cased which will restrict groundwater mixing within the pile; and/or
  - The ground improvement technique for rigid inclusions avoids the creation of voids because concrete is placed via a tremie pipe (refer Sections 3.6).

However, it is assessed that ground improvements in the vicinity of Cam River bridge are expected to have a moderate effect on the mixing of groundwater over the localised area of the ground improvements.

To reduce the potential effects of mixing groundwater between aquifers, these will be managed by the Contractor through specification in the GMP which will include management of:

- Artesian groundwater conditions if encountered.
- Groundwater quality to ensure no surface contaminants can enter the probe holes during installation.
- Installation procedures during the placement of concrete.
- Measures such as documented grout volumes, inspection of a test rigid inclusion to ensure integrity of the grout and groundwater monitoring at different depths.
- Reference to the erosion and sediment controls for the site works at the edge of Cam River/Ruataniwha (ESCMP).

These mitigation measures will reduce the scale of effect to low.

**Groundwater flow and level**

The resulting ground improvement area is likely to have effects on groundwater flows and levels, whilst these effects may be initiated during the construction works, overall, they will have a permanent effect and they are described in Section 8.4.3.

**Groundwater quality**

There is the potential for temporary localised changes to groundwater quality to occur due to the ground improvement works relating to:

- Use of concrete in the piles and rigid inclusions in a small area which could result in localised increases to the pH level of groundwater and a rise in groundwater temperature.
- Increased turbidity in shallow groundwater may occur as a result of the piling activities such as placement of the concrete into the pile holes and the displacement of water, and vibrations induced during the construction works.

As described in Section 6.3.2 introducing concrete into groundwater can result in a localised pH increase (i.e. an increase in alkalinity) due to the leaching of hydroxide ions from the concrete[30]. These changes to groundwater quality could affect groundwater users, wetlands, or water quality of Cam River/Ruataniwha. The amount of leaching depends on several factors including the concrete mixture, volume/surface area of the pile/inclusion, and pile geometry [30]. The mobility of leachate in groundwater depends on the aquifer matrix composition with more permeable materials resulting in increased mobility (and vice versa). The extent of the increased alkalinity plume around the ground improvements is expected to be small and likely to have a localised effect.

Once the concrete forming the ground improvements has cured[43], the risk of hydroxide ions leaching into groundwater reduces significantly. Based on the low permeability sediments in the Cam River/Ruataniwha and the low hydraulic gradient of the shallow aquifer, the extent of mobilisation of high pH/alkalinity groundwater is expected to be limited. It is assessed that the temporary effect on groundwater quality from the construction of ground improvements in the vicinity of Cam River bridge is low. The effects of piling will have a lower effect on groundwater quality than the rigid inclusions because the piles are cased and concrete will not directly interact with the aquifer matrix. In addition, the scale of effect is reduced due to fewer piles than the rigid inclusions

[43] Concrete hardening typically occurs after 48 hrs and curing takes up to 28 days.

#### 8.4.2.2.2 Effects on surface waters and wetlands

The Cam River/Ruataniwha is the nearest ecological receptor for groundwater discharge. Whilst the area of the ground improvements is relatively large and adjacent to the river, shallow groundwater discharging into the Cam River/Ruataniwha has been confirmed[12] as small and therefore makes only a small contribution to river flows. Given the large volume of river water (when compared with the inferred groundwater discharge volumes, as described in Section 4.4.), any high alkalinity/pH groundwater which discharges into the river is likely to be diluted quickly and have negligible influence on pH levels in the river. In addition, the ground improvement length coinciding with and above the river elevation is relatively short i.e. less than 5 m, therefore the contact between the ground improvements and groundwater, and the resulting effect on the Cam River/Ruataniwha is limited and considered to be a negligible effect.

The nearest wetland to Cam River bridge is CR_W1_NPSFM located 50 m southeast and down gradient of the ground improvements. This wetland is likely to be beyond the potential zone where temporary changes in groundwater quality from the ground improvements could occur. In addition, this wetland receives most of its water contribution from the Cam River/Ruataniwha where effects on water quality are assessed as negligible. Therefore, the potential effect on the closest wetland is negligible.

#### 8.4.2.2.3 Effects on groundwater users

The nearest shallow downgradient bore (i.e. less than 20 m depth) to the ground improvements is bore M35/5187, located 130 m to the southwest. This bore is the closest out of all of the surrounding bores. It is assessed that the increased turbidity and alkalinity in shallow groundwater induced during the construction works as a result of the ground improvements/vibrations and any changes in groundwater quality from the concrete will result in a negligible effect on the nearby groundwater user.

In summary, the effects of any temporary changes in groundwater quality is low and the effect on the receiving environment is assessed as negligible. The risk of the residual effects on groundwater will be managed by the Contractor through specification in the standard controls in the GMP.

### 8.4.3 Permanent effects

#### 8.4.3.1 Road embankment

As described in Section 3.9, the road embankments could result in effects on groundwater with potential changes to the local regime. The overall effects are the same as described in the Project-wide items in Section 6.4.3.1. and there are no location specific groundwater effects at this location. The overall effect on the groundwater environment from the new SH1 is negligible and therefore the effect on groundwater receptors will be negligible.

#### 8.4.3.2 Piling & ground improvements

There will be permanent effect from the piling and ground improvement works. The resulting ground improvement area is likely to have a lower permeability following improvement due to the filling with concrete over a small, localised area. The permanent effects of the piles and rigid inclusions could result in:

- Penetration and damage to the confining layer.
- Potential to change groundwater levels.

Short-term permanent effects also include:

- Formation of a zone reducing localised groundwater flow toward the river.
- Increases in shallow groundwater levels to allow groundwater to flow between the piles and rigid inclusions i.e. there is a reduction in the aquifer matrix around the piles and ground improvements.

Based on the surface water/groundwater interaction assessment[12] at Cam River/Ruataniwha, the effect of the piling and ground improvements, and the potential to form a barrier to groundwater flows that are hydraulically connected with Cam River/Ruataniwha are expected to be small. This is due to the compact (i.e. approximately 60 m x 20 m) construction area along the Cam River/Ruataniwha and any flow or level changes are likely to be buffered by the volume of Cam River/Ruataniwha (particularly at high tide) compared with the potential low discharge from groundwater to surface water (as described in Section 4.4). In addition, these effects are expected to be temporary and groundwater flows and levels are expected to equilibrate once pore water pressures have dissipated.

It is assessed that piles and ground improvements in the vicinity of Cam River bridge are expected to have low temporary effects on shallow groundwater flow and level over the localised area of the permanent ground improvements and negligible effect on groundwater receptors such as at Cam River/Ruataniwha.

As described in the above sections, once the concrete at the ground improvements has cured, the risk of leaching into groundwater reduces significantly with decrease in pH. Therefore, the permanent long-term effects on groundwater quality are significantly reduced. There is the potential for these permanent structures to act as a pathway between the surface and groundwater i.e. the ground improvements facilitating migration of contaminants at the interface between the structure and the soil matrix if the SPR linkage is complete. Any contaminant source at the surface (e.g. roadside accidental spills, contaminated stormwater) would be intercepted by the stormwater swales. In addition, most of the ground improvements are beneath the road embankment. Therefore, there is an incomplete SPR linkage between the surface and the ground improvements and these permanent structures are very unlikely to act as a contaminant pathway. The effect on groundwater receptors is negligible.

#### 8.4.3.3 Stormwater retention, drainage and cut-off drains

The effects from the stormwater systems at Cam River Bridge on groundwater are described in the Project wide items (Section 6.3.4.2). The overall effect on the groundwater environment from the stormwater swales and drainage is assessed as negligible.

## 8.5 Summary of effects

A summary of the temporary and permanent effects on groundwater from the activities at Cam River Bridge, principally comprising bridge construction piling and ground improvements are provided in Table 8.7. and Table 8.8. Mitigation to reduce/minimise of these effects is provided where the scale of effect is greater than ‘low’.

**Table 8.7: Temporary groundwater effects from activities at Cam River Bridge**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Ground improvements (rigid inclusions) | Groundwater level & flow (mixing aquifers) | Low | - | - |
| | Overall groundwater quality | Low | - | - |
| | Surface waters | Negligible | - | - |
| | wetlands | Negligible | - | - |
| | Groundwater users | Negligible | - | - |
| Foundation piling | Groundwater level & flow (mixing aquifers) | Low | - | - |
| | Overall groundwater quality | Low | - | - |
| | Surface waters | Negligible | - | - |
| | wetlands | Negligible | - | - |
| | Groundwater users | Negligible | - | - |
| Embankments | Overall groundwater | Negligible | - | - |
| Shallow excavations | Overall groundwater | Negligible | - | - |

**Table 8.8: Permanent groundwater effects from activities at Cam River Bridge**

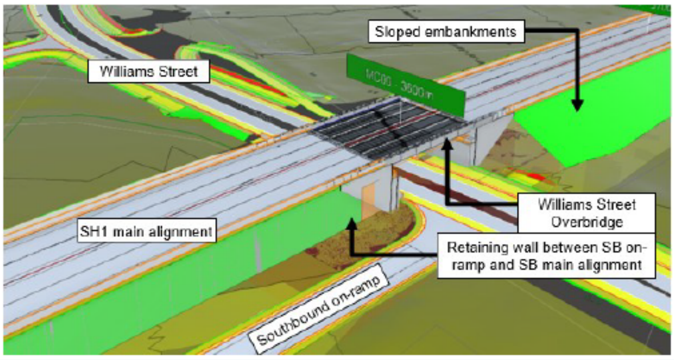
| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Road embankment | Overall groundwater | Negligible | - | - |
| Ground improvements | Groundwater level and flow on receptors | Negligible | - | - |
| | Groundwater quality on receptors | Negligible | - | - |
| Stormwater discharges | Overall groundwater | Low | - | - |

# 9 Williams Street interchange

## 9.1 Proposed activities

A new overbridge structure at Williams Street interchange will be constructed to carry the proposed SH1 alignment over Williams Street. At this location, the new road alignment will have approach embankments leading up to the bridge from either side. The new overbridge structure at Williams Street is summarised in Table 9.1. The southern approach will have a retaining wall to the eastern side, located between the main alignment and a southbound on-ramp, while all other ramped approach sides will have sloped embankments. The ramped approach to the southwest interacts with the Cam River Crossing Structures, while the approaches to the northeast cross Quarry Lakes.

**Table 9.1: Summary details of Williams Street overbridge structure**

| Details | |
|---|---|
| Figure |  |
| Surface water crossing | • None. |
| Total bridge structural footprint | • 29 m x 22 m. |
| Foundations | • Shallow footings on MSE abutment walls. |
| Ground improvement | • Rigid inclusions underneath MSE abutment walls (510 mm diameter, 1.5 m centres, 13 m long).<br>• Stone columns (8.5 m deep) under full width of embankment to south toward Cam River/Ruataniwha on west side of bridge, and halfway to Quarry Lakes on east side of bridge. |
| Approaches | • Embankments with retaining wall on east side between mainline and onramp. |

The proposed key activities relating to the hydrogeology effects at this location comprise:

- Ground improvements to 13 m depth.
- Embankments for the overbridge and raised SH1.
- Minor excavations for MSE abutment walls.
- Installation of two culverts.
- Shallow excavations for stormwater swale.

## 9.2 Environmental setting

### 9.2.1 Site location and general description

Williams Street sits between the Cam River/Ruataniwha and Quarry Lakes and is east of the existing SH1. The proposed SH1 is near parallel to Cam River/Ruataniwha between the Cam River/Ruataniwha crossing and Williams Street. In this area, and southwest of Williams Street, the proposed SH1 is located on land lying between 2 m RL to 3 m RL, and within an area of mature willows and an identified wetland. On the northeast side of Williams Street, the area is undeveloped farmland with a pin shelter belt separating the fields and the quarry lake boundary. This area is slightly elevated at approximately 3 m RL to 4 m RL.

Pineacres Holiday Park is approximately 175 m north of the interchange. Kaiapoi Lakes, with housing around much of the lakes is located east of Williams Street.

### 9.2.2 Geology and hydrogeology

Table 9.2 provides a summary of the local geology. A schematic geological and hydrogeological section is presented in Figure 9.3.

**Table 9.2: Summary of local geology and hydrogeology at Williams Street interchange**

| Geology & Hydrogeology | | Details |
|---|---|---|
| Published geology[3] | • Holocene river alluvial deposits. | • Predominantly soft silts shown as river swamp[3] in the area between Cam River/Ruataniwha and Williams Street. |
| | • Holocene dune sand. | • Transition to dune sand is close to existing SH1 and Williams St, extending toward the quarry. |
| Site specific investigations | • Interbedded sediments of sand/ gravelly sand to depths to up to 12.8 m bgl.<br>• Deeper gravel sequence confirmed from depths of 6.0 m to 30.5 m bgl.<br>• Thin (0.5 m) silt stratum at approximately 24 m bgl. | • Based on range of investigations including boreholes BH_06 & piezometers BH_07, BH_10, BH_58.<br>• Test pits TP_18 to TP_26.<br>• BH_10, predominantly gravel 9 m to 30.5 m bgl. Other boreholes taken to 20 m bgl.<br>• See Figure 9.1. |
| Depth to shallow groundwater | • Range 1 m to 1.34 m RL (1.2 m to 2.95 m bgl). | • Based on range of piezometers BH_07, BH_10, BH_58.<br>• Test pits water strikes TP_18 to TP_26.<br>• See Figure 9.1. |
| Identified aquifer system[1] | • Coastal Confined Aquifer System. | • See Figure 3.3. |
| | • Unconfined /Semi-confined Aquifer System. | • Small area in vicinity of culvert ID004. |
| Groundwater flow direction | • Toward east-southeast[40] | • See Figure 3.3. |

Note: 1. As defined on the LWRP planning maps.

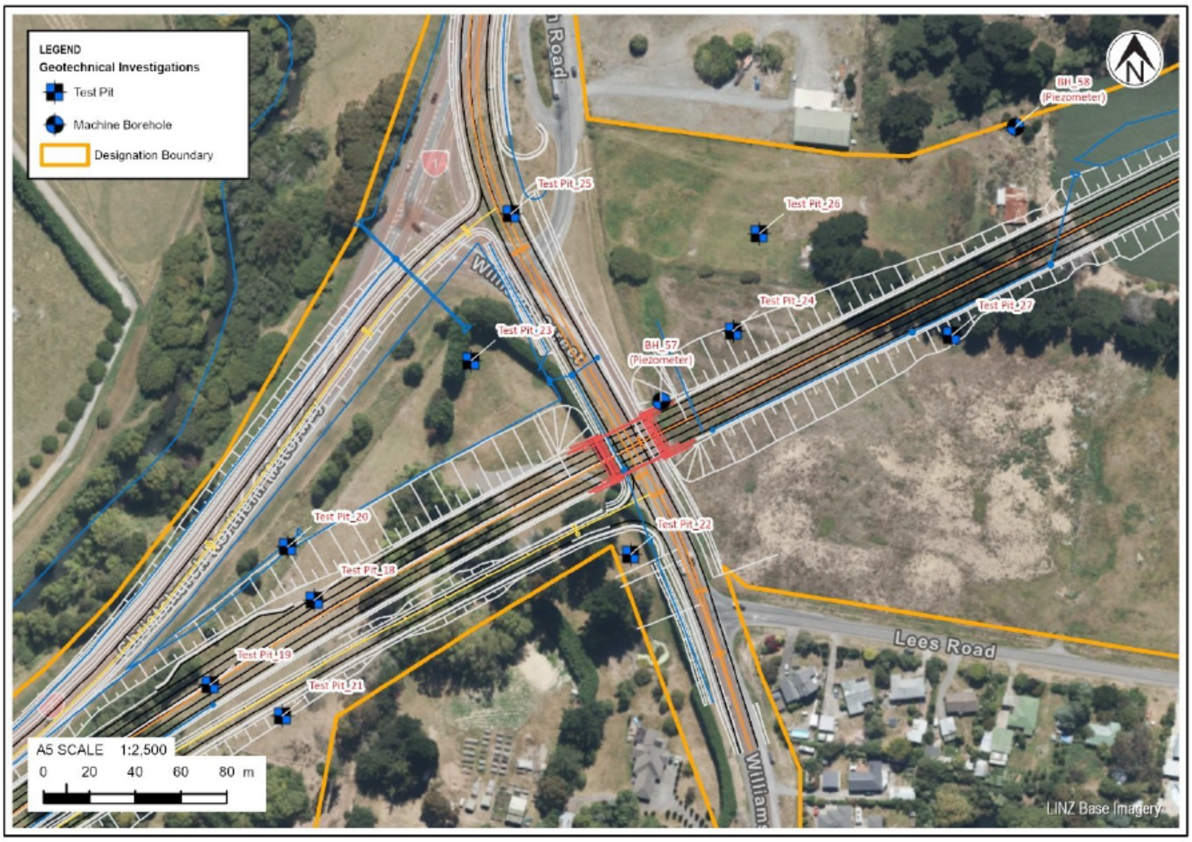



*Figure 9.1: Locations of monitoring wells and test pits in the vicinity of Williams Street interchange.*

### 9.2.3 Hydrology

Table 9.3 provides a summary of the nearby water features. Full descriptions of the wetlands are in in Appendix H.

**Table 9.3: Summary of nearby water features to Williams Street interchange**

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| Surface water catchment | • Cam River/Ruataniwha | • n/a | • SW side of Williams Street.<br>• As defined on Canterbury Maps[20].<br>• See Figure 4.5. |
| | • Waimakariri River | • n/a | • NE side of Williams Street. |
| Surface waters | • Cam River/Ruataniwha | • Crosses SH1 | • Typically between 50 m and 150 m from the SW side of the new overbridge. |
| Wetlands | • CR_W1_NPSFM | • 20 m SW | • A very small (c.0.03 ha) area of wetland directly connected with Cam River/Ruataniwha at high tide.<br>• Not permanently connected with groundwater.<br>• Limited hydrological connection with adjacent wetland CR_W2_NPSFM.<br>• See Wetland assessment in Appendix H.<br>• See Figure 9.2. |

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| | • CR_W2_NPSFM | • Mostly within designation | • A small (c.0.33 ha) wetland located within paleo-channel of Cam River/Ruataniwha.<br>• Receives water via overland flow from the surrounding catchment, high tide from Cam River/Ruataniwha.<br>• Hydraulic connection with groundwater, no standing water visible.<br>• See Figure 9.2. |
| Springs | • Yes | • On road alignment | • Intermittent spring at constructed pond/depression at 565 Williams St. |


*Figure 9.2: Existing wetland extents and defined catchments near to Cam River/Williams Street intersection.*

### 9.2.4 Surrounding groundwater users

Details of the bore survey are described in Section 4.6. Bores within 400 m of the designation boundary for the Williams Street interchange are included in Table 10.3 and shown in Figure 10.4 (see Section 10).

Table 9.4 is a subset of bores shown on Table 10.4 and provides details of those bores that may be affected by the temporary and permanent activities associated with the Project. Due to the nature of the proposed activities, there will be limited effects on the surrounding bore users and only bores with the potential to take water from the shallow groundwater within 20 m of the surface are included. This selected depth is to include consideration of the potential effects from the ground improvements. The effects on bores within the alignment are not considered because these will be decommissioned, as described in Section 6.4.2.4.

**Table 9.4: Bores within 400 m of the designation at Williams Street that may be affected by the Project**

| Bore use | Number of bores | Comments |
|---|---|---|
| Shallow bores[1] (0 m - 20 m depth) for water supply purposes | 7 | Includes 2 bore unknown depth |
| Community drinking water bores | 0 | n/a |
| Bores within alignment requiring decommissioning | 3 | Owned by NZTA |

Note:

[1] Water supply purposes are classified as those bores from which water is actively abstracted for a defined use such as domestic, stock water supply or irrigation. Community drinking water bores are listed separately.

## 9.3 Localised conceptual hydrogeology model

In summary, the hydrogeological conceptual model for the site comprises:

- An unconfined (water table) aquifer within alluvial deposits predominantly comprising interbedded sand and gravelly sand to depths ranging between 6 m to 12.8 m underlain by a thick gravel sequence.
- Gravel of the Riccarton/Burnham Formation is generally encountered at 10 m depth and this is considered to be a semi-confined aquifer.
- This gravel sequence extends to depths of at least 30 m bgl. A thin confining layer was recorded only in one of the four bores which extended below 20 m depth. This is inferred to form the aquitard between the Riccarton/Burnham aquifer (Aquifer 1) and the Linwood aquifer (Aquifer 2).
- Groundwater within the shallow aquifer is recorded to vary between approximately 1 m and 3 m bgl, (approximately 1 m RL and 1.3 m RL).
- Shallow groundwater is hydraulically connected with the tidally influenced Cam River/Ruataniwha and surface water levels in Quarry Lakes (shown in the conceptual hydrogeological model sketch at Figure 10.5.
- The spring fed pond at 565 Williams Street was reported[44] to flow after the heavy rainfall event on 30 April/1 May 2025. A spring had not been observed at this pond for many years. It is considered that a relatively shallow groundwater flow path exists in this localised area and/or vertical leakage from the Riccarton/Burnham aquifer and water is observed in the pond when groundwater levels are sufficiently high. The base of the pond is approximately 1.4 m RL, rising to approximately 1.9 m RL at the edges.

Figure 9.3 shows the developed conceptual hydrogeological model for the Williams Street interchange with indicative depths of the ground improvement works. In addition, Figure 10.5 also shows a cross section of the hydrogeology between Cam River/Ruataniwha and Quarry Lakes which passes through Williams Street interchange.

[44] Discussions between T+T Ecologists and property owners on 6 May 2025.

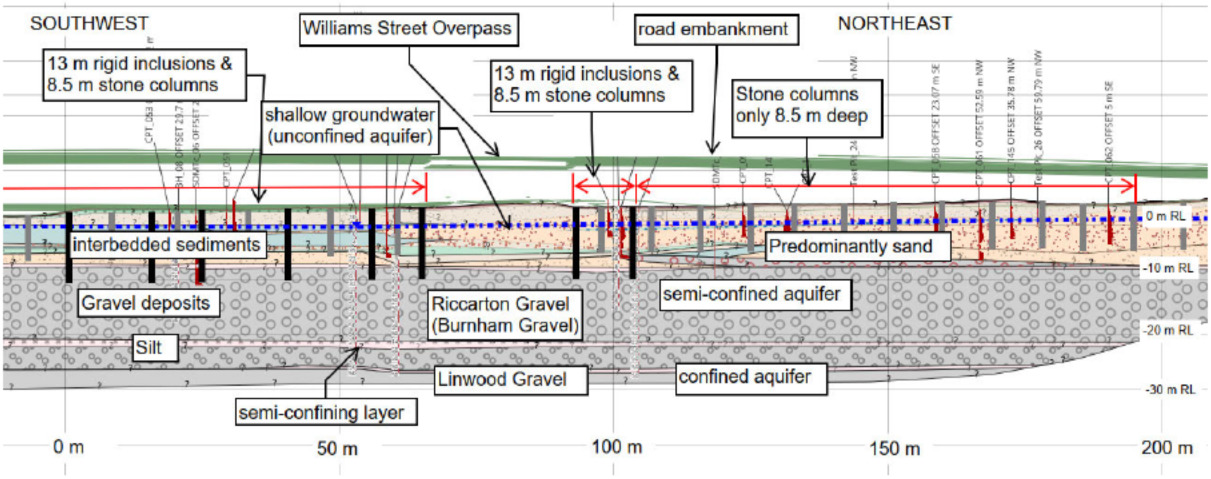



*Figure 9.3: Conceptual hydrogeological model - schematic sketch based on specific site investigation information (based on information contained in Appendix B).*

## 9.4 Hydrogeological effects assessment for William Street interchange

### 9.4.1 Overview

The proposed activities are summarised in Table 9.5 and the assessment of effects from these activities on groundwater are provided in Sections 9.4.2 and 9.4.3. A summary of the effects including the scale of effect is included in Section 9.5.

**Table 9.5: Summary of proposed activities at William Street interchange**

| Proposed activities | Activity has potential to affect groundwater: | | |
|---|---|---|---|
| | Level | Quality | Flow |
| Temporary activities during construction | | | |
| Ground improvements rigid inclusions | Yes | Yes | Yes |
| Ground improvements stone columns | Yes | Yes | No |
| Embankment construction | Yes | No | Yes |
| Culvert installation | No | No | No |
| Shallow excavations | No | Yes | No |
| Permanent activities during operation | | | |
| Ground improvements rigid inclusions | No | No | No |
| Ground improvements stone columns | No | No | No |
| Road embankments | No | No | No |
| Stormwater discharges | Yes | Yes | No |

### 9.4.2 Temporary effects

#### 9.4.2.1 Culvert installations

Two culverts will be installed in the vicinity of Williams Street interchange. One culvert will provide stormwater drainage from the bioretention basin located between the existing SH1 and the proposed alignment. The other culvert provides drainage for an overland flow path.

The key excavation details for each culvert are shown in Table 9.6.

**Table 9.6: Excavation dimensions for culvert installations at Williams Street interchange**

| Culvert ID | Surface water | Width (m) | Length (m) | Excavation depth range (m bgl) | | Excavation Base (m RL) |
|---|---|---|---|---|---|---|
| Culvert ID003 | Dry channel | 1.6 | 60 | 0 | 0.8 | 2.3 |
| Culvert ID004 | Dry channel | 1.6 | 25 | 1.0 | 2.4 | 1.5 |

Based on the range in depth to groundwater of approximately 1 m to 1.34 m RL (1.2 m to 2.95 m bgl) shallow groundwater is unlikely to be encountered in the excavations. As dewatering will not be required for construction purposes there is considered to be no effect on groundwater and groundwater receptors, and no further assessment of effects for culvert installation has been completed in this area.

#### 9.4.2.2 Earthworks

##### 9.4.2.2.1 Effects on groundwater from excavation

Minor, shallow excavation activities will occur for the formation of the road embankment. The general conclusions are the same as described in the Project-wide items in Section 6.4.2.3. For that reason, these points are summarised below:

- Excavations will be within 1 m of the local unconfined groundwater level. If groundwater is encountered, these excavations will not require dewatering as placement of the backfill material can be completed in a wet excavation.
- Shallow excavations for the cut-off drain adjacent to the west side of the existing SH1, south of the river could intercept shallow groundwater when completed close to the river.
- There will be no excavation of any confining layer (piling and ground improvement works will occur into the confining layer and these activities are described in the following section).
- The area within culvert 004, where excavations will occur, overlies the unconfined/ semiconfined aquifer system. However, the potential to intercept groundwater at this location is limited.
- Excavations required for the shallow footing for the MSE abutment walls will occur over the ground improvement works, therefore excavation into natural ground will not occur for this activity (beyond an initial site scrape to remove topsoil and vegetation).
- In the area of the intermittent spring-fed pond, there is the potential to excavate into groundwater, these effects are described in Section 9.4.3.2 (ground improvements).
- The Contaminated Land Investigation (Volume 3F) completed at the northeastern side of Williams Street (refer BH_47) showed no evidence of ground or groundwater contamination.

- Other investigation locations have encountered natural ground conditions and investigations have not identified the local area in the vicinity of Williams Street to be contaminated or potentially contaminated land. The potential for contaminants to be encountered from the excavation activities in this area is very low, with a correspondingly low risk of contaminants entering groundwater, as described in Section 6.3.1.

In summary, while there could be some excavation within 1 m of groundwater it is assessed that excavations in the vicinity of Williams Street interchange are expected to have negligible effects on shallow groundwater receptors.

##### 9.4.2.2.2 Effects on groundwater and wetlands from filling

**Effect on groundwater recharge and water levels**

Temporary filling activities and associated stockpiling of material could result in effects on groundwater with potential changes to local groundwater recharge, levels and flows. The overall effects are the same as described in the Project-wide items in Section 6.4.2.3.2 and there are no location specific groundwater effects at this location. The overall effect on the groundwater environment and thus groundwater receptors from the temporary filling is negligible.

**Effects on Wetlands**

The temporary effects on the natural inland wetlands CR_W1_NPSFM and CR_W2_NPSFM and their associated catchments from the construction activities is the same as the permanent effects. Therefore, these potential effects on the wetlands are described in Section 9.4.3.4.

#### 9.4.2.3 Ground improvements

##### 9.4.2.3.1 Effects on groundwater

Installation of rigid inclusions (13 m depth) and stone columns (8.5 m depth) will intercept the shallow unconfined groundwater and the rigid inclusions are likely to reach the semi-confined groundwater of the Riccarton/Burnham aquifer over a relatively large footprint at Williams Street overbridge.

**Mixing of groundwater from different aquifers**

The overall effects are the same as described for Cam River bridge in Section 8.4.2.2 where there is the potential for mixing of groundwater from different aquifers. In addition to effects described in Section 8.4.2.2, there is the low potential for the installation of stone columns to intercept and penetrate into the underlying semi-confined aquifer.

In addition, the resulting ground improvements will have a slightly higher permeability than the surrounding ground due to the filling with clean stones/aggregate. These columns could act as a pathway for any upwards groundwater flows, should this exist at the relatively shallow depths of 8.5 m and further mixing of aquifers could occur. This overall risk is low, however at the location of the intermittent spring-fed pond, this is likely and, in combination with the rigid inclusions, the effect on the mixing of groundwater is a moderate effect at this very localised area.

A consent condition has been included to address the issue should there be accidental artesian aquifer interception. One of the management methods to reduce the potential effects of mixing groundwater between aquifers, is described in Section 8.4.2.2, and in addition the following item should be considered and this will be included in the GMP:

- To reduce the potential effects at the spring-fed pond, stone columns filled with a lower permeability material should be undertaken (to reduce upward groundwater flows).

These mitigation measures will reduce the scale of effect to low.

**Groundwater flow and level**

The resulting ground improvement area is likely to have effects on groundwater flows and levels, whilst these effects may be initiated during the construction works, overall, they will have a permanent effect and they are described in Section 9.4.3.

**Groundwater quality**

There is the potential for temporary localised changes to groundwater quality to occur due to the ground improvement works. The overall effects are the same as described for Cam River bridge in Section 8.4.2.2. where the use of concrete in rigid inclusions could result in localised increases to the pH level of groundwater and a rise in groundwater temperature, and increased turbidity in shallow groundwater may occur as a result of these activities induced during the construction works.

#### 9.4.2.3.2 Effects on surface waters and wetlands

The Cam River/Ruataniwha is the nearest ecological receptor for groundwater to discharge into from the Williams Street ground improvement works, therefore the details provided in Section 8.4.2.2 remain the same.

It is assessed that construction of the ground improvements in the vicinity of Williams Street overbridge is expected to have low effects on groundwater quality from the ground improvements, and this effect, when compared to the effects at Cam River bridge is expected to be reduced due to fewer rigid inclusions over a wider area (although assessed at the same level of effect for a conservative approach). There is the potential for temporary localised changes to groundwater quality to occur due to the stone columns relating to a potential increased turbidity in shallow groundwater in the hole as a result of the augering of the hole and placing of the clean aggregate. This potential effect will be very localised within the augered hole and the overall effect on groundwater quality on receptors will be a negligible effect.

The nearest wetland to Williams Street overbridge is CR_W1_NPSFM located 50 m southeast and down gradient of the ground improvements. This wetland is likely to be beyond the potential zone where temporary changes in groundwater quality from the ground improvements could occur. In addition, this wetland receives most of its water contribution from the Cam River/Ruataniwha where effects on water quality are assessed as negligible. Therefore, the potential effect on the closest wetland is negligible.

The nearest shallow downgradient bore (i.e. less than 20 m depth) to the ground improvements is bore M35/5187, located 130 m to the southwest. The potential effects on this bore user is negligible.

In summary, the effects of any temporary changes in groundwater quality is low and the effect on the receiving environment is assessed as negligible.

#### 9.4.2.3.3 Effects on other groundwater users

The nearest groundwater user to the designation is bore M35/0515 approximately 45 m to the southeast at 565 Williams Street with a bore depth of 91.4 m depth. The depth of the neighbouring bore is significantly deeper than the temporary activities and likely penetrates the deep Linwood or Burwood aquifer. It is assessed that the increased turbidity in shallow groundwater induced during the construction works as a result of the ground improvements/vibrations and on groundwater quality will result in a negligible effect on the nearby groundwater user.

### 9.4.3 Permanent effects

#### 9.4.3.1 Road embankment

As described in Section 3.9, the road embankments could result in effects on groundwater with potential changes to the local regime. These overall effects are described in the Project-wide items in Section 6.4.3.1. and there are no location specific groundwater effects at this location. The overall effect on the groundwater environment from the road embankments is assessed as negligible and therefore the effect on groundwater receptors will be negligible.

#### 9.4.3.2 Ground improvements

As described in 8.4.3.2, the resulting ground improvement area at the localities of the rigid installations are likely to have a lower permeability following improvement due to the filling with concrete over a small localised area. The effects are described in Section 8.4.3.2.

Potential to changes to the groundwater flow and level from the rigid intrusions are likely to be offset by the installation of the stone columns which are likely to have a slightly higher permeability than prior to the improvement due to the filling with stones, which cover a large footprint area than the rigid installations. Noting that there will be some densification of the ground surrounding each stone column. However, this means that conversely, stone columns could provide a vertical flow path for groundwater movement within the unconfined aquifer and act as a conduit, if vertical leakage occurs from the underlying aquifer.

Therefore, the effect of the ground improvements to form a barrier to local groundwater flows is expected to be negligible, but the more permeable stone columns could alter the groundwater levels and thus flows. Therefore, the overall effect on shallow groundwater flow and level over the localised area of the ground improvements is assessed as a low effect, and the effect on groundwater receptors is negligible.

As described in the Section 8.4.3.2, the permanent long-term effects on groundwater quality on groundwater receptors are negligible.

#### 9.4.3.3 Effect on groundwater recharge and water levels

Williams Street overbridge embankment could locally reduce groundwater recharge in the area with the fill material limiting rainfall recharge to the underlying shallow aquifer. Reduction in recharge could reduce groundwater levels in the shallow aquifer. Stormwater collected from the road will be diverted to a stormwater bioretention basin on the north side of the road embankment, this will provide recharge as described in Section 9.4.3.4. The overall effect on the groundwater environment and groundwater receptors from the embankment is assessed as negligible.

#### 9.4.3.4 Stormwater retention and drainage

The effects from the stormwater systems at Williams Street interchange on groundwater are described in the Project wide items (Section 6.3.4.2).

In addition, the stormwater bio-retention basin will collect stormwater from the wider area and stormwater will be retained prior to discharge either to groundwater through infiltration or surface water. These discharges will provide groundwater recharge and potentially will balance or result in a minor reduction in groundwater recharge. The overall changes in recharge are likely to be a non-measurable effect on groundwater levels and therefore a negligible effect on groundwater levels and flows. The overall effect on the groundwater environment from the stormwater systems is assessed as negligible.

#### 9.4.3.4.1 Effects on Wetlands

There is the potential for effects to occur on the Cam River/Ruataniwha wetlands and their associated catchments on a permanent basis. These changes are compared with the existing (pre-construction) setting. Table 9.7 provides a summary of the potential permanent loss of wetland areas and catchments with the scale of effect, full details are provided in Appendix H.

**Table 9.7: Summary showing permanent loss of wetland areas and catchments**

| Wetland ID | Permanent loss of wetland extent | Permanent loss of wetland catchment | Mitigation required to reduce level of effect? | Permanent scale of effect |
|---|---|---|---|---|
| CR_W1_NPSFM | No | No | No | Low |
| CR_W2_NPSFM | 100 % | n/a | see EcIA (Volume 3I) | |

The key points, applicable to wetland CR_W1_NPSFM are:

- There will be no direct effect on the wetland extent.
- Road operation will not occur within 10 m of the wetland.

The potential for effects to occur on the wetland catchment for CR_W2_NPSFM on a permanent basis are because the wetland extent and part of the catchment will be beneath the road.

## 9.5 Summary of effects

A summary of the temporary and permanent effects on groundwater from the Williams Street interchange, principally comprising embankment, overbridge construction and ground improvements are provided in Table 9.8 and Table 9.9. Mitigation to reduce/minimise these effects is provided where the scale of effect is greater than 'low'.

**Table 9.8: Temporary groundwater effects from activities at Williams Street interchange**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Ground improvements (rigid inclusions & stone columns) | Groundwater level & flow (mixing aquifers & artesian groundwater) | Moderate | Refer to consent condition for accidental interception of artesian groundwater | Low |
| | Overall groundwater quality | Low | - | - |
| | Surface waters | Negligible | - | - |
| | Wetlands | Negligible | - | - |
| | Groundwater users | Negligible | - | - |
| Embankments & earthworks | Overall groundwater | Negligible | - | - |

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Culvert installation | Overall groundwater | Negligible | - | - |
| Shallow excavations | Overall groundwater | Negligible | - | - |

**Table 9.9: Permanent groundwater effects from activities at Williams Street interchange**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| All Ground improvements | Groundwater level & flow (mixing aquifers & artesian groundwater). | Low | - | - |
| | Groundwater level & flow on groundwater receptors. | Negligible | - | - |
| | Groundwater quality on receptors. | Negligible | - | - |
| Road embankment | Overall groundwater. | Negligible | - | - |
| | Loss of wetland extent & catchment to CR_W1_NPSFM. | Low | - | - |
| | Loss of wetland extent & catchment area to CR_W2_NPSFM. | High | Refer to EcIA (Volume 3I) | |
| Stormwater discharge | Overall groundwater. | Low | - | - |

# 10 Quarry Lakes embankment and southern remnant lake infilling

## 10.1 Proposed activities

A new tiered embankment will be installed through two artificial lakes (formed through quarrying), including dynamic compaction. The southern remnant lake created by the causeway will be filled and a wetland constructed in this area. Note: The initial (partial) reclamation is part of the Early Works consenting package so the effects of that reclamation have not been assessed here.

The proposed key activities relating to the hydrogeology effects are:

- Overfilling to form embankments.
- Dynamic compaction to create a compacted hardfill embankment which will form the foundation for the road.
- Infilling of the southern remnant lake.
- Surface water take from lakes for construction activities, including dust suppression.

### 10.1.1 Remnant lake Infilling

The main details of the infilling of the southern remnant lake are provided in the construction methodology (Volume 3A) and the key details are provided below:

- Approximately 50,000 $m^3$ of pitrun will be required to reclaim the remnant lake.
- Estimated infilling rate is up to 2000 $m^3$/day over 25 to 50 working days.
- Filling of the lake will be up to approximately 0.5 m to 1.0 m below the water level (noting that lake levels vary).
- Approximately one third of the remnant lake will remain as open water, with topsoil cover (approximately 10,000 $m^3$) over the filled portion of the remainder to form a wetland planting area.

### 10.1.2 Surface water take

A temporary water take from the Quarry Lakes is required for the duration of the construction works and the main details are provided below:

- Maximum daily water take will be 2000 $m^3$ during the peak dry season.
- Expected range in daily water take volumes is between 800 $m^3$ to 2000 $m^3$.
- Total annual water volume sought is 470,000 $m^3$.

## 10.2 Environmental setting

### 10.2.1 Site location and general description

The southern lake and the eastern lake are shown in Figure 10.1. The total surface area of both lakes, with the embankment construction is approximately 10 hectares. At the widest points, the southern lake is approximately 350 m wide and the eastern lake is approximately 380 m wide. These two lakes are connected by a cutting. The elevation of the lake water level is typically at 1 m to 2 m RL depending on seasonal fluctuations. The land elevation within the designation between the southern and eastern lakes rises to approximately 9 m RL.

Bathymetric surveys of the lakes were completed in April/May 2025[45] and the survey results are included in Appendix A. The survey included all of the southern lake and the southeastern part of the eastern lake. Based on the proposed infilled area to construct the embankment, the remaining southern lake depth ranges from approximately 6.5 m to 2 m (relative to the lake level surveyed on 28 April 2025). The eastern lake depth in the surveyed portion ranges from approximately 7 m to 3.5 m.

LiDAR completed on 28 April 2025 reported lake levels at 0.86 m RL. Anecdotal information[46] suggests lake levels vary and were approximately 1 m lower in April 2025 than "normal water levels". This information suggests typical lake water levels may be approximately 1.9 m RL. A recent survey[47] of the lake level recorded a lake level at 1.3 m RL.

Lake water has been sampled to determine the water quality. The results show lake water quality is as expected for an artificial lake, as described in the EcIA (Volume 3I).

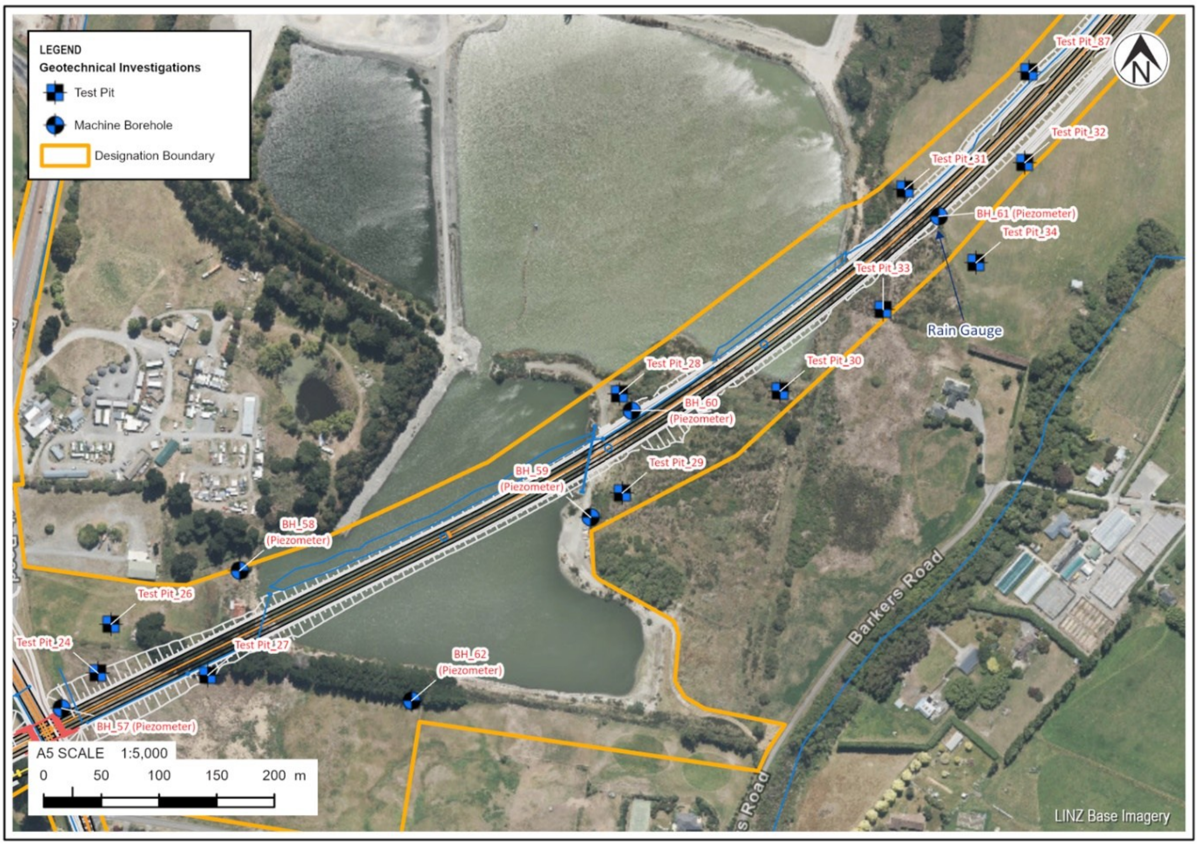



*Figure 10.1: Locations of monitoring wells, test pits and overland flow paths in the vicinity of Quarry Lakes.*

The surrounding land use beyond the southern and eastern quarry property boundary comprises rural land use with Barkers Road to the southeast. Pineacres Holiday Park is located immediately west of the southern lake with the existing SH1 beyond.

### 10.2.2 Geology and hydrogeology

Table 10.1 provides a summary of the local geology. A schematic geological and hydrogeological section is presented in Figure 10.5.

[45] Bathymetric survey completed on 28 April 2025 by Aurecon.
[46] As described by the Quarry operator to T+T during site investigations (April 2025).
[47] Aurecon survey on 01 September 2025.

**Table 10.1: Summary of local geology and hydrogeology at Quarry Lakes**

| Geology & Hydrogeology | | Details |
|---|---|---|
| Published geology[3] | • Holocene dune sand. | • up to approximately 800 m wide in the vicinity of the quarry. |
| | • Holocene river deposits to the east. | • East at approximately Barkers Road and west at approximately SH1. |
| Site specific investigations | • Interbedded sediments of sand/ gravelly sand to depths of 9 m - 10 m bgl.<br>• Deeper gravel sequence confirmed to 31 m bgl.<br>• Silt strata encountered at approximately 20 m bgl.<br>• Interbedded silt/fine to medium sand layer within the deep gravel sequence from 22.80 to 29.3 m bgl. | • Identified at southern lake.<br>• Five monitoring piezometers.<br>• See Figure 10.1. |
| Depth to shallow groundwater | • Range approx. -0.3 to 1.3 m RL (0 to 2.2 m bgl). | • Based on piezos BH_59, BH_60 and BH_61.<br>• Based on TP_29, TP_28, TP_30, TP_34 and TP_31. |
| Identified aquifer system[1] | • Coastal Confined Aquifer System.<br>• Unconfined /Semi-confined Aquifer System. | • See Figure 3.3. |
| Groundwater flow direction | • Toward southeast[40]. | • In the immediate vicinity of the lakes, it is inferred that the Quarry Lakes act as a groundwater sink and may locally influence the shallow groundwater flows, i.e. potentially radially toward the lakes. |
| Groundwater quality | • Groundwater samples collected from monitoring wells; BH_58 and BH_59. | • Overall groundwater quality is comparable with other groundwater quality data[48] with the exception of pH (high alkalinity) in BH58. This alkalinity is similar to the lake water pH.<br>• Groundwater quality reflects the natural expected groundwater conditions. |

Note: 1. As defined on the LWRP planning maps.

### 10.2.3 Hydrology

The Quarry Lakes are a closed system – there is no surface water input or output. However, the local groundwater is in direct hydraulic connection with the lake water at the quarry as illustrated in Figure 10.2 and Figure 10.5, and described in the conceptual hydrogeology model.

Table 10.2 provides a summary of the nearby water features and Figure 10.3 shows the location of the identified wetlands. A full description of the wetland assessments is provided in the (EcIA (Volume 3I).

[48] PDP (11 March 2025) Water quality monitoring for consent CRC093754.1 (Christchurch Ready Mix, Woodend). Sent to RMA Compliance & Enforcement Manager at ECan.

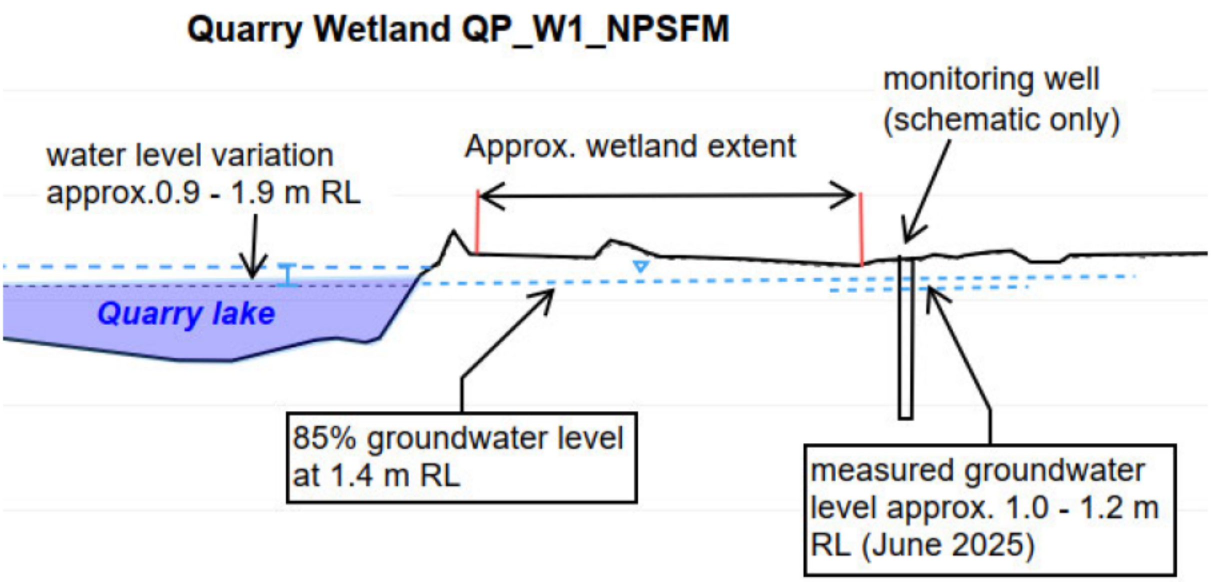



*Figure 10.2: Quarry Lakes Wetland 1 schematic cross section showing lake level variation and groundwater levels.*

**Table 10.2: Summary of nearby water features to Quarry Lakes**

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| Surface water catchment | • Waimakariri River | • n/a | • As defined on Canterbury Maps[20].<br>• See Figure 4.5. |
| Surface waters | • Cam River/Ruataniwha | • 350 m W of southern lake | • See Figure 9.1 (Williams St). |
| Wetlands | • QP_W1_NPSFM | • Part within designation | • See Figure 10.3.<br>• See Wetland assessment in Appendix H. |
| | • QP_W2_LWRP | • 75 m NW | • Does not meet definition of a natural inland wetland in NPSFM (LWRP wetland definition only).<br>• Located at Pineacres Holiday Park.<br>• Historical pond/constructed wetland.<br>• Wetland directly connected with pond.<br>• See Figure 10.3. |
| | • QP_W3_LWRP | • 55 m NW | • Does not meet definition of a natural inland wetland in NPSFM (LWRP wetland definition only).<br>• Constructed wetland.<br>• Wetland directly connected with lake.<br>• Vegetation has formed naturally on the margins of the eastern lake.<br>• See Figure 10.3. |
| | • QP_W4_NPSFM | • Part within designation | • See Figure 10.3.<br>• See Wetland assessment in Appendix H. |

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| | • Barkers Road Wetlands (BR_W1 to W4_NPSFM) | • 15 m E | • Located in historic stream channel east of Barkers Road which forms the tributary to Mcintosh Drain.<br>• Standing water along wetland length (July 2025).<br>• Wetland BR_W4_NPSFM locally known as Pohio Wetland where weed control of willows has been completed[49].<br>• See Figure 10.3. |
| Springs | • None | • n/a | • n/a |

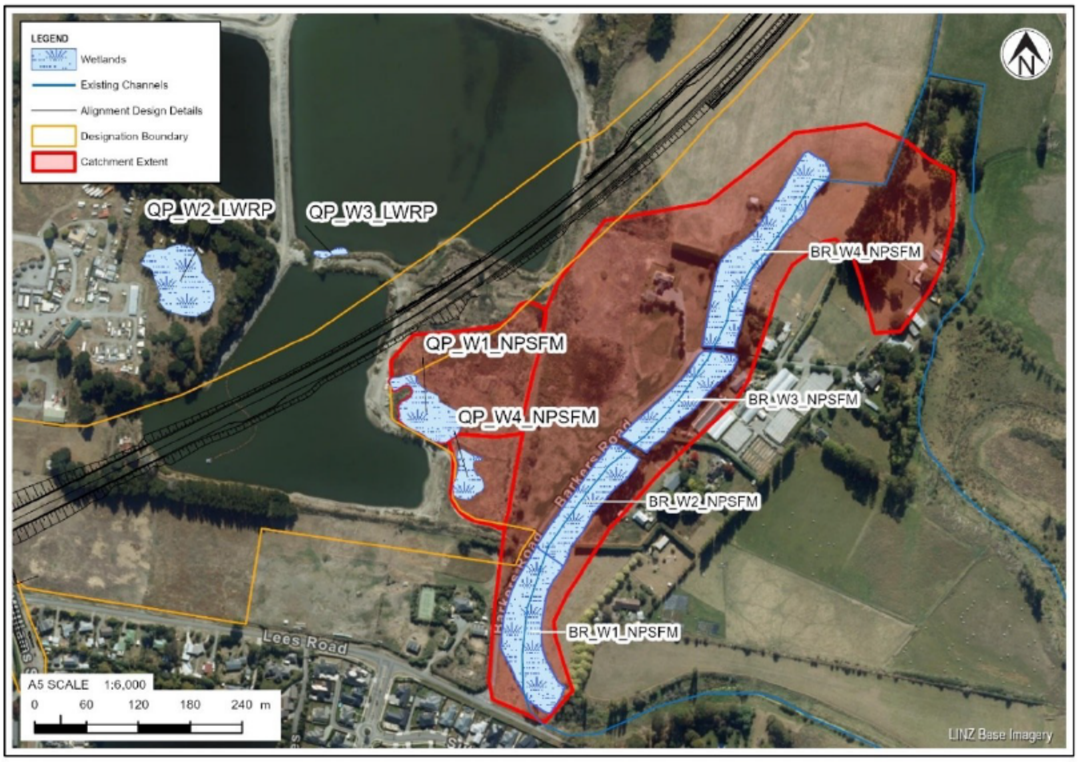



*Figure 10.3: Existing wetland extents and defined catchments near to Quarry Lakes.*

### 10.2.4 Surrounding groundwater users

Details of the bore survey are described in Section 4.6. Bores included in Table 10.3 are all of those bores within 400 m of the designation boundary surrounding the Quarry Lakes as shown in Figure 10.4.

[49] WDC/ECan (6 May 2024) Agenda: Canterbury Water Management Strategy Waimakariri Zone Committee (Pohio Wetland on pages 60-73).

**Table 10.3: Results of bore survey for all known bores[27] within 400 m of the designation at Quarry Lakes**

| Bore status | Bore use | Number of bores | Depth range (m) |
|---|---|---|---|
| Confirmed as present | Water supply purposes | 15 | 8 - 93.3 |
| | Other uses | 2 | 4 - 23.9 |
| Unconfirmed | Bore details not confirmed by owner | 7 | 19 - 131.1 |
| Unsure | Owner unsure if bore exists | 2[1] | 17.2 - 18.3 |
| Capped/sealed | n/a | 0 | - |

Notes: Details of bore use are provided in Section 4.6.1.
1. Bore BW24/0690 listed as not existing, but comments it is sampled by Waimakariri District Council every two months.

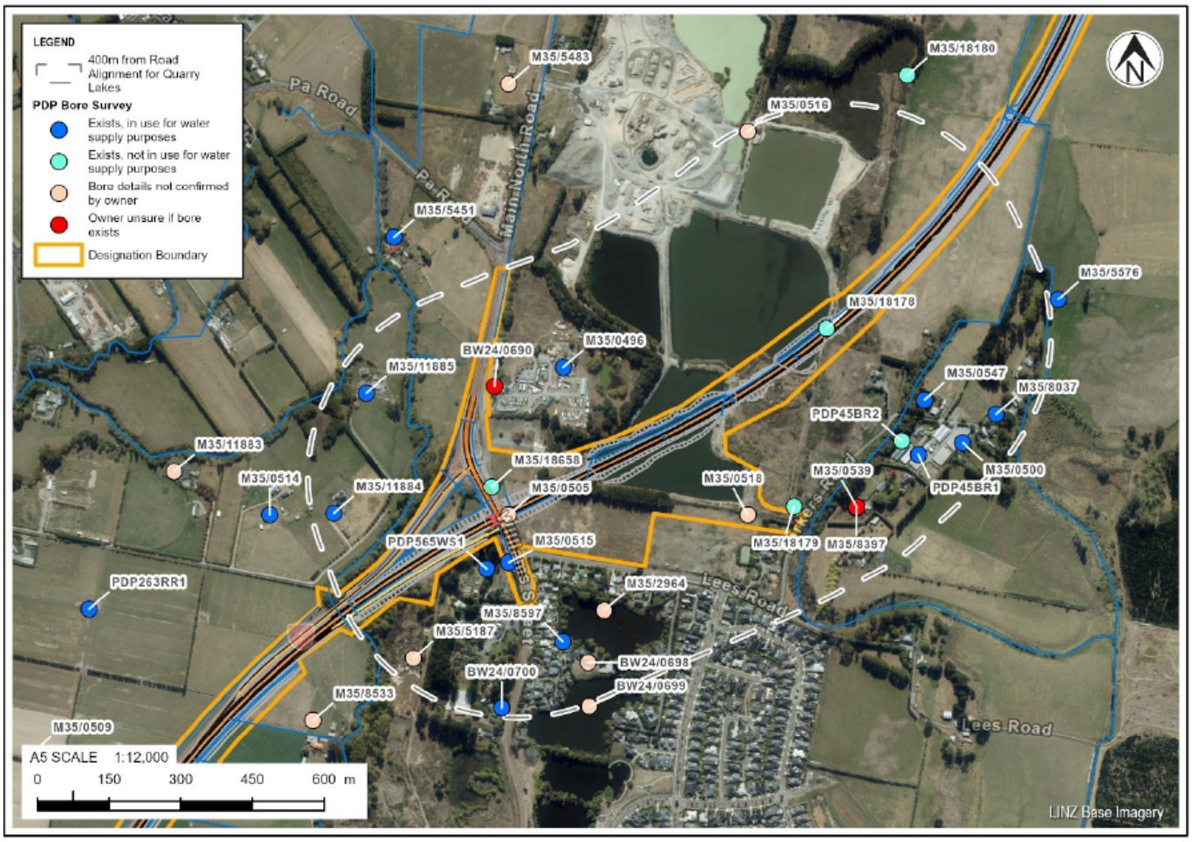



*Figure 10.4: All known bores within 400 m of the Designation surrounding Quarry Lakes (source: modified from PDP Bore Use Survey[27]).*

Table 10.4 provides details of those bores that may be affected by the temporary and permanent activities associated with the Project. Due to the nature of the proposed activities, there will be limited effects on the surrounding bore users and only bores with the potential to take water from the shallow unconfined groundwater within 20 m of the surface are included. This selected depth is to include consideration of the potential effects from the dynamic compaction activities. The effects on bores within the alignment are not considered because these will be decommissioned, as described in Section 6.4.2.4.

**Table 10.4: Bores within 400 m of the designation at Quarry Lakes that may be affected by the Project**

| Bore use | Number of bores | Comments |
|---|---|---|
| Shallow bores[1] (0 m - 20 m depth) for water supply purposes | 7 | Includes 1 bore unknown depth & 1 bore recorded "about 14 m" |
| Community drinking water bores | 0 | n/a |
| Bores within alignment requiring decommissioning | 1* | Owned by NZTA |

Notes: *3 bores are beneath the Williams Street interchange and these are included in Section 9.2.4.

[1] Water supply purposes are classified as those bores from which water is actively abstracted for a defined use such as domestic, stock water supply or irrigation. Community drinking water bores are listed separately.

## 10.3 Localised conceptual hydrogeology model

In summary, the hydrogeological conceptual model for the site comprises:

- The quarry lake water is in direct hydraulic connection with shallow groundwater and the lakes reflect the groundwater surface, albeit slightly modified by evaporation and rainfall.
- Groundwater levels are close to lake level with inflows expected from the sides and floor of the quarry.
- The reclaimed Quarry Lakes are generally adjacent to the mapped western boundary of the Coastal Confined Gravel Aquifer System. Site investigations confirm a confining layer at depth which is assessed as the boundary separating the unconfined aquifer from the deeper aquifer system.
- Interbedded sediments comprising predominantly sands extend to approximately 10 m depth which are underlain by gravels inferred to be the Riccarton/Burnham gravels.
- The interbedded sand and gravel sequence is likely to exhibit a moderate or medium permeability[50].
- The Riccarton/Burnham aquifer is likely to be semi-confined at this location.
- Recent site investigations have identified a thin i.e. less than 3 m thick confining layer at approximately 20 m depth around the southern lake. This is considered to be the confining layer to the Linwood Gravel aquifer.
- The surface water features identified in Table 10.2 are considered to be hydraulically connected with shallow groundwater.
- Figure 10.5 shows the developed conceptual hydrogeological model for the Quarry Lakes with a cross section extending from the Cam River/Ruataniwha in the west to beyond Barkers Road in the east where the wetlands are in connection with or close to the groundwater surface.

[50] GHD (18 December 2024) ECan Guidance on dewatering abstractions. Prepared for ECan.

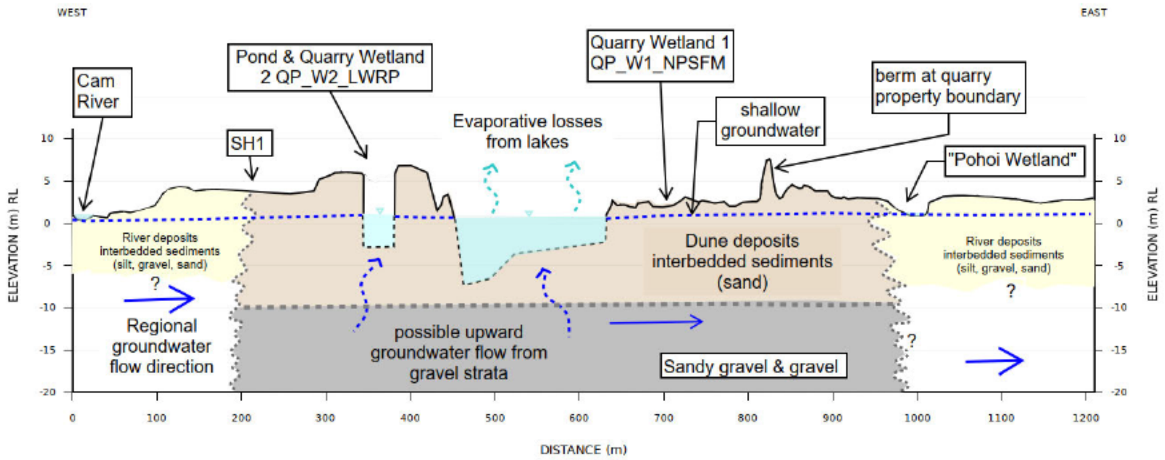



*Figure 10.5: Conceptual hydrogeological model - schematic sketch based on existing geological information (obtained from NZ Geotechnical Database (NZGD)).[51]*

## 10.4 Hydrogeological effects assessment for Quarry Lakes embankment

### 10.4.1 Overview

The proposed activities are summarised in Table 10.5 and the assessment of effects from these activities on groundwater are provided in Sections 10.4.2 and 10.4.3. A summary of the effects including the scale of effect is included in Section 10.5.

**Table 10.5: Summary of proposed activities**

| Proposed activities | Activity has potential to affect groundwater: | | |
|---|---|---|---|
| | Level | Quality | Flow |
| Temporary activities during construction | | | |
| Culvert installation | Yes | Yes | Yes |
| Embankment construction | Yes | No | Yes |
| Dynamic compaction | Yes | Yes | Yes |
| Water take | Yes | No | Yes |
| Lake infilling | Yes | Yes | Yes |
| Permanent activities during operation | | | |
| Road embankment | No | No | No |
| Stormwater discharges | Yes | Yes | No |
| Wetland offset area | Yes | No | No |

### 10.4.2 Temporary effects

#### 10.4.2.1 Culvert installation

One culvert will be installed at southern quarry lake to provide a balance of water between each side of the fill embankment. Excavation details are yet to be confirmed, but the excavations will not

[51] This does not include the recent T+T site investigations.

require any dewatering. Therefore, there will be no effects on the groundwater from the culvert excavation. Overall, the effects on groundwater quality will be negligible.

#### 10.4.2.2 Earthworks

##### 10.4.2.2.1 Effects on groundwater

Minor, shallow excavation activities will occur for the formation of the road embankment. The general conclusions are the same as described in the Project-wide items in Section 6.4.2.3.

Most of the Quarry Lakes area overlies the unconfined and semi-confined aquifer system, with the Coastal Confined Gravel Aquifer System crossed by the southern part of the southern lake. Despite these boundaries, there is a confining layer at depth within the area identified as the unconfined and semi-confined aquifer system.

In summary, whilst there could be some excavation within 1 m of groundwater, it is assessed that excavations in the vicinity of the Quarry Lakes are expected to have negligible effects on shallow groundwater receptors.

##### 10.4.2.2.2 Effects on Wetlands

There is the potential for effects to occur on the natural inland wetlands QP_W1_NPSFM, QP_W4_NPSFM and Barkers Road wetland complex BR_W1 to W4_NPSFM and their associated catchments from the temporary activities. These potential effects on the wetlands include changes to groundwater and surface catchments from the associated earthwork activities.

An assessment on the quantified loss of these wetlands has been completed with full details in Appendix H. Table 10.6 provides a summary of the potential loss of the wetland area and catchment during construction.

**Table 10.6: Summary showing temporary loss of wetland areas and catchments**

| Wetland ID | Works within 10 m? | Temporary loss of wetland extent | Temporary loss of wetland catchment | Mitigation required to reduce level of effect? |
|---|---|---|---|---|
| QP_W1_NPSFM | Yes | 3 % | 17 % | Yes, see EcIA (Volume 3I) |
| QP_W4_NPSFM | Yes | None | 5 %* | No |
| Barkers Rd Complex BR_W1 to W4_NPSFM | None | None | No | No |

Note: * Represents the area within the designation, but no works will occur in this area.

It is assessed that the effect on wetland QP_W1_NPSFM associated with construction activities is moderate based on the following points:

- There will be a temporary direct effect on the wetland extent with disturbance in part of the wetland that extends into the designation.
- Works will occur within 10 m of the wetland.
- Potential for reduction in the wetland catchment extent will be approximately 17 %.

Recommendations to address the scale of effects for wetland QP_W1_NPSFM are provided in the EcIA (Volume 3I).

It is assessed that the effect on wetland QP_W4_NPSFM associated with construction activities is negligible since there will be no excavation or earthworks within the wetland catchment and the only activity will be vehicle movements on the existing access track adjacent to the wetland catchment boundary. There are no assessed effects on Barkers Road wetland complex BR_W1 to W4_NPSFM for the same reason above and the effects will be negligible.

The catchments for the two other wetlands (as defined within the LWRP); QP_W2_LWRP and QP_W3_LWRP are considered to be the same as the wetland extent and these are assessed to have no direct effects from the construction activities.

#### 10.4.2.3 Dynamic compaction

Dynamic compaction (DC) involves the repeated dropping of a heavy weight onto the ground surface (road embankment) to densify loose fill. Ground vibration can propagate through the ground via different mechanisms and the effects of DC on aquifers and groundwater may occur.

A vibration assessment has been completed and a summary assessment in relation to the effects on groundwater is provided in Appendix I. Overall, vibration effects will tend to zero at depth and for sandy soils and gravels, it is likely that this will occur at depths of 10 m - 20 m.

Potential impacts on groundwater systems are primarily associated with pore pressure responses in saturated soils and disruption of confining layers. In aquifers confined by relatively thin or weakly consolidated layers (e.g., silt or clay), there is a potential, albeit limited, for vibration to reduce the integrity of that confining unit. This could allow vertical water migration or temporary rises in groundwater levels if preferential flow paths are created. The likelihood of this occurring is considered low due to the depth of the confining layer being approximately 20 m depth and at the assessed limit of the vibration effects. Therefore, the overall effect of the DC on groundwater is assessed as negligible.

##### 10.4.2.3.1 Effect on groundwater quality

There is the potential for temporary localised changes to groundwater quality to occur due to the construction works and increased turbidity in shallow groundwater may occur as a result of the vibrations induced during dynamic compaction. Changes to groundwater quality could affect groundwater users and wetlands. Whilst lateral vibrations will reach 200 m from the energy source, they will be below 2 mm/s which means that while they may be perceptible at times to people, the vibrations are not sufficient to displace soil particles within the aquifer matrix. It is assessed that construction works in the vicinity of Quarry Lakes are expected to have negligible effects on groundwater quality.

As described in Section 5.3.2.1, to confirm this scale of effect, pre-construction monitoring of groundwater conditions could be completed to confirm the groundwater levels and quality to provide baseline data and to allow effective groundwater monitoring during the road construction.

##### 10.4.2.3.2 Effects on other groundwater users

The nearest groundwater user to the designation is bore M35/0496 approximately 170 m to the northwest at 750 Main North Road (Pineacres Holiday Park) with a bore depth of 57.9 m depth. The next closest groundwater user to the designation is bore M35/8397 approximately 330 m to the southeast at 16 Barkers Road with a bore depth of 36 m depth. The depth of these nearby bores are deeper than the temporary activities (dynamic compaction vibrations). It is assessed that the increased turbidity in shallow groundwater induced during the construction works as a result of the vibrations will result in a negligible effect on the nearby groundwater users.

#### 10.4.2.4 Quarry lake infilling

##### 10.4.2.4.1 Overview

The infilling of the southern remnant lake for the creation of an ecological enhancement and wetland offsetting area has the potential to change the groundwater regime (flow and levels) if the infill material is significantly less permeable than the surrounding ground conditions. A lower permeability fill may lead to a disruption of the natural groundwater flow and recharge patterns. in addition, fine and compressible sediments remaining on the quarry lakebed (residuals from quarrying where finer particles were not extracted), may form a silt layer that locally restricts vertical groundwater exchange with the Quarry Lakes. This condition could impede recharge or discharge processes. Furthermore, the presence of these sediments has the potential to affect groundwater quality through leaching or chemical interactions.

As there are no structures at low elevations (less than 2.5 m RL) within 500 m of the quarry lakes, an assessment of potential flooding risk to structures from groundwater mounding has not been undertaken.

##### 10.4.2.4.2 Effects on groundwater flow

As described in Section 10.3 the permeability of the ground conditions (shallow aquifer) in the vicinity of the southern lake is considered to be of moderate or medium permeability[50]. The proposed infill material will have a higher permeability than the surrounding ground. Therefore, infilling of the southern remnant lake will not restrict groundwater flows across the Quarry Lakes.

Site investigation data from borehole drilling over the southern and eastern lakes indicates that the presence of silt deposits on the lake floor is limited to only one location (cone penetrometer test; CPT153 to the west of the southern remnant lake) where approximately 0.5 m of silt was reported on the lake floor. Therefore, the potential to create a low permeability layer on the lake floor as a result of the placement of the infill is considered unlikely/negligible. This means that if vertical groundwater movement into or out of the Quarry Lakes is occurring, these flows will not be disturbed by the placement of the high permeability of the infill.

In summary, the potential effects on the groundwater flow regime from the infilling of the southern remnant lakes are considered to be negligible.

##### 10.4.2.4.3 Effects on groundwater levels

The infilling will result in lake water being displaced, initially matching the same volume[52] as the infill i.e. the volume of solid infill displaces the same volume of water. This may cause the lake levels at the southern remnant lake to rise and could cause hydraulically connected groundwater levels to rise in the adjacent shallow aquifer and result in groundwater mounding. If groundwater levels change as a result of infilling this could potentially affect wetlands, surface waters and nearby wells (groundwater users).

To assess the effects of lake infilling on groundwater levels, the solid infill volume has been compared with the surface area of the southern remnant lake. Based on the assessment inputs in Table 10.7, and the lake infilling details in Section 10.1.1., it is calculated that the daily infilling will result in approximately a 30 mm (0.03 m) temporary daily rise in the lake levels as a result of the volume displacement.

Infilling will occur gradually over the 10-hour working day for up to 50 days, and concurrently lake water will begin to dissipate into the sides and the floor of the lake. This means the cumulative

[52] Solid or skeletal volume is the bulk volume of the infill minus the void (air) space i.e. the physical volume that will displace the water.

effects from the daily infilling will not increase by the same daily amount due to the continued dissipation of the lake water into the surrounding permeable ground. The total estimated water level increase is likely to be similar to the assumed[46] fluctuation in lake water levels of approximately 1 m.

**Table 10.7: Input parameters for lake discharge assessment (Part 1)**

| Parameter | value | unit | Description |
|---|---|---|---|
| Perimeter of remnant lake | 800 | m | Estimate measured using geospatial tools |
| Surface area of remnant lake | 25,000 | $m^2$ | Estimate measured using geospatial tools |
| Maximum daily bulk fill volume | 2,000 | $m^3$ | Estimate based on volumes provided in construction methodology |
| Estimated void ratio (specific yield) | 15 | % | Conservative estimate for granular pit run[53] |
| Maximum daily solid fill volume | 1,700 | $m^3$ | Calculated bulk volume minus voids |
| Daily lake water displacement | <0.03 | m | Calculated daily solid infill volume divided by lake surface area; displacement will be less than this due to dissipation |

Since the lake is recharged by groundwater, by determining the groundwater inflows to the lake, i.e. through the side walls of the lakes and vertical flows through the quarry lake floors, an estimate on the cumulative groundwater mounding effects can be calculated. Table 10.8 shows the input parameters used for this assessment and the results are present in Table 10.9.

**Table 10.8: Input parameters for lake discharge assessment (Part 2)**

| Parameter | Symbol | Values for lateral flows | Values for vertical flows | Unit | Description |
|---|---|---|---|---|---|
| Hydraulic gradient | I | 0.0001 | 0.001 | m/m | For lateral flows - value is a local conservative value based on a lake level change of 0.01 m over 100 m. |
| | | | | | For vertical flows – value based on 0.01 m (daily displacement) over 10 m. |
| Discharge area | A | 800 | 25,000 | $m^2$ | For lateral flows - Measured approximate perimeter x 1 m (depth) at edge of lake. |
| | | | | | For vertical flows - Measured approximate surface area. |
| Hydraulic conductivity | K | 10 to 900 | | m/d | Mean values for sand and sand gravel mixtures and clean gravel[50] for aquifer. |

[53] Kruseman, G.P. & de Ridder, N.A. (1991) Analysis and Evaluation of Pumping Test Data. Second Ed. Publication 47. International Institute for Land Reclamation and Improvement. The Netherlands.

**Table 10.9: Results for lake discharge assessment**

| Insert heading | Horizontal discharge rate ($m^3/d$) | Vertical discharge rate ($m^3/d$) | Description |
|---|---|---|---|
| Discharge rate* (Q) from lake, using Darcy's Law | 1 | 250 | Lower bound rate based on mean K for sand/gravel mixtures. |
| | 72 | 22,500 | Upper bound rate based on mean K for gravel. |
| | **36** | **11,375** | **Median discharge rate** of upper and lower bound results. |

*Calculated as Q=K.A.I

The results show that due to the surface area of the filling, vertical groundwater flows are much greater than the lateral groundwater flows and dissipation of lake water will occur predominantly through the quarry lake floor. The median discharge rate, shown in Table 10.9, estimates the daily volume of groundwater inflow is significantly greater than the displacement volume caused by the daily infilling. Conversely, this means the raised lake level from the infilling will quickly dissipate into the surrounding aquifer formation and the calculated increase in lake levels is expected to be imperceptible in the adjacent groundwater levels.

Nearby groundwater users (bore owners) whose bores penetrate the same shallow groundwater, are unlikely to notice an increase of groundwater levels in their bores and thus, the effect of filling is considered to be a negligible effect.

The temporary changes (increase) to the water levels at the two adjacent wetlands are expected to be significantly less than the expected seasonal variation and are expected to be barely perceptible. Therefore, the effects are assessed as negligible.

Cam River/Ruataniwha is located at distances of greater than 430 m west of the southern remnant infilling area. It is assessed that there will be no changes to the shallow groundwater that provide baseflow to the Cam River/Ruataniwha as a result of the infilling of the southern remnant lake.

In conclusion, the potential change in the groundwater levels from infilling the southern remnant lake is considered to be negligible.

#### 10.4.2.4.4 Effects on groundwater quality

The Quarry Lakes are artificial, and the lake water quality is characterised as expected for an artificial lake. The fill material will comprise clean pitrun that may include locally sourced river run and will be free from organic matter. As such, the water quality is not expected to be significantly changed by the placement of the infill with the exception of the temporary water quality effects of increased suspended sediment/ turbidity levels.

Consent compliance monitoring completed by Ready Mix[54], where high turbidity water is observed as a result of the quarrying activities, indicates that a deterioration in local shallow groundwater quality is not observed. Overall, it is concluded that the groundwater quality is generally reflective of the natural groundwater quality conditions[54]. This indicates that any displacement of lake water (which may have increased turbidity levels) into groundwater from the infilling would not significantly alter the groundwater quality as per the baseline sample collected in June 2025 (EcIA (Volume 3IE). In addition, while lake water enters groundwater the movement of suspended

[54] PDP (11 March 2025) Water quality monitoring for consent CRC093754.1 (Christchurch Ready Mix, Woodend). Sent to RMA Compliance & Enforcement Manager at ECan.

sediment into the aquifer matrix is expected to be imperceptible considering the likely low groundwater velocity and filtering action of the aquifer material.

The overall effect of the lake filling on groundwater quality assessed as negligible.

#### 10.4.2.5 Water take

A temporary water take from the Quarry Lakes is required for the duration of the construction works allowing for dust suppression and other minor miscellaneous water uses associated with the works.

The maximum daily water take will be 2000 $m^3$ during the peak dry season when dust suppression is required for the earthworks. The expected range in daily water take volumes is between 800 $m^3$ to 2000 $m^3$. The total annual water volume sought is 470,000 $m^3$. This annual volume is based on the assumed maximum number of dry days of 235 days as described in the Air Quality Assessment (Volume 3E), calculated from rainfall data taken over a 5-year period (2017 to 2021), and the peak daily volume. It is noted that the number of dry days when winds are greater than 5 m/s (assumed when dust suppression is required) are less than the total dry days. However, 235 days has been used in the assessment of effects to provide a conservative assessment for the indicative water requirements.

Surface water will be taken from the eastern quarry lake which is connected to the southern lake. The surface area of the lakes is approximately 10 ha (blue hashed area in Figure 10.6). This area is smaller than the total surface area of the existing lakes because it allows for the reclaimed lake areas from the filling for the road embankment and the infilling of the southern remnant lake.


*Figure 10.6: Available lake area (blue hashed area) for surface water take. Remaining Southern lake area will be infilled for the road embankment and for the wetland offsetting area.*

When considering the abstraction at the maximum daily take volume (2000 m$^3$/d), this will have a direct lowering of the lake (water) level of 0.02 m/d (assuming no rainfall recharge or groundwater inputs).

As described in Section 10.3, the Quarry Lakes is a closed system and recharge to this surface water occurs predominantly from groundwater discharge into the lakes (with only a minor amount from rainfall recharge). Therefore, there is ongoing replenishment of the lake water from groundwater inflows, and the lowering of lake levels will not be at a scale of the total cumulative effect from the surface water take, i.e., will be less than 0.02 m/d.

Given that the lakes are in direct hydraulic connection with the shallow groundwater, a simplified groundwater calculation has been used to model the conservative effects on groundwater levels (drawdown) based on the surface water take of 2,000 m$^3$/d.

#### 10.4.2.5.1 Effects on groundwater levels

A high-level analytical assessment has been undertaken to estimate the amount of groundwater drawdown likely from a surface water take of 2000 m$^3$/d at the Quarry Lakes. For this assessment, it is assumed that the groundwater inflow into the lake due to the surface water take is at least 2,000 m$^3$/day (the same as the surface water take). This assumption is based on the inference that shallow groundwater is in direct hydraulic connection with the Quarry Lakes, providing the majority of water input to the lakes. As described Section 10.4.2.4.3, actual groundwater inflows into the lake are much larger than the surface water take. Therefore, while the surface water take will be removing 2,000 m$^3$/day from the lakes, groundwater will be replenish the lakes at an equivalent rate.

The adopted method of assessment is based on groundwater inflows into a pit by Marinelli & Niccoli (2000)[55]. Whilst this analytical model is more commonly used for dewatering, as described in Appendix G, it can be used as a sensitivity assessment to model the potential groundwater inflow volumes and the resulting potential drawdown effects on groundwater levels due to the surface water take. This assessment evaluates the horizontal and vertical hydraulic conductivities of the unconfined aquifer and calculates the radial extent of the predicted drawdown. The results are based on the development of steady state conditions.

**Input parameters**

To model groundwater inflow and predict the drawdown in shallow groundwater levels due to the surface water take, the parameter values shown in Table 10.10 have been used in the calculations.

**Table 10.10: Input parameters used to predict effects of surface water take on shallow groundwater**

| Input parameters | Unit | Value | Source |
|---|---|---|---|
| **Lake geometry & details** | | | |
| Surface area of lakes | Ha | 9.92 | Estimate measured using geospatial tools |
| Perimeter of lakes | m | 1895 | |
| Width & length of eastern lake | m | 300 x 300 | |
| Lake level | m RL | 1 | Bathymetric survey[45] |
| **Aquifer parameters** | | | |

55 https://www.researchgate.net/profile/Walter-Niccoli/publication/249469020_Simple_Analytical_Equations_for_Estimating_Ground_Water_Inflow_to_a_Mine_Pit/links/5a450f21aca272d2945d983d/Simple-Analytical-Equations-for-Estimating-Ground-Water-Inflow-to-a-Mine-Pit.pdf.

| Input parameters | Unit | Value | Source |
|---|---|---|---|
| Horizontal hydraulic conductivity range (Kh) | m/d | 10 | Lower bound, mean value for sand and sand gravel mixtures adopted from ECan dewatering guidance permeability table. |
| Vertical hydraulic conductivity range (Kv) | m/d | 1 | Calculated based on the Kv to Kh anisotropy ratio (factor of 10). |
| Aquifer thickness (B) | m | 10 to 20 | Site investigations |
| Aquifer transmissivity (T) | $m^2$ | >100 | Expected minimum value calculated. |
| **Other details** | | | |
| Range in No. of dry days | days | 202 to 235 | Air Quality Assessment (Volume 3E) |
| Summer rainfall recharge | mm/yr | 60 | GNS Nationwide Groundwater Recharge Model[26] |
| | m/d | 0.0002 | |
| **Water take** | | | |
| Maximum daily volume | $m^3$ | 2000 | Peak dry season daily rate. |
| Take duration | days/yr | 235 | Maximum number of dry days, calculated over a 5-year period (2017 to 2021). |
| Annual volume | $m^3$/yr | 470,000 | Calculated. |

**Assumptions**

This assessment is based on the current available data and the following assumptions have been made:

- The method of assessment is based on assumptions described in Marinelli (2000)[55] and is based on steady state groundwater conditions, reflective of the stable lake levels (the magnitude of seasonal change in lake levels does not significantly alter the results).
- The surface water take is in direct hydraulic connection with groundwater in the shallow unconfined aquifer and the assessment assumes the aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the water take.
- The shallow unconfined aquifer in the area is composed of interbedded sand/gravelly sand to 10 m depth and therefore the assumption that the aquifer is homogeneous, isotropic and of uniform thickness is considered reasonable.
- The water take will be abstracted at a constant maximum rate and the volume of water removed from the lake is conservatively assumed to result in the removal of the same volume of groundwater stored in the unconfined aquifer, discharged instantaneously into the lake - with decline in groundwater head.
- The hydraulic conductivity value for the shallow unconfined aquifer is selected from the ECan published range for 'medium permeability' material and the mean value has been used for this assessment based on interpretation of the ground conditions completed at the quarry from the investigations (as described in Appendix B).
- For simplicity, the assessment is based on groundwater inputs to the eastern lake only, therefore the results are conservative i.e., the model is based on a circular pit represented by the eastern lake dimensions and do not include the contribution from the Southern lake.

**Results**

Based on the surface water take 2000 $m^3$/d volume (and therefore groundwater inflow), a conservative recharge rate, an no rainfall input to the lake, the predicted drawdown radius of influence on groundwater is approximately 560 m from the lake centre (i.e. where the drawdown effects are calculated to be zero). This is equivalent to a distance of approximately 400 m from the lake edge.

Figure 10.7 shows the drawdown results with the greatest predicted groundwater drawdowns occurring close to the lake edge (at approximately 0.5 m) and significantly reducing with distance away from the lake edge.

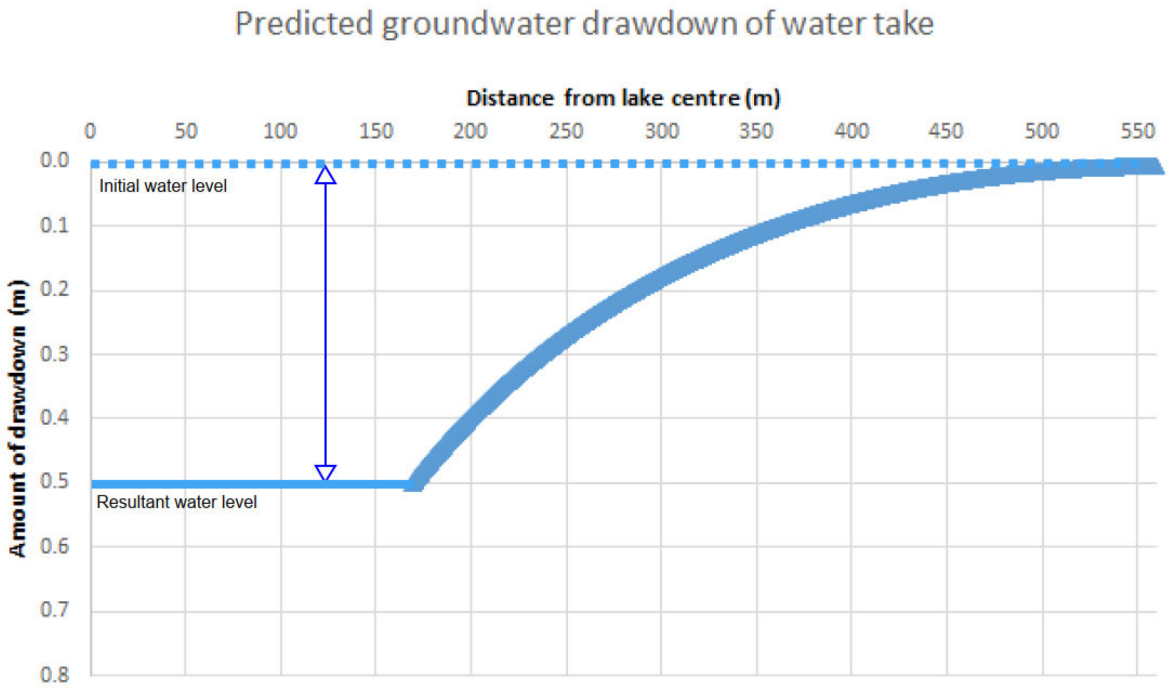



*Figure 10.7: Predicted steady state drawdown in groundwater levels in the unconfined aquifer.*

This drawdown assessment is conservative for the following reasons:

- The lake area from which the surface water will be taken will mostly be greater than assessed, i.e. the residual area of the southern lake has not been included.
- The hydraulic conductivity values are low for the material type and if higher values were used, i.e. to represent more permeable material, the predicted drawdowns at the lake would be significantly less.

In summary, whilst the radial extent of the drawdown has been assessed to reach 400 m from the lake edges, the assessment has layers of cumulative conservatism. Furthermore, the surface water take is temporary. The following assessments (described below) on groundwater users and surface waters show the potential effects are small, therefore the overall temporary effect on of the surface water take is assessed as low.

#### 10.4.2.5.2 Effects on groundwater users

There are eight bores within approximately 560 m of the centre of the lake that take groundwater for water supply (or the use is unknown). These bores are reported in Table 10.11. Based on the calculations in the above section, the largest predicted drawdown is approximately 0.1 m at bore M35/0496 and the amount of drawdown on groundwater levels in the other bores is much smaller than this. This amount of well interference effect is very small, it is likely to be unmeasurable and will not affect the way the bore owner can use their bore. Overall, the effect on neighbouring groundwater users is assessed as negligible.

**Table 10.11: Predicted drawdown effects on nearby groundwater users from the surface water take**

| Bore ID | Depth (m bgl) | Address | Approximate distance from centre of eastern lake (m) | Estimated drawdown (m) | Bore use |
|---|---|---|---|---|---|
| M35/0496 | 57.9 | 750 Main North Road | 340 | 0.12 | Water supply |
| M35/0516 | 31.1 | 788 Main North Road | 400 | 0.07 | Unknown |
| M35/0518 | 32.6 | Lees Rd | 400 | 0.07 | Unknown |
| M35/0547 | 14 | 51 Barkers Road | 460 | 0.03 | Water supply |
| PDP45BR1 | 28 | 54 Barkers Road | 480 | 0.02 | Water supply |
| M35/0539 | 17.2 | 16 Barkers Road | 480 | 0.02 | Unknown |
| M35/8397 | 36 | 16 Barkers Road | 500 | 0.02 | Water supply |
| M35/0500 | 93.3 | 54 Barkers Road | 565 | 0.01 | Water supply |

#### 10.4.2.5.3 Effects on nearby surface water features

The drawdown effects on other surface water features receiving baseflows from shallow groundwater, e.g., nearby wetlands and Cam River/Ruataniwha, could be affected by the surface water take. The closest surface water features are shown in Table 10.12 and include the predicted drawdown effects on groundwater levels at these surface water features. The results and potential effects are summarised as follows:

- The largest predicted groundwater drawdown is at the closest surface water feature: wetland QP_W3_LWRP of approximately 0.5 m. This wetland is located on the southern edge of the eastern lake. This wetland has adapted to high seasonal fluctuations and is still present despite the seasonal fluctuations. Therefore, the drawdown effect at this wetland are not expected to significantly affect the wetland and this temporary drawdown effect on the wetland is assessed as a negligible effect.
- At the location of wetland QP_W1_NPSFM the maximum predicted drawdown is approximately 0.3 m at the closest part of the wetland to the proposed take location, the drawdown effects will be less than this amount at the furthest part of the wetland. This wetland is assessed not to be dependent on groundwater inputs, and as such is unlikely to be affected by potential drawdown effects.
- At the location of wetland QP_W2_LWRP the maximum predicted drawdown is approximately 0.3 m, as per above the range in drawdown is expected to be less than this amount. This temporary effect on the wetland is assessed as a low effect.
- At the locations of wetlands QP_W4_NPSFM and the Barkers Road wetland complex BR_W1 to W4_NPSFM, the predicted drawdown effects are likely to be unmeasurable. This temporary effect on these wetlands is assessed as a negligible effect.
- The predicted drawdown effects do not extend beyond approximately 400 m from the lake edge, therefore, there will be no effects on baseflows to the Cam River/Ruataniwha and no stream depletion effects. This temporary effect on the surface water is assessed as no more than negligible effect.

**Table 10.12: Predicted steady state drawdown in water levels on nearby surface water features**

| Surface water feature | Approximate distance from centre of eastern lake (m) | Predicted groundwater drawdown (m) |
|---|---|---|
| QP_W3_LWRP | 150 | 0.5 |
| QP_W1_NPSFM | 250 | 0.3 |
| QP_W2_LWRP | 250 | 0.3 |
| QP_W4_NPSFM | 400 | <0.1 |
| Barkers Road wetland complex; BR_W1 to W4_NPSFM | 400 | <0.1 |
| Cam River/Ruataniwha | >700 | 0 |

In summary, the overall effect on surface water features from the surface water take from the Quarry Lakes is a negligible to low effect. The direct effect of the surface water take on the lake will be less than 0.02 m/d and the groundwater inflows into the lake are expected to meet this volume of daily take, therefore the effect on this artificial lake is assessed as negligible.

### 10.4.3 Permanent effects

#### 10.4.3.1 Road embankment

As described in Section 3.9, the road embankments could result in effects on groundwater with potential changes to the local regime. These overall effects are described in the Project-wide items in Section 6.4.3.1. and there are no location specific groundwater effects at this location. The overall effect on the groundwater environment from the road embankments is assessed as negligible and therefore the effect on groundwater receptors will be negligible.

##### 10.4.3.1.1 Effects on Wetlands

There is the potential for effects to occur on wetlands QP_W1_NPSFM, QP_W4_NPSFM and Barkers Road wetland complex BR_W1 to W4_NPSFM and their associated catchments on a permanent basis. These changes are compared with the existing (pre-construction) setting. Table 10.13 provides a summary of the potential permanent loss of wetland areas and catchments with scale of effect, full details are provided in Appendix H.

**Table 10.13: Summary showing permanent loss of wetland areas and catchments**

| Wetland ID | Permanent loss of wetland extent | Permanent loss of wetland catchment | Mitigation required to reduce level of effect? | Permanent scale of effect |
|---|---|---|---|---|
| QP_W1_NPSFM | None | None | No | Negligible |
| QP_W4_NPSFM | None | None | No | Negligible |
| Barkers Rd Complex BR_W1 to W4_NPSFM | None | None | No | Negligible |

The key points, applicable to the two wetlands at Quarry Lakes are:

- The road operation will not occur within 10 m of any of the wetlands.
- There are changes to the wetland catchments. However, the effects are reduced when compared with the temporary effects because part of the catchment used during construction i.e. the area within the designation that does not include the road footprint, will be returned to its previous condition e.g. by removal of the haul road and stock piling.

In addition, there will be a negligible direct effect (for QP_W1_NPSFM) and no direct effect (for QP_W4_NPS_FM) on the wetland extents.

The potential for permanent effects to occur on wetlands; Barkers Road wetland complex BR_W1 to W4_NPSFM, QP_W2_LWRP and QP_W3_LWRP are assessed to be negligible.

#### 10.4.3.1.2 Quarry lake infilling

The filling of the southern remnant lake will result in permanent changes to the groundwater regime. These changes have a positive effect on the shallow groundwater because the lake filling is restoring the aquifer matrix (albeit with different materials) and the area of the exposed surface water (directly connected with the groundwater) will be reduced to approximately one third of the current lake area.

The infilling will restore the physical connection between each side of the lake and will not alter the existing groundwater flows. Changes to groundwater levels may rise slightly as a result of the wetland offset area and the lake level of the remaining lake is expected to fluctuate in the same seasonal water level range as the existing lake setting.

The overall effect on the groundwater environment from the lake filling is assessed as negligible or even a beneficial effect.

#### 10.4.3.2 Stormwater retention and drainage

The effects from the stormwater systems at Quarry Lakes on groundwater are described in the Project wide items (Section 6.3.4.2). The stormwater discharges at this locality will discharge to ground in the embankments and potentially into the adjacent lakes. The overall effect on the groundwater environment from the stormwater systems is assessed as negligible.

## 10.5 Summary of effects

A summary of the temporary and permanent effects on groundwater from the activities at Quarry Lakes, principally comprising dynamic compaction, construction of the road, additional lake infilling and water take are provided in Table 10.14 and Table 10.15. Mitigation to reduce/minimise these effects is provided where the scale of effect is greater than ‘low’.

**Table 10.14: Temporary groundwater effects from activities at Quarry Lakes**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Culvert installation | Overall groundwater on receptors. | Negligible | - | - |
| Earthworks | Overall groundwater on receptors. | Negligible | - | - |

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| | Loss of wetland extent & catchment to QP_W1_NPSFM. | Moderate | Refer to EcIA (Volume 3I) | |
| | Loss to wetland extent & catchment to QP_W4_NPSFM, BR_W1 to W4_NPSFM. | Negligible | | |
| Dynamic compaction | Groundwater level and flow on receptors. | Negligible | - | - |
| | Groundwater quality on groundwater users. | Negligible | - | - |
| Lake infilling | Overall groundwater. | Negligible | - | - |
| Water take | Well interference. | Negligible | - | - |
| | stream depletion. | Negligible | - | - |
| | Groundwater level effect on Wetlands QP_W1_ NPSFM & QP_W3_ LWRP, QP_W4_NPSFM & BR_W1 to W4_NPSFM. | Negligible | - | - |
| | Groundwater level effect on Wetlands QP_W2_LWRP. | Low | - | - |
| | Groundwater level and flow on receptors. | Negligible | - | - |

**Table 10.15: Permanent groundwater effects from activities at Quarry Lakes**

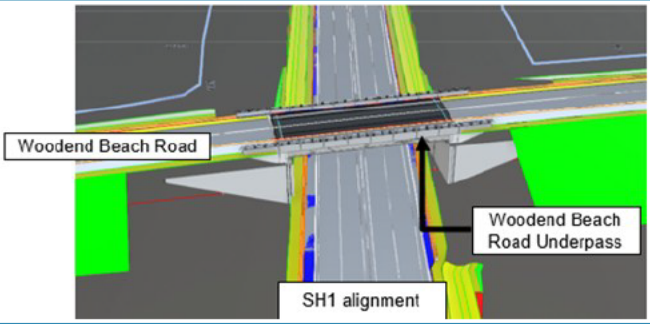
| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Road embankment | Overall groundwater. | Negligible | - | - |
| | Loss of wetland extent & catchment to QP_W1_NPSFM & QP_W4_NPSFM. | Negligible | - | - |
| Stormwater discharge | Overall groundwater. | Low | - | - |
| Wetland offset | Overall groundwater. | Negligible | - | - |

# 11 Woodend Beach Road overbridge

## 11.1 Proposed activities

A new overbridge structure at Woodend Beach Road will be constructed to carry the locally realigned Woodend Beach Road over the proposed SH1 alignment. The new overbridge structure at Woodend Beach Road will be constructed offline, details are summarised in Table 11.1. At this location, the new road alignment will have approach embankments leading up to the bridge from either side.

**Table 11.1: Summary details of Woodend Beach Road overbridge structure**

| Details | |
|---|---|
| Figure |  |
| Surface water crossing | • None. |
| Total bridge structural footprint | • 35 m x 16 m. |
| Foundations | • Shallow footings on MSE abutment walls. |
| Ground improvement | • Ground improvements beneath embankments (6.5 m stone columns). |
| Approaches | • Embankments |

The proposed key activities relating to the hydrogeology effects at this location are limited and comprise:

- Embankments for the overbridge and raised SH1.
- Minor excavations for MSE abutment walls.
- Ground improvements to 6.5 m depth.
- Installation of a culverts for overland flow paths each side of the embankments.
- Shallow excavations for stormwater swale and cut-off drain adjacent to the overbridge embankments.

## 11.2 Environmental setting

### 11.2.1 Site location and general description

The area of the new overbridge structure is situated on low-lying rural farmland adjacent to the existing Woodend Beach Road, as shown on Figure 11.1. A couple of residential properties lie to the north and south of Woodend Beach Road. The surrounding land use comprises rural land use with lifestyle blocks to the west and forestry plantations to the east.


*Figure 11.1: Locations of monitoring wells, test pits and overland flowpaths in the vicinity of Woodend Beach Road.*

### 11.2.2 Geology and hydrogeology

Table 11.2 provides a summary of the local geology. A schematic geological and hydrogeological section is presented in Figure 11.4.

**Table 11.2: Summary of local geology and hydrogeology at Woodend Beach Road**

| Geology & Hydrogeology | | Details |
|---|---|---|
| Published geology[3] | • Holocene river deposits. | • Situated in a former river channel.<br>• Variably sorted predominantly sand, silt, gravel strata. |
| | • Holocene dune sand. | • Approximately 350 m to east. |
| Site specific investigations | • Interbedded sediments of silt/ gravelly fine to coarse sand to 40 m depth.<br>• Top of confining silt layer at 18 m to 19.5 m & up to 6 m thick.<br>• Deeper interbedded sediments of silt/ gravelly fine to coarse sand sequence confirmed to 40 m bgl. | • Based on piezometer BH_65 and test pits; TP_45 to TP_50.<br>• See Figure 11.1.<br>• Thick silt identified in BH_65. |
| Depth to shallow groundwater | • Range approx. 0.9 m to 2.5 m RL (approx. 1 m to > 4 m bgl). | • Based on piezometer BH_65 and test pits; TP_45 to TP_50.<br>• See Figure 11.1. |

| Geology & Hydrogeology | | Details |
|---|---|---|
| Identified aquifer system[1] | • Coastal Confined Aquifer System. | • See Figure 3.3. |
| Groundwater flow direction | • Toward east-southeast[40]. | • See Figure 3.3. |

Note:

[1] As defined on the LWRP planning maps.

### 11.2.3 Hydrology

There are no surface waters near to Woodend Beach Road, only overland flow paths exist. Table 11.3 provides a summary of the nearby water features. The identified wetlands are more distant from Woodend Beach Road, however, they are close to the designation to the south of this area and for completeness are included in this section. Full descriptions of the wetlands are included in Appendix H.

**Table 11.3: Summary of nearby water features to Woodend Beach Road**

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| Surface water catchment | • Saltwater Creek | • n/a | • As defined on Canterbury Maps[20].<br>• See Figure 4.5. |
| Surface waters | • McIntosh Drain | • 700 m south | • Nearest surface water. |
| Wetlands | • FR_W1_NPSFM | • 230 m east* | • Wetlands collectively form the Fullers Road wetland complex.<br>• See Figure 11.2.<br>• Wetland assessment in Appendix H. |
| | • FR_W2_NPSFM | • 310 m east* | |
| | • FR_W3_NPSFM | • 65 m east* | |
| | • FR_W4_NPSFM | • 5 m east* | |
| Springs | • None | • n/a | • n/a |

Note: * The wetland complex is located between 450 m and 1600 m south of Woodend Beach Road.

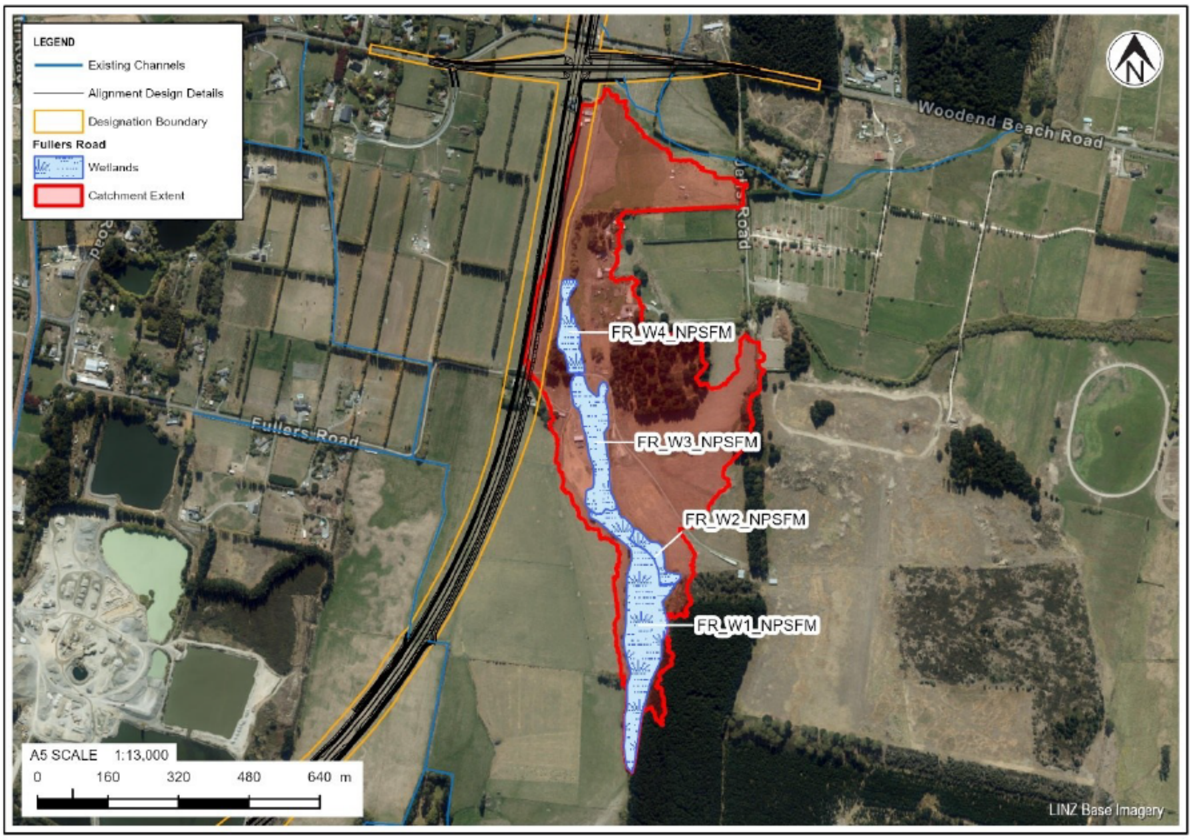



*Figure 11.2: Existing wetland extents and defined catchments south of Woodend Beach Road.*

### 11.2.4 Surrounding groundwater users

Details of the bore survey are described in Section 4.6. The bores included in Table 11.4 are all bores within 400 m of the designation boundary surrounding Woodend Beach Road as shown in Figure 11.3.

**Table 11.4: Results of bore survey for all known bores[27] within 400 m of the designation at Woodend Beach Road**

| Bore status | Bore use | Number of bores | Depth range (m) |
|---|---|---|---|
| Confirmed as present | Water supply purposes | 10 | 18 - 100.5 |
| | Other uses | 0 | - |
| Unconfirmed | Bore details not confirmed by owner | 18 | 16.58 – 100.97 (and two unknown) |
| Unsure | Owner unsure if bore exists | 1 | 18 |
| Capped/sealed | n/a | 0 | - |

Note: Details of bore use are provided in Section 4.6.1.

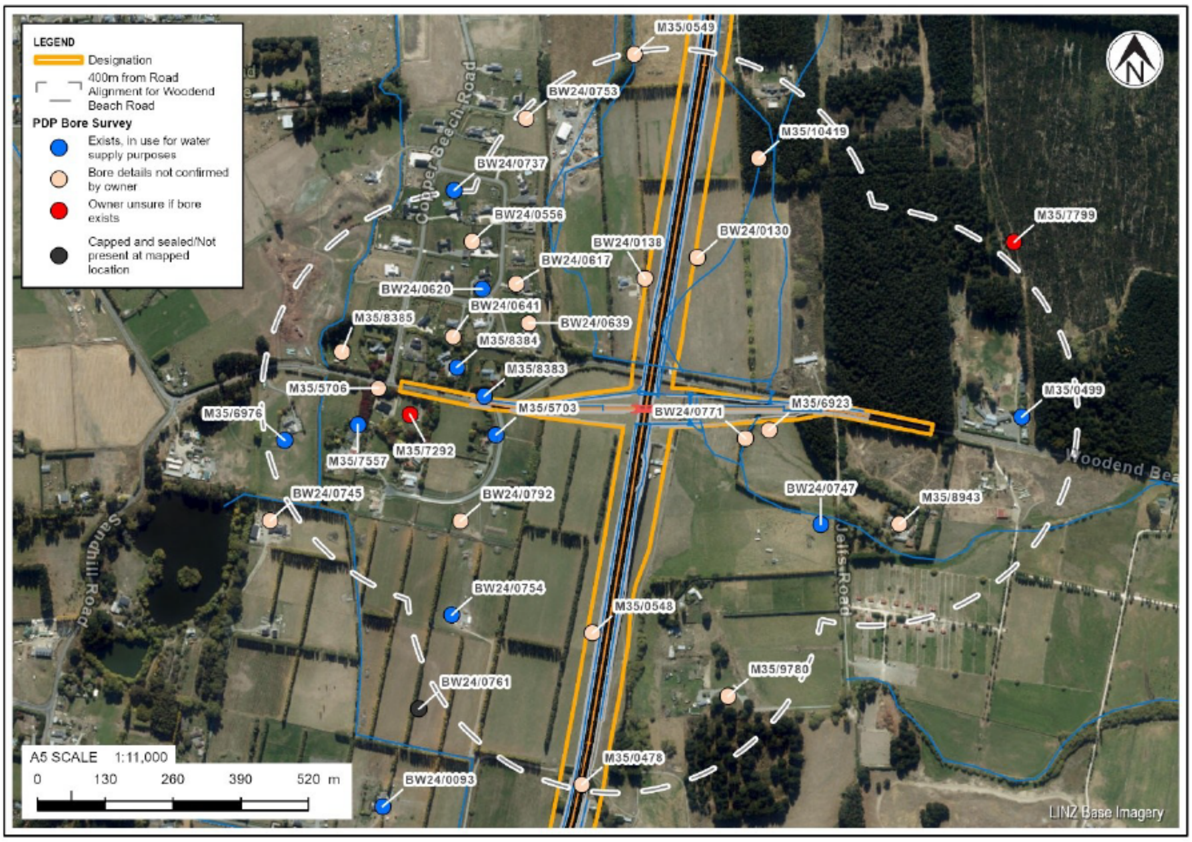



*Figure 11.3: All known bores within 400 m of the Designation surrounding* Woodend Beach Road *(source: modified from PDP Bore Use Survey*[27]*).*

Table 11.5 provides details of those bores that may be affected by the temporary and permanent activities associated with the Project. Due to the nature of the proposed activities, there will be limited effects on the surrounding bore users and only bores with the potential to take water from the shallow unconfined groundwater within 10 m of the surface are included. This selected depth is to include consideration of the potential effects from the ground improvement activities. The effects on bores within the designation are not considered because these will be decommissioned, as described in Section 6.4.2.4.

**Table 11.5: Bores within 400 m of the designation at Woodend Beach Road that may be affected by the Project**

| Bore use | Number of bores | Comments |
|---|---|---|
| Shallow bores[1] (0 m - 10 m depth) for water supply purposes | 2 | Two bores with unknown use and unknown depth |
| Community drinking water bores | 0 | n/a |
| Bores within designation requiring decommissioning | 2 | Owned by NZTA |

Notes:

1. Water supply purposes are classified as those bores from which water is actively abstracted for a defined use such as domestic, stock water supply or irrigation. Community drinking water bores are listed separately.
2. None of these bores are listed as shallow bores for water supply purposes.

## 11.3 Localised Conceptual hydrogeology model

In summary, the hydrogeological conceptual model for the site comprises:

- An unconfined (water table) aquifer within the interbedded silts and sands, with depths to groundwater level varying between approximately 1.8 m and 3 m bgl, underlain by a thick sequence of gravelly sand.
- Gravel of the Riccarton/Burnham Formation appear to be very thin or absent in this area. Therefore, it is likely that the overlying sediments form the unconfined to semi-confined aquifer.
- A thick silt layer, inferred to form an aquitard is encountered at 18 m to 19.5 m, and this extends to approximately 25 m bgl in the vicinity of Woodend Beach Road.
- The underlying aquifer is identified at depths of between approximately 20 m and 25 m bgl with deeper interbedded sediments confirmed to 40 m bgl. This is likely to be the confined aquifer of the Linwood Gravel, although it is noted that there is a distinct absence of gravel in the one deep borehole.

Figure 11.4 provides a conceptual hydrogeology model for Woodend Beach Road showing the depth of the ground improvements extending into the shallow groundwater. The confined aquifer is separated by greater than 10 m of predominantly sand deposits.

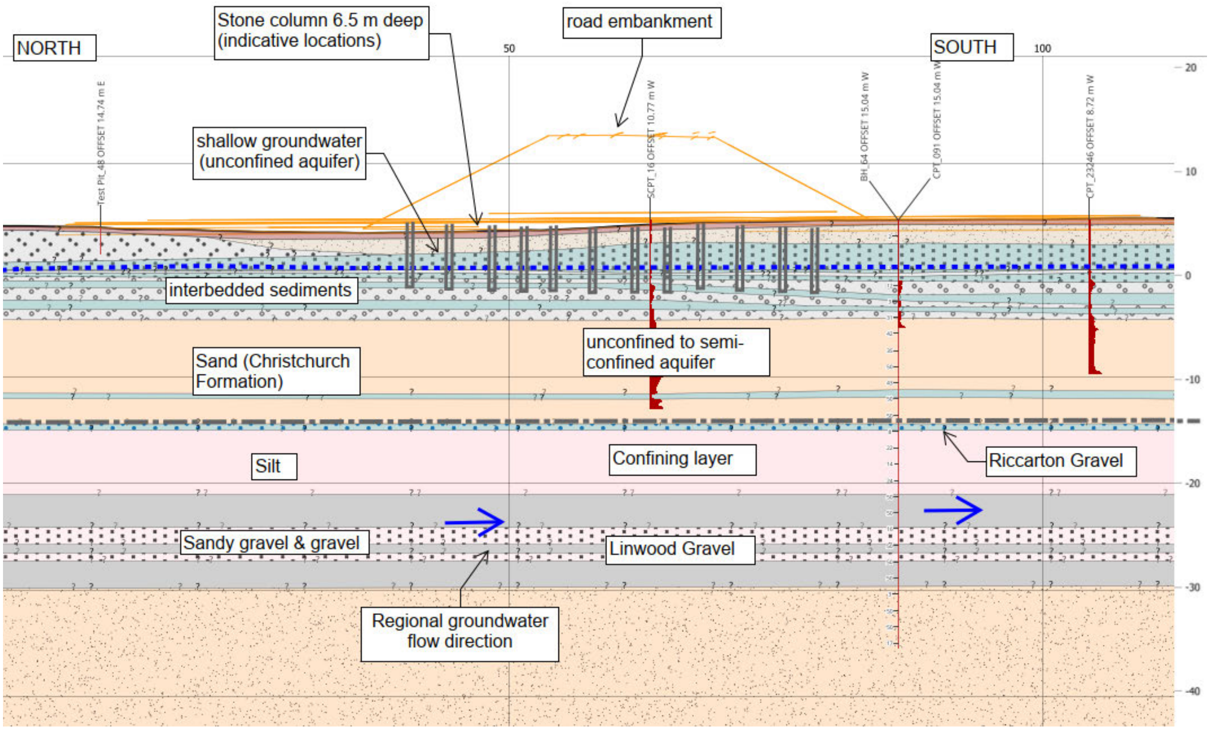



*Figure 11.4: Conceptual hydrogeological model - schematic sketch based on investigation information.*

## 11.4 Hydrogeological effects assessment for Woodend Beach Road overpass

### 11.4.1 Overview

The proposed activities are summarised in Table 11.6 and the assessment of effects from these activities on groundwater are provided in Sections 11.4.2 and 11.4.3. A summary of the effects including the scale of effect is included in Section 11.5.

**Table 11.6: Summary of proposed activities at Woodend Beach Road**

| Proposed activities | Activity has potential to affect groundwater: | | |
|---|---|---|---|
| | Level | Quality | Flow |
| **Temporary activities during construction** | | | |
| Culvert installation | Yes | Yes | Yes |
| Ground improvements stone columns | Yes | Yes | No |
| Embankment construction | Yes | No | Yes |
| Shallow excavations | No | Yes | No |
| **Permanent activities during operation** | | | |
| Ground improvements stone columns | No | No | No |
| Road embankments | No | No | No |
| Stormwater discharge | Yes | Yes | No |

### 11.4.2 Temporary effects

#### 11.4.2.1 Culvert installations

Three culverts will be installed at Woodend Beach Road. Two extend through the SH1 embankment (ID:006 & 007) and one (ID:008) extends through the eastern overbridge embankment. All culverts are to provide flow paths for overland flow i.e. there is no stream flow at the surface. The key excavation details for each culvert are shown in Table 11.7.

**Table 11.7: Excavation dimensions for culvert installations at Woodend Beach Road**

| Culvert ID | Surface water | Width (m) | Length (m) | Excavation depth range (m bgl) | | Excavation Base (m RL) |
|---|---|---|---|---|---|---|
| Culvert ID006 | Dry channel | 1.6 | 30 | 1.5 | 2.5 | 2.2 |
| Culvert ID007 | Dry channel | 2.5 | 40 | 1.3 | 1.7 | 2.2 |
| Culvert ID008 | Dry channel | 2.5 | 30 | 1.4 | 1.6 | 2.0 |

Based on the recorded depth to groundwater of 0.9 m to 2.5 m RL (1 m to > 4 m bgl) in this locality, shallow groundwater may not be encountered in all excavations, however, some dewatering could be required during the construction.

An assessment on the dewatering effects is included in Appendix G which includes a list of assumptions used to make this assessment. The results for maximum assessed effects are presented in Table 11.8 and the general conclusions are the same as described in the Project-wide items in Section 6.4.2.1. For that reason, these points are summarised below:

- Results are based on conservative groundwater levels, indicative excavation dimensions and anticipated dewatering duration.
- Radial drawdown effects from the dewatering are limited to local distances from the excavation.
- The maximum predicted distance from the centre of each excavation to where the amount of drawdown is estimated to be nil/less than measurable is 160 m.
- Groundwater induced settlement effects are localised to near the excavation and can be mitigated thorough construction methodologies.

**Table 11.8: Maximum assessed drawdown effect from dewatering at culverts ID006, ID007 & ID008**

| Culvert ID | Drawdown within excavation(s) (m) | Radius of drawdown extent (m) |
|---|---|---|
| Culvert ID006 | 0.5 | 160 |
| Culvert ID007 | 0.5 | 160 |
| Culvert ID008 | 0.5 | 160 |

The groundwater effects for culvert installation are described in the following sections.

#### 11.4.2.1.1 Effects on surface waters

The maximum radius of drawdown extent is predicted to be approximately 160 m from the edge of the excavation where dewatering could occur. There are no surface waters in the vicinity of Woodend Beach Road and existing overland flow paths are dry. Therefore, there will be no stream depletion effects from the short-term temporary dewatering for the culvert installations.

#### 11.4.2.1.2 Effects on other groundwater users

The nearest groundwater user to the culvert excavations is bore BW24/0771 at 40 m to the south of culvert ID008. The closest cDWPZ is approximately 750 m northeast of the culvert excavations. Given these bores are beyond the radius of drawdown extent the overall effects on groundwater users from the dewatering activities is negligible.

#### 11.4.2.1.3 Effects on groundwater quality

The effects on groundwater quality will be limited to increased sediment loading in the water at the base of each excavation. These overall effects are described in the Project-wide items in Section 6.4.2.1.3. and there are no location specific groundwater effects at this location. Overall, the effects on groundwater quality will be negligible and therefore the effect on groundwater receptors will be negligible.

#### 11.4.2.1.4 Effects of discharge water quality at point of discharge

Dewatering will generate water to discharge. These overall effects are described in the Project-wide items in Section 6.4.2.1.4. In addition, due to the absence of any surface water nearby, no discharges will go directly into surface water and soakage to ground is expected. Overall, the effects on groundwater quality will be negligible.

### 11.4.2.2 Earthworks

#### 11.4.2.2.1 Effects on groundwater

Minor, shallow excavation activities will occur for the formation of the road embankment and for creation of shallow footings for the MSE abutment walls. These excavations are expected to be more than 1 m above the local unconfined groundwater level. However, even if groundwater is encountered, these excavations will not require dewatering as placement of the backfill material can be completed in a wet excavation. Similarly, there will be shallow excavations for a stormwater swale and cut-off drain adjacent to the overbridge embankments. These excavations will be in natural ground but are expected to be dry excavations.

The general conclusions are the same as described in the Project-wide items in Section 6.4.2.3. It is assessed that site excavations in the vicinity of Woodend Beach Road are expected to have negligible effects on shallow groundwater and therefore the effect on groundwater receptors will be negligible.

##### 11.4.2.2.2 Effects on wetlands

There is the potential for effects to occur on the Fullers Road wetland complex (natural inland wetlands) and their associated catchments from the temporary activities. These potential effects include changes to groundwater and surface catchments from the associated earthwork activities.

An assessment on the quantified loss of these four wetlands has been completed with full details in Appendix H. Table 11.9 provides a summary of the potential loss of the wetland areas and catchments during construction.

**Table 11.9: Summary showing temporary loss of wetland areas and catchments**

| Wetland ID | Works within 10 m? | Temporary loss of wetland extent | Temporary loss of wetland catchment | Mitigation required to reduce level of effect? |
|---|---|---|---|---|
| FR_W1_NPSFM | No | None | 7 % | No |
| FR_W2_NPSFM | No | None | 7 % | No |
| FR_W3_NPSFM | No | None | 8 % | No |
| FR_W4_NPSFM | Yes | None | 16 % | Yes, see EcIA (Volume 3I) |

It is assessed that the effect on wetland FR_W4_NPSFM associated with construction activities is low based on the following points:

- Works will occur within 10 m of the wetland.
- Potential for reduction in the wetland catchment extent will be approximately 16 %.

Recommendations to address the scale of effects for wetland FR_W4_NPSFM are provided in the EcIA (Volume 3I).

It is assessed that the effect on wetlands FR_W1, W2, and W3_NPSFM associated with construction activities is negligible based on the following points:

- Works will not occur within 10 m of the wetlands.
- Potential for reduction in the wetland catchment extent will be less than 10 %.

#### 11.4.2.3 Ground improvements

##### 11.4.2.3.1 Effects on groundwater

Installation of stone columns to 6.5 m depth will intercept the shallow unconfined groundwater and are not expected to penetrate into the underlying semi-confined aquifer. There will be minor disturbance of the shallow aquifer during construction, however, no groundwater removal occurs during these temporary works.

**Mixing of groundwater from different aquifers**

The resulting ground improvement area is likely to have effects on groundwater flows and levels, whilst these effects may be initiated during the construction works, overall, they will have a permanent effect and they are described in Section 11.4.3.

**Groundwater flow and level**

The resulting ground improvement area is likely to have effects on groundwater flows and levels, whilst these effects may be initiated during the construction works, overall, they will have a permanent effect and they are described in Section 11.4.3.

**Groundwater quality**

There is the potential for temporary localised changes to groundwater quality to occur due to the stone columns relating to a potential increased turbidity in shallow groundwater in the hole as a result of the augering of the hole and placing of the clean aggregate. This potential effect will be very localised within the augered hole and the overall effect on groundwater quality and thus groundwater receptors will be a negligible effect.

### 11.4.3 Permanent effects

#### 11.4.3.1 Road embankment

As described in Section 3.9, the road embankments could result in effects on groundwater with potential changes to the local regime. These overall effects are described in the Project wide-items in Section 6.4.3.1. and there are no location specific groundwater effects at this location. The overall effect on the groundwater environment from the road embankments is negligible and therefore the effect on groundwater receptors will be negligible.

##### 11.4.3.1.1 Ground improvements

Potential to changes to the groundwater regime may occur from the permanent placement of the stone columns.

**Mixing of groundwater from different aquifers**

Due to the relatively shallow installation depth of the stone columns, there is limited potential for mixing of groundwater from different aquifers. The ground improvements will have a slightly higher permeability than the surrounding ground due to the filling with clean stones/aggregate. These columns could provide a vertical flow path for groundwater movement within the unconfined aquifer and act as a conduit, if vertical leakage from the underlying semi-confined aquifer occurs. However, this overall risk is low given the relatively shallow depths of 6.5 m and unlikely, therefore, the permanent effect on the mixing of groundwater is a negligible effect.

**Groundwater flow and level**

As described above, the resulting ground improvement area is likely to have a slightly higher permeability than prior to the improvement due to the filling with clean stones/aggregate. Noting that there will be some densification of the ground surrounding each stone column. However, this means that conversely, stone columns could provide a vertical flow path for groundwater movement within the unconfined aquifer and act as a conduit, if vertical leakage occurs from the underlying aquifer. Therefore, the effect of the ground improvements to form a barrier to local groundwater flows is expected to be negligible, but the more permeable stone columns could alter the groundwater levels and thus flows, have a low effect on shallow groundwater flow and level over the localised area of the ground improvements. and the effect on groundwater receptors is negligible.

**Groundwater quality**

As described in the Section 8.4.3.2, the permanent long-term effects on groundwater quality on groundwater receptors are negligible.

#### 11.4.3.1.2 Effects on Wetlands

There is the potential for effects to occur on the Fullers Road wetland complex and their associated catchments on a permanent basis. These changes are compared with the existing (pre-construction) setting. Table 11.10 provides a summary of the potential permanent loss of wetland areas and catchments with the scale of effect, full details are provided in Appendix H.

**Table 11.10: Summary showing permanent loss of wetland areas and catchments**

| Wetland ID | Permanent loss of wetland extent | Permanent loss of wetland catchment | Mitigation required to reduce level of effect? | Permanent scale of effect |
|---|---|---|---|---|
| FR_W1_NPSFM | None | 4 % | No | Negligible |
| FR_W2_NPSFM | None | 5 % | No | Negligible |
| FR_W3_NPSFM | None | 6 % | No | Negligible |
| FR_W4_NPSFM | None | 11 % | Yes | Low |

The key points, applicable to all four wetlands in the Fullers Road wetland complex are:

- There will be no direct effect on the wetland extents.
- The road operation will not occur within 10 m of any of the wetlands.

There are changes to the wetland catchments. However, the effects are reduced when compared with the temporary effects because part of the catchment used during construction i.e. the area within the designation that does not include the road footprint, will be returned to its previous condition e.g. by removal of the haul road and stock piling. Recommendations to address the scale of effects for wetland FR_W4_NPSFM are provided in the EcIA (Volume 3I).

## 11.5 Summary of effects

A summary of the temporary and permanent effects on groundwater from the activities at Woodend Beach Road, principally comprising overbridge construction including ground improvements, construction of the road, and culvert installation are provided in Table 11.11 and Table 11.12. Mitigation to reduce/minimise these effects is provided where the scale of effect is greater than 'low'.

**Table 11.11: Temporary groundwater effects from activities at Woodend Beach Road**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Culvert installation | Overall groundwater on receptors | Negligible | - | - |
| Ground improvements (stone columns) | Groundwater level & flow (mixing aquifers) | Low | - | - |
| | Groundwater quality on receptors | Negligible | - | - |

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Earthworks | Overall groundwater on receptors | Negligible | - | - |
| | Loss of wetland extent & catchment to FR_W1_NPSFM, FR_W2_NPSFM & FR_W3_NPSFM | Negligible | Refer to EcIA (Volume 3I) | |
| | Loss of wetland extent & catchment to FR_W4_NPSFM | Low | | |
| Shallow excavations | Overall groundwater | Negligible | - | - |

**Table 11.12: Permanent groundwater effects from activities at Woodend Beach Road**

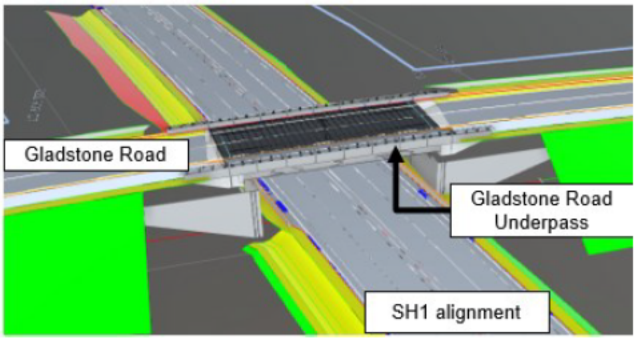
| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Ground improvements (stone columns) | Groundwater level & flow (mixing aquifers) | Low | - | - |
| | Groundwater quality on receptors | Negligible | - | - |
| Road embankment | Overall groundwater on receptors | Negligible | - | - |
| | Loss of wetland extent & catchment to FR_W1_NPSFM, FR_W2_NPSFM & FR_W3_NPSFM | Negligible | - | - |
| | Loss of wetland extent & catchment to FR_W4_NPSFM | Low | Refer to EcIA (Volume 3I) | |
| Stormwater discharge | Overall groundwater | Low | - | - |

# 12 Gladstone Road overpass

## 12.1 Proposed activities

A new overbridge structure at Gladstone Road will be constructed to carry the existing road over the proposed SH1 alignment, details are summarised in Table 12.1. It will be constructed online and will require a temporary road diversion during construction. The new road alignment will have approach embankments leading up to the bridge from either side. The overbridge will also provide for the Waihora Stream flow path which will connect to the new culvert being constructed as part of the approach embankments.

**Table 12.1: Summary details of Gladstone Road overbridge structure**

| Details | |
|---|---|
| Figure |   |
| Surface water crossing | • Waihora Stream flowpath only – no surface water. |
| Total bridge structural footprint | • 38 m x 16 m. |
| Foundations | • Shallow footings on MSE abutment walls. |
| Ground improvement | • No ground improvements beneath embankments, but excavation to 1.5 m depth and replace with geogrid raft 1.2 m – 3 m thick. |
| Approaches | • Embankments. |

In addition to the bridge construction, ground improvement works will be completed at the adjacent landfill. There are three options for the works at the landfill, which are described below.

Treatment of the landfill will be one of the first construction activities in this area once the site is established. This treatment will comprise either:

1. Full removal and replacement with hardfill material;
2. Compaction of landfill in place; or
3. A combination comprising partial removal, compaction, and replacement with some hardfill.

Dewatering is expected to be required if full or partial removal of landfill material is undertaken.

Following clearance of the construction footprint, and excavation to approximately 1.5 m below existing ground, a geogrid reinforced gravel raft will be laid under the bridge structure footprint. Relocation of existing services will be completed to the north of the overbridge outside the bridge ground improvement footprint.

The proposed key activities relating to the hydrogeology effects at this location comprise:

- Works to Gladstone landfill.
- Shallow excavations for utilities installations.
- Shallow excavations to 1.5 m depth for the geogrid raft.
- Minor excavations for MSE abutment walls.
- Construction of embankments for the overbridge and raised SH1.
- Installation of a culverts for overland flow paths each side of the embankments.
- Shallow excavations for stormwater swale and cut-off drain adjacent to the overbridge embankments.

## 12.2 Environmental setting

### 12.2.1 Site location and general description

The new overbridge structure is situated on the existing Gladstone Road and the surrounding area comprises low-lying rural farmland and some residential properties. A former landfill (described in the following section) is located immediately north of Gladstone Road. Gladstone Park which includes sports fields and the WDC Gladstone public water supply bores is located to the east of the proposed overbridge.

The wider surrounding land use comprises rural land use with lifestyle blocks. Woodend is located to the west of the Project with Pegasus to the northeast. The Woodend Wastewater Treatment Plant lies 600 m to the east of Gladstone Road.

#### 12.2.1.1 Gladstone landfill

The property at 162 Gladstone Road has historically been used as a landfill. The material used to fill the site has been investigated and the findings are reported in the Contaminated Land Investigation (Volume 3F) which includes information on the nature of the landfill and records of previous investigations .

Based on the Contaminated Land Investigation, the key points relating to the groundwater environment are summarised as follows and full descriptions are contained in the Contaminated Land Investigation (Volume 3F):

- Site was a council owned borrow pit (approximately 0.6 hectares) from at least 1945 and was infilled from 1960s to 1974. Records document infilling with “domestic rubbish and fill material”.
- A historical aerial photograph shows the presence of water in the borrow pit excavation which is assumed to be groundwater. The date of the photograph and the depth of the excavation is not known.
- During historical test pitting (July 2012) in the landfill the presence of fill materials of variable composition was recorded. It was noted that the proportion of ‘non-soil’ material was low, and organics/putrescible proportion was very low, indicating that these materials are primarily hardfill. Further details from the July 2012 investigations are as follows:
  - Fill material was encountered at depths of up to 4.2 m bgl (based on ground surface at 2012) during the historical test pitting.
  - One test pit; TP4 reached the base of the fill and encountered alluvium at 3.2 m and proven to 4.2 m depth. Another test pit; TP6 recorded a shallow depth of fill to 0.2 m underlain by alluvium, proven to 3 m depth.
  - Groundwater was not encountered during the July 2012 investigation where four trenches reached up to 2.2 m depth in fill and six test pits reached up to 4.2 m in the fill.
- The August/September 2025 investigations comprised soil sampling from seven machine dug test pits/boreholes/trenches and three hand augers, up to 5.8 m depth, and water sampling from one monitoring bore. Further details from these investigations are provided in the Contaminated Land Investigation report (Volume 3F) and are summarised as follows:
  - Fill was observed across the site surface and in all investigation locations, to depths of up to 5.35 m bgl.
  - Three test pits were constructed into the perimeter bunds. The materials encountered comprised fill of sand with minor silt and organic material, and trace refuse (wood, plastic, steel, concrete and bricks). Suspected asbestos containing material (ACM) was observed in one test pit.

  - Test pits/boreholes excavated into the underlying landfill encountered sand, silt, or gravel with variable amount of refuse observed at all locations typically comprising a combination of wood and logs, brick and concrete fragments, plastic, geofabric, glass, steel rebar, rope, charcoal, and tyres.
- The natural material immediately underlying the fill comprises sandy gravel, underlain by silt, sand and peat layers.
- Groundwater was encountered at depths of between 3.83 m and 5.35 m bgl (3.5 m to 4.24 m RL) in the four boreholes within the landfill.
- One piezometer has been installed in BH_38 (approximately centred in the middle of the landfill), and measured groundwater levels ranged between 3.88 m RL to 4.16 m RL, representing early spring groundwater levels.

- Groundwater samples were collected from the borehole over two sampling rounds. The assessment of the 2025 groundwater sampling data indicates:
  - Only very trace (0.2 ppm) volatiles were detected in field monitoring during groundwater monitoring/sampling.
  - No exceedances of the DWSNZ MAVs or the ECan water quality[56] limits for groundwater were recorded.
  - Hydrocarbons and pesticides were not detected above the laboratory reporting limit for both samples.
  - Copper and zinc exceeded the 90 and 95 % species protection criteria in surface water for both samples. All other dissolved heavy metals were detected below the criteria for 95 % species protection, with a number of metals below the laboratory reporting limit.
- Figure 12.1 shows a conceptual sketch of the landfill with the depth to fill,  approximate groundwater level  and road embankment outline.

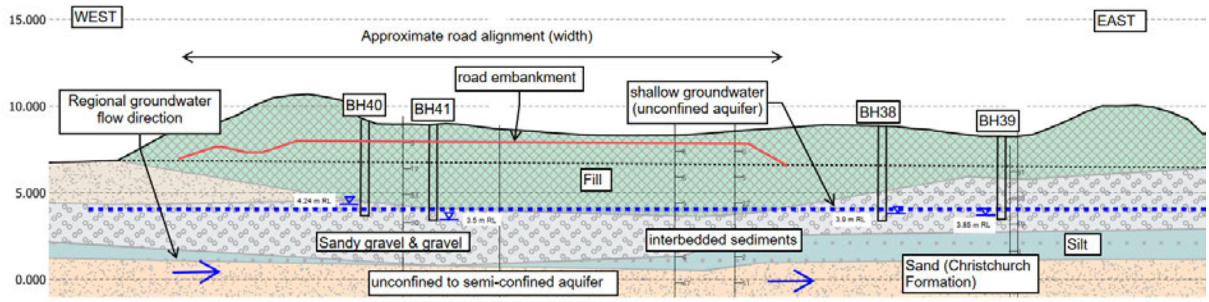



*Figure 12.1: Conceptual hydrogeological model of Gladstone landfill - schematic sketch based on investigation information.*

### 12.2.2 Geology and hydrogeology

Table 12.2 provides a summary of the local geology.

[56] Environment Canterbury Regional Council. Canterbury Land and Water Regional Plan, Volume 1, 2025. Water Quality Limits and Targets for Groundwater (Table 8i), based on the NZ drinking water standards MAVs.

**Table 12.2: Summary of local geology and hydrogeology at Gladstone Road**

| Gladstone Road Geology & Hydrogeology | | Details |
|---|---|---|
| Published geology[3] | • Holocene river deposits. | • Situated in a former river channel.<br>• Variably sorted gravel, sand, silt and clay mixtures. |
| | • Holocene dune sand. | • Approximately 120 m to east of the road alignment and at the eastern end of the Gladstone Road embankment. |
| Site specific investigations | • Typically sand/ gravelly sand to depths of 3.5 m to 4.5 m bgl.<br>• Silt strata up to 6 m bgl.<br>• Fine to coarse sand reaching depths between 15 m to 18.75 m.<br>• Thin silt strata up to 0.5 m thick.<br>• Deeper gravel sequence from approx. 15 m confirmed to 35 m bgl.<br>• Fill to depths of 5.35 m at Gladstone landfill. | • Based on piezos BH_67, BH_68.<br>• Boreholes BH24, BH37.<br>• Top of thin possible confining layer between 15 m & 18.75 m bgl.<br>• See Figure 12.2.<br>• Based on investigations at landfill (refer Contaminated Land Investigation (Volume 3F) |
| Depth to shallow groundwater | • Range at landfill approx. 3.5 m to 4.24 m RL (approx. 3.83 m and 5.35 m bgl)<br>• Range approx. 3.5 m to 4.2 m RL (approx. 2.7 m to 4.7 m bgl). | • Based on investigations at Gladstone landfill including piezo BH_38<br>• Based on piezo at 167 Gladstone Road & BH_69<br>• TP_58, TP_59, TP_62, TP_63, TP_64<br>• See Figure 12.2. |
| Identified aquifer system[1] | • Coastal Confined Aquifer System. | • See Figure 4.3. |
| Groundwater flow direction | • Toward east-southeast[40]. | • See Figure 4.3. |
| Groundwater quality | • Low level contamination.<br>• No exceedances of the DWSNZ MAVs or the ECan water quality limits for groundwater were recorded. | • Results of investigations at Gladstone Landfill(ref Contaminated Land Investigation (Volume 3F). |
| Additional data | • cDWPZ for bores M35/7542 & M35/11693 at Gladstone Rd. | • M35/7542, depth 205.8 m.<br>• M35/11693, depth 205.4 m.<br>• Both into the confined artesian aquifer, see Figure 4.6. |

Note: 1. As defined on the LWRP planning maps.


*Figure 12.2: Locations of monitoring wells, test pits, extent of historical landfill and overland flow paths in the vicinity of Gladstone Road. BH 38 is not shown, it is located near the centre of the red, shaded area.*

### 12.2.3 Hydrology

There are no surface waters in the immediate vicinity of Gladstone Beach Road, only an overland flow path of Waihora Stream, a former flood channel of Ashley River/Rakahuri. Table 12.3 provides a summary of the nearby water features. Full descriptions of the wetlands are provided in Appendix H.

**Table 12.3: Summary of nearby water features to Gladstone Road**

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| Surface water catchment | • Saltwater Creek | • n/a | • As defined on Canterbury Maps[20].<br>• See Figure 4.5. |
| Surface waters | • Waihora Stream | • 1 km WNW | • Nearest surface water.<br>• Location coincides with wetland WC_W2_NPSFM where stream noted as going to ground. |
| Wetlands | • FA_W2_NPSFM | • 15 m NE | • Small wetland approximately 50 m from northeast corner of Gladstone landfill at closest location.<br>• See Figure 12.3. |
| | • WC_W1_NPSFM | • 550 m WNW | • Part of the Waihora wetland complex of six wetlands.<br>• See Figure 13.2. |

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| | | | • Assessed in Section 13. |
| Springs | • M35/7465 | • 100 m E | • The spring is categorised as a gravitational seepage and is located within woodland on a residential property at 171 Gladstone Road. |

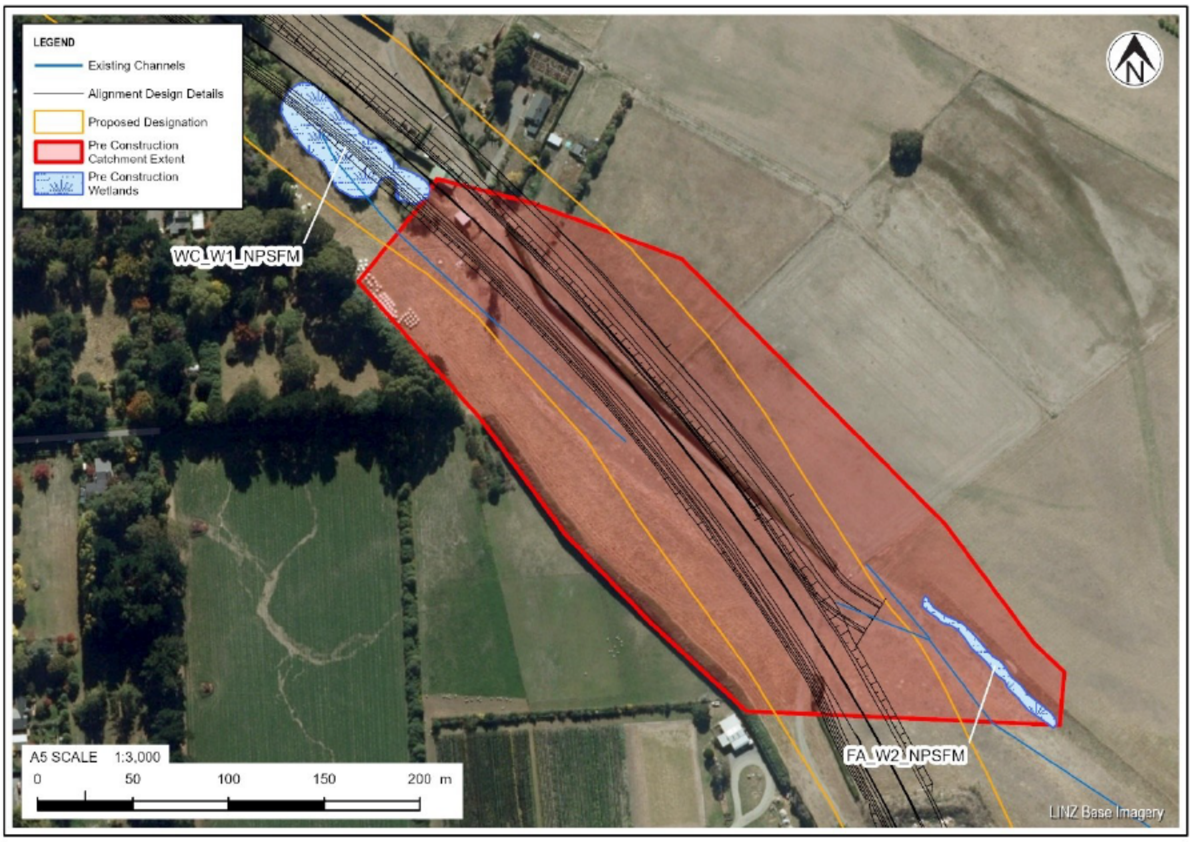



*Figure 12.3: Existing wetland extents and defined catchments near to Gladstone Road.*

### 12.2.4 Surrounding groundwater users

Details of the bore survey are described in Section 4.6. The bores included in Table 12.4 are all of those bores within 400 m of the designation boundary surrounding Gladstone Road as shown in Figure 12.4.

**Table 12.4: Results of bore survey for all known bores[27] within 400 m of the designation at Gladstone Road**

| Bore status | Bore use | Number of bores | Depth range (m) |
|---|---|---|---|
| Confirmed as present | Water supply purposes | 9 | 4.8 - 214.2 |
| | Other uses | 0 | - |
| Unconfirmed | Bore details not confirmed by owner | 7 | 17.1 – 23.4 (one unknown) |
| Unsure | Owner unsure if bore exists | 1 | Unknown |
| Capped/sealed | n/a | 0 | - |

Note: Details of bore use are provided in Section 4.6.1.

Table 12.5 provides details of those bores that may be affected by the temporary and permanent activities associated with the Project. Due to the nature of the proposed activities, there will be limited effects on the surrounding bore users and only bores with the potential to take water from the shallow unconfined groundwater within 10 m of the surface are included. This selected depth is to include consideration of the potential effects from possible dewatering activities if groundwater is encountered during remedial works at the landfill.

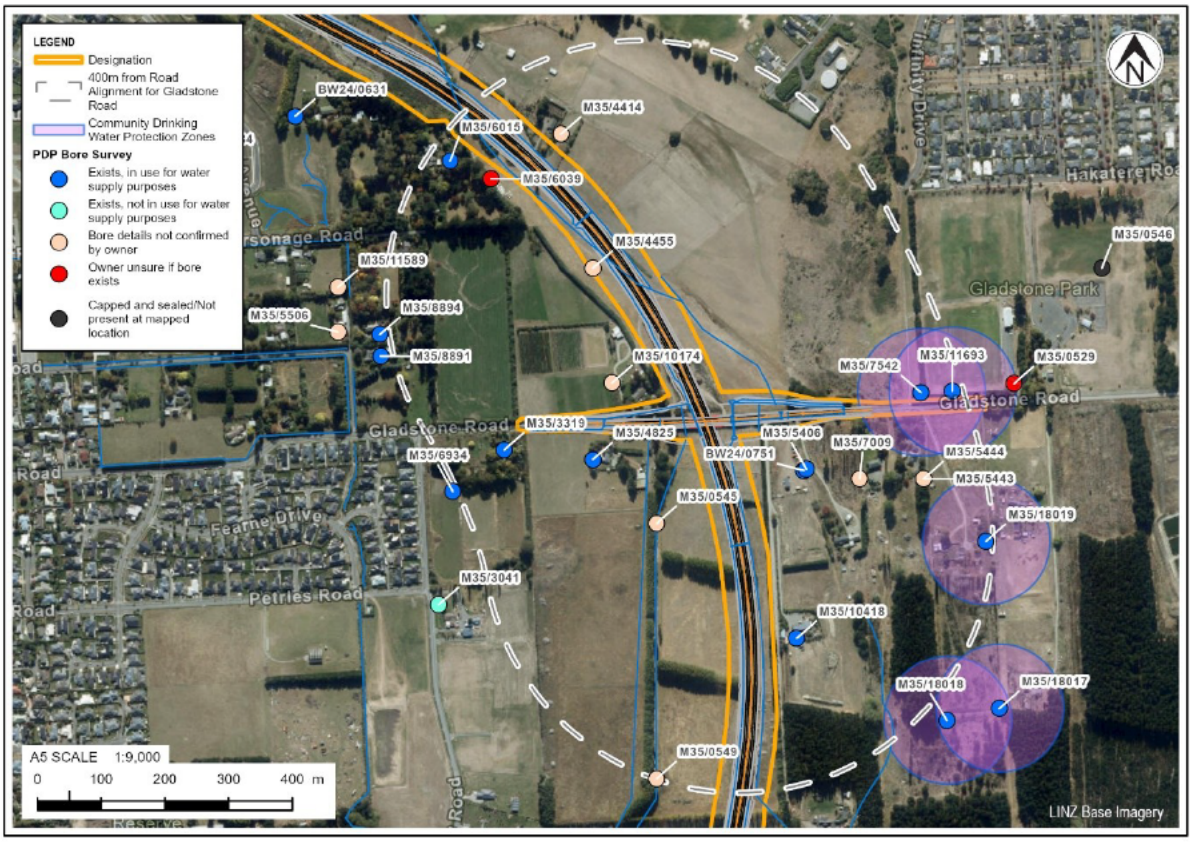



*Figure 12.4: Surrounding bores and proximity of cDWPZ to the road alignment and Designation. Source: ECan Canterbury Maps.*

**Table 12.5: Bores within 400 m of the designation at Gladstone Road that may be affected by the Project**

| Bore use | Number of bores | Comments |
|---|---|---|
| Shallow bores[1] (0 m - 10 m depth) for water supply purposes | 2 | M35/5444 is 4.8 m deep and one bore with unknown depth (and unknown use) are included. |
| Community drinking water bores | 2 | Described in Section 12.2.4.1. |
| Bores within designation requiring decommissioning | 1 | |

Note:

[1] Water supply purposes are classified as those bores from which water is actively abstracted for a defined use such as domestic, stock water supply or irrigation. Community drinking water bores are listed separately.

#### 12.2.4.1 Community drinking water supplies

There are two public water supply bores close to the road alignment at Gladstone Road. Both of these bores have deep water sources in the coastal confined aquifer system and have static water levels that are at or near to the ground surface indicating artesian confined aquifer conditions. A schematic conceptual hydrogeology model for the public water supply bores is shown in Figure 4.6 in Section 4.1.6.

The key details of these WDC owned bores[57] are:

- Gladstone 1 (M35/7542), screen depth between 201.8 m and 205.8 m, located 120 m from the eastern end of the overbridge embankment.
- Gladstone 2 (M35/11693), screen depth between 212.2 and 214.2 m, located 170 m from the eastern end of the overbridge embankment.

The cDWPZ around these two bores extend to within 15 m of the eastern end of the overbridge embankment. Three other public water supply bores (M35/18019, M35/18018 and M35/18017) and their respective cDWPZ are located further away (approximately 300 m and 500 m) to the southeast of eastern end of the overbridge embankment, as shown in Figure 12.4.

## 12.3 Localised conceptual hydrogeology model

In summary, the hydrogeological conceptual model for the site comprises:

- An unconfined (water table) aquifer within granular sediments comprising sand and gravelly sand to shallow depths (up to 4.5 m bgl) underlain by silt deposits up to 6 m thick.
- Groundwater is encountered in the shallow granular deposits between approximately 2.7 m and 4.7 m bgl, and locally this may be perched water on the silt strata.
- Shallow groundwater (unconfined aquifer) is present at Gladstone landfill, where fill is deepest and is less than 0.5 m above the base of the fill.
- Deep deposits of sand are identified extending depths of between approximately 15 m to 18.75 m bgl, and these are only separated with a thin silt layer which could act as a leaky aquitard/semi-confining layer over the deeper gravels.
- The underlying aquifer is identified at depths of 15 m and has been confirmed to extend to 35 m bgl. Based on other investigations along the Project alignment, this is likely to be the confined aquifer of the Riccarton/Burnham Gravel, potentially grading into the Linwood aquifer.
- The overland flow path of Waihora Stream lies to the north of Gladstone Road, this is approximately 500 m downstream of wetland WC_W1_NPSFM where shallow groundwater intersects the ground surface.
- Gladstone landfill occupies the site of a former gravel pit within the wider Waihora Stream overland flow channel. The depth of fill has been identified in investigation locations to extend to 5.35 m bgl..

[57] ECan. Borelogs for M35/7542, M35/11693.

## 12.4 Hydrogeological effects assessment for Gladstone Road overpass

### 12.4.1 Overview

The proposed activities are summarised in Table 12.6 and the assessment of effects from these activities on groundwater are provided in Sections 12.4.2 and 12.4.3. A summary of the effects including the scale of effect is included in Section 12.5.

**Table 12.6: Summary of proposed activities at Gladstone Road**

| Proposed activities | Activity has potential to affect groundwater: | | |
|---|---|---|---|
| | Level | Quality | Flow |
| Temporary activities during construction | | | |
| Works at landfill | Yes | Yes | Yes |
| Culvert installation | No | No | No |
| Embankment construction | Yes | No | Yes |
| Shallow excavations | No | No | No |
| Permanent activities during operation | | | |
| Landfill (Compaction only) | No | No | No |
| Road embankments | No | No | No |
| Stormwater discharge | Yes | Yes | No |

### 12.4.2 Temporary effects

#### 12.4.2.1 Works in the landfill

There are three options to construct the proposed alignment through the landfill. The options covered in this assessment include:

- Option 1 - Completely dig out and replace the landfill material with hard fill;
- Option 2 – Compaction of landfill material in place; or
- Option 3 - Partial dig out of landfill material followed by compaction the remaining landfill material in situ using impact rollers or similar, then placement of compacted hardfill up to the base of road embankment.

For options 1 and 3, the placement of fill needs to be completed in dry conditions. Therefore, if groundwater is encountered, dewatering will be required.

##### 12.4.2.1.1 Option 1

**Effects on groundwater**

For Option 1, key effects on groundwater are the excavation within 1 m of groundwater and potential excavation into shallow groundwater and the requirement for dewatering activities.

Recent site investigations have confirmed winter groundwater levels at the landfill to be at or lower than 4.2 m RL, where the base of the fill was indicated as 3.7 mRL. This equates to a groundwater level above the base of the fill at less than 0.5 m. An assessment on the effects of dewatering at the landfill has been made based on groundwater being intercepted up to 0.5 m depth above the base of the excavation. For excavation purposes, it is assumed that the maximum size of excavation open and dewatered at one time would be 60 m length x 30 m wide which represents the approximate width of the landfill and approximately one third of its length.

An assessment on the dewatering effects is included in Appendix G which includes a list of assumptions used to make this assessment. The results are presented in Table 12.7 and show the calculated results for maximum assessed effects based on a conservative groundwater level, the indicative excavation dimensions and anticipated dewatering duration.

**Table 12.7: Maximum assessed drawdown effect from potential dewatering at Gladstone Landfill**

| Excavation dimensions (length x width) (m) | Drawdown within excavation(s) (m) | Radius of drawdown extent (m) |
|---|---|---|
| 60 x 30 | 0.5 | 160 |

Based on the Contaminated Land Investigation (Volume 3F):

- Low level groundwater contamination is identified.
- No exceedances of the DWSNZ MAVs or the ECan water quality limits for groundwater were recorded.
- The proportion of fill material present below groundwater is anticipated to be small.

Therefore, deeper excavation is unlikely to have an adverse effect (if any) on shallow groundwater quality beneath Gladstone Road Landfill. The confining layer will not be excavated as confining layer depth is greater than 15 m bgl.

If dewatering is required, pumped groundwater removed from the excavation(s) will be discharged to ground outside (and likely east of) the landfill footprint. The discharge will ultimately return into the same shallow groundwater as it has been taken from, i.e. the groundwater at the landfill is the same groundwater as that adjacent to the landfill and is expected to be of similar water quality. There will be no discharges to any surface water features (including wetlands) or into cDWPZs. The closest bore is approximately 100 m west of Gladstone Landfill. In addition, the discharge water quality at the point of discharge will be managed by the Contractor through specification in the GMP to meet the water quality requirements for discharge.

### Effects on wetlands

Natural inland wetland FA_W2_NPSFM is located between 50 m and 100 m from the northern edge of the landfill. There is the potential for adverse effects to occur on the wetland from dewatering activities. These temporary potential effects on the wetland include changes to groundwater and surface catchments as well as temporary lowering of the shallow groundwater below wetland FA_W2_NPSFM. The estimated temporary drawdown effect at 50 m from the edge of the excavation after 30 days of continuous dewatering is in the order of 150 mm and decreases to approximately 50 mm at 100 m from the edge of the excavation. These effects are assessed to be negligible and have a temporary effect i.e. for the short duration of the dewatering. In addition, based on the catchment area for this wetland, it will continue to receive groundwater recharge to upgradient of the wetland and more distant to the landfill which is beyond the radial effects of the possible dewatering.

### Effects on surface waters

With the exception of wetland FA_W2_NPSFM, there are no surface waters in the vicinity of Gladstone Road, therefore, the stream depletion effects from dewatering will not occur and no further assessment on the stream depletion effects from dewatering has been completed.

**Effects on other groundwater users**

The nearest groundwater user to the potential landfill excavations is bore M35/10174 at 165 Gladstone Road, approximately 100 m to the west. The proposed dewatering is for a short duration and it is assessed as resulting in approximately 50 mm drawdown 100 m from the landfill. Therefore, a well interference assessment using Schedule 12 (WQN10) well interference tool[36] is not considered as necessary and the effects on groundwater users is negligible.

In addition, bore M35/10174 is screened between 16 m to 18 m. The bore log describes ground conditions to be *"pug clay and sand"* and *"sandy clay"* between depths of 4.3 m to 11 m, which indicates soils of low permeability and the ability to transmit water is poor. The dewatering will not result in poor water quality entering into the water supply at this bore.

**Effects on groundwater quality**

If dewatering activities were to occur at the landfill excavations, the effects on groundwater quality could include low level contaminants from leachate and an increased sediment loading in the water at the base the excavations. These overall effects are described in the Project-wide items in Section 6.4.2.1.3. and as described above, no exceedances of the DWSNZ MAVs or the ECan water quality limits for groundwater were recorded. The discharge water quality at the point of discharge (to land) will be managed by the Contractor through specification in the GMP. Overall, the effects on groundwater quality will be a low effect.

**Effects of discharge water quality at point of discharge**

Dewatering will generate water to discharge. These overall effects are described in the Project-wide items in Section 6.4.2.1.4. In addition, due to the absence of any surface water nearby, no discharges will go directly into surface water and soakage to ground is expected. The Contaminated Land Investigation (Volume 3F) has identified that groundwater at the landfill is suitable for discharge to ground, i.e. the groundwater at the landfill is the same groundwater as that adjacent to the landfill and is expected to be of similar water quality. . Standard controls and procedures to manage discharge will be provided in the GMP, in particular the Contaminated Site Management Plan. Overall, the effects on groundwater quality will be managed in a way so that the effects on groundwater receptors will be negligible.

#### 12.4.2.1.2 Option 2

**Compaction of landfill**

Based on the depth to groundwater identified at depths greater than 2.7 m, there will be no effect on shallow groundwater if compaction of the fill by roller is undertaken. Therefore, the overall effects on groundwater and groundwater receptors will be negligible.

#### 12.4.2.1.3 Option 3

**Effects on groundwater**

Based on the investigations at Gladstone landfill, it is likely that Option 3 (partial excavation) will not encounter groundwater. As shown in Figure 12.1, the depth to groundwater is at the base of the fill and partial excavation will not extend into groundwater. The option 3 construction works within the landfill would have negligible effects on shallow groundwater.

#### 12.4.2.2 Culvert and utilities installation

Two culverts will be installed at Gladstone Road which extend through the SH1 embankment (ID:010 & 011). Both culverts will provide flow paths for overland flow i.e. there is no stream flow at the surface and the larger culvert ID:010 will convey the Waihora flow path. Other culverts at ID:009 and ID:012 to the south and north of Gladstone Road will also provide overland flow paths. The key excavation details for each culvert are shown in Table 12.8.

**Table 12.8: Excavation dimensions for culvert installations at Gladstone Road**

| Culvert ID | Surface water | Width (m) | Length (m) | Excavation depth range (m bgl) | | Excavation Base (m RL) |
|---|---|---|---|---|---|---|
| Culvert ID009 | Dry channel | 1.6 | 30 | 1.3 | 1.9 | 4.3 |
| Culvert ID010 | Dry channel | 2.5 | 55 | 2.1 | 2.9 | 4.4 |
| Culvert ID011 | Dry channel | 1.6 | 55 | 1.2 | 5.8 | 5.0 |
| Culvert ID012 | Dry channel | 1.6 | 30 | 1.2 | 1.7 | 4.7 |

Relocation of utilities is also required through the landfill footprint. These excavations will be up to 1 m depth and approximately 4 m wide beneath the road footprint and 2 m wide beyond the road.

Based on the recorded depth to groundwater of 3.5 m – 4.2 m RL (2.7 m – 4.7 m bgl) in this locality, it is unlikely that groundwater will be encountered in the excavations. As dewatering will not be required for culvert construction purposes there is considered to be no effect on groundwater and no further assessment has been completed in this area.

In the unlikely event that dewatering is required for the culvert and utilities installation, given there are no surface waters and the nearest groundwater user to the culvert excavations is bore M35/10174 at 165 Gladstone Road, approximately 120 m to the west, the effects of dewatering would be negligible. Discharge of dewatering water and potential effects on receiving groundwater would need to be managed by the controls in the GMP.

#### 12.4.2.3 Earthworks

##### 12.4.2.3.1 Effects on groundwater

Minor, shallow excavation activities will occur for the formation of the road embankment and for creation of shallow footings for the MSE abutment walls. These excavations are expected to be more than 1 m above the local unconfined groundwater level and these excavations will occur on the remediated landfill within the clean fill. There will be no excavation of any confining layer since this confining layer is estimated to be greater than 15 m bgl.

Similarly, there will be shallow excavations for a stormwater swale and cut-off drain adjacent to the overbridge embankments. These excavations will be in natural ground but are expected to be dry excavations.

It is assessed that site excavations in the vicinity of Gladstone Road are expected to have negligible effects on shallow groundwater and therefore the effect on groundwater receptors will be negligible.

#### 12.4.2.4 Effects on drinking water supply source water (cDWPZ)

As described in Section 6.4.2.4.3, given the close proximity of the WDC Gladstone PWS bore sources to the Project, and the regional groundwater flow direction, it is assumed that the project alignment sits within the SWRMA 2 and SWRMA 3.

In assessment of Option 1 (works at the landfill), the nearest WDC drinking water supply source to the potential landfill excavations is bore M35/7542 on Gladstone Road, approximately 320 m to the east. The edge of the closest cDWPZ is approximately 220 m east of the landfill. If dewatering at the landfill were to occur, the proposed dewatering would be for a short duration and it is assessed as resulting in approximately 50 mm drawdown 100 m from the landfill. Therefore, the effects from any dewatering on this drinking water supply source will be negligible.

Based on the source-pathway-receptor model described in Section 6.3.1, the actual and potential effect of the Project activities on the source of the registered drinking water supplies are assessed as negligible. This is because there is a likely absence of a complete SPR linkage because the pathway components of the SPR relationship are not viable due to the WDC public water supply bores being very deep confined water source (> 200 m). In addition, no exceedances of the DWSNZ MAVs or the ECan water quality limits for groundwater were recorded. Therefore, the effects from any dewatering discharges to land, associated with the works at the landfill on this drinking water supply source will be negligible.

The other WDC PWS bores water sources are further away and there will be negligible effects on these bores. WDC also has another deep PWS bore sources near to the Project, which forms part of the Pegasus supply (Bore M35/10908). This WDC PWS bore is located approximately 600 m northeast of the Project designation (between Gladstone Road and Pegasus approach). Whilst the cDWPZ is at a distance greater than 500 m from the Project, it is likely that the SWRMA 2 and SWRMA 3 for this bore source is crossed by the Project and therefore assessed here. Based on the negligible effects identified at PWS bores closer to the project, the water quality at the Pegasus PWS bore source, identified at depths greater than 140 m[42], is unlikely to be influenced by the project activities, and the effects on these other local drinking water supply source waters is assessed as negligible.

### 12.4.3 Permanent effects

#### 12.4.3.1 Road embankment

As described in Section 3.9, the road embankments could result in effects on groundwater with potential changes to the local regime. These overall effects are described in the Project wide items in Section 6.4.3.1. and there are no location specific groundwater effects at this location. The overall effect on the groundwater environment from the road embankments is negligible and therefore the effect on groundwater receptors will be negligible.

##### 12.4.3.1.1 Effects on groundwater

Potential to changes to the groundwater regime may occur from the permanent compaction of fill (Option 2) as part of the landfill works. The ground compaction is likely to result in a slightly lower material permeability than prior to the improvement. However, it is identified that the depth to groundwater is greater than 2.7 m and the effect of the ground compaction to form a barrier to local groundwater flows is not expected occur. Therefore, the effects on groundwater and groundwater receptors from the fill compaction is negligible.

## 12.5 Summary of effects

A summary of the temporary and permanent effects on groundwater from the activities at Gladstone Road, principally comprising partial or full removal of Gladstone landfill, overbridge construction including excavation and placement of geogrid, construction of the road, and culvert installation are provided in Table 12.9 and Table 12.10. Mitigation to reduce/minimise these effects is provided where the scale of effect is greater than 'low'.

**Table 12.9: Temporary groundwater effects from activities at Gladstone Road**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Landfill works | Groundwater flow & level on receptors. | Negligible | - | - |
| | Groundwater quality on receptors. | Low | | |
| | Groundwater level effect on wetland FA_W2_NPSFM. | Negligible | - | - |
| Culvert installation | Overall groundwater on receptors. | Negligible | - | - |
| Earthworks | Overall groundwater on receptors. | Negligible | - | - |
| Shallow excavation | Overall groundwater on receptors. | Negligible | - | - |

**Table 12.10: Permanent groundwater effects from activities at Gladstone Road**

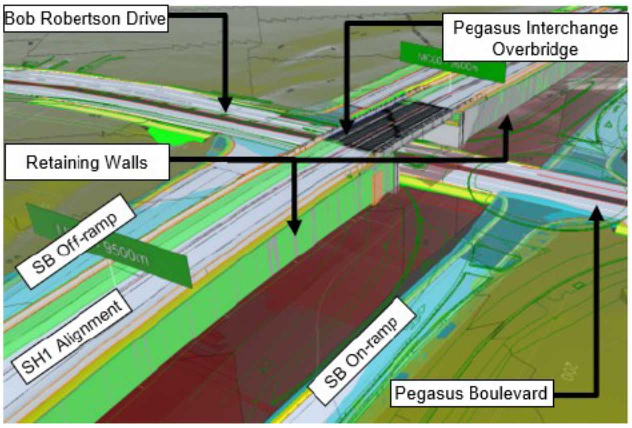
| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Road embankment | Overall groundwater | Negligible | - | - |
| Landfill compaction | Overall groundwater | Negligible | - | - |
| Stormwater discharge | Overall groundwater | Low | - | - |

# 13 Pegasus interchange

## 13.1 Proposed activities

The Pegasus approach and interchange comprises a number of works connections and culverts. A new overbridge structure at Pegasus interchange will be constructed to carry the proposed SH1 alignment over Pegasus Boulevard and Bob Robertson Drive. SH1 will have approach ramps supported by retaining walls leading up to the bridge from either side. The new road will cross Taranaki Stream twice. The new overbridge structure is summarised in Table 13.1.

**Table 13.1: Summary details of Pegasus Interchange overbridge structure**

| Details | |
|---|---|
| Figure |  |
| Surface water crossing | • Taranaki Stream. |
| Total bridge structural footprint | • 34 m x 17 m. |
| Foundations | • Shallow footings on MSE abutment walls. |
| Ground improvement | • Ground improvements beneath embankments (18 m rigid inclusions. 510 mm diameter, 2 m centres). |
| Approaches | • Retaining walls. |

The proposed key activities relating to the hydrogeology effects at this location comprise:

- Shallow excavations for utilities installations.
- Embankments for the overbridge and raised SH1.
- Minor excavations for MSE abutment walls.
- Ground improvements to 18 m depth.
- Installation of a new major culvert conveying Taranaki Stream and extension of the existing Taranaki Stream culvert.
- Installation of a new major culvert conveying Waihora Stream and another stormwater culvert.
- Shallow excavations for stormwater bio-retention basin, swales and cut-off drains and stream diversion channels for Waihora Stream and Taranaki Stream.
- Shallow excavations for realignment of Main North Road to connect with Garlick Street in Ravenswood.

## 13.2 Environmental setting

### 13.2.1 Site location and general description

Pegasus interchange is centred around the existing SH1 roundabout linking Ravenswood Development (a recent new commercial and residential development) to the west, Pegasus to the east and Woodend to the south, as shown in Figure 13.1. Pegasus Golf Club is immediately east of SH1 with a large lifestyle block and rural land to the south before reaching residential properties at Woodend.


*Figure 13.1: Locations of monitoring wells, test pits, surface waters and overland flow paths in the vicinity of Pegasus interchange.*

The immediate area surrounding SH1 and the proposed SH1 is crossed by Waihora Stream and Taranaki Stream. These surface waters are summarised in section 13.2.3 and described in detail in Section 4.4. The surrounding area is the highest elevation of the Project at approximately 10 m RL.

### 13.2.2 Geology and hydrogeology

Table 13.2 provides a summary of the local geology. A schematic geological and hydrogeological section is presented in Figure 13.5 and Figure 13.6.

**Table 13.2: Summary of local geology and hydrogeology at Pegasus interchange**

| Geology & Hydrogeology | | Details |
|---|---|---|
| Published geology[3] | • Holocene river deposits. | • Situated in a former river channel.<br>• variably sorted gravel, sand, silt and clay mixtures. |
| Waihora Stream area | | |
| Site specific investigations | • Interbedded sediments of silt & gravelly fine to coarse sand to 4.5 m.<br>• Silt stratum to 8.5 m & 11 m depth.<br>• Interbedded sediments of sand & gravel to 18.5 m.<br>• Approx. 1 m silt from 18.1 m underlain by gravel to 20.3 m bgl. | • Based on bores BH_36 & BH_70.<br>• See Figure 13.1. |
| Depth to shallow groundwater | • Range approx. 8.1 m to 9.0 m RL (1.3 to 2.0 m bgl). | • Based on piezos BH_70.<br>• Based on TP_74, TP_75, TP_76, and TP_77. |
| Taranaki Stream area | | |
| Site specific investigations | • Predominantly silt to 6 m depth<br>• Interbedded sediments, predominantly silt to approx. 16 m & 18.5 m bgl.<br>• Gravel to EOH typically at 20.25 m.<br>• Deeper bores identified approx. 2 m silt at 30 m bgl.<br>• Gravel up to 39.7 m. | • Based on bores BH_26 to BH_33.<br>• Silt stratum at approx. 30 m considered to be aquitard 2 at BH_29, BH_32.<br>• BH_29 reached 39.7 m.<br>• See Figure 13.1. |
| Depth to shallow GW | • Range approx. 6.4 m to 8.1 m RL (1.3 to 2.4 m bgl). | • Based on piezos BH_29 and BH_73.<br>• Based on TP_78, TP_79, TP_71, TP_80<br>• TP_81 groundwater level at 5.9 m RL (2.9 m bgl). |
| Identified aquifer system[1] | • Coastal Confined Aquifer System. | • See Figure 3.3. |
| Groundwater flow direction | • Toward east-southeast[40]. | • See Figure 3.3. |
| Groundwater quality | • Groundwater sample collected from monitoring wells; BH_71. | • Total Ammoniacal-N and dissolved zinc exceed the water quality parameter values for ANZWQG (2018) 95 %.<br>• Hardness, dissolved, calcium, boron, iron, sodium and chloride have elevated |

| Geology & Hydrogeology | | Details |
|---|---|---|
| | | concentrations when compared to other groundwater quality data collected by T+T (June 2025). |

Note: 1. As defined on the LWRP planning maps.

### 13.2.3 Hydrology

Two surface waters exist in the immediate vicinity of Pegasus interchange. Table 13.3 provides a summary of these and other nearby water features. Full descriptions of the wetlands are in Appendix H.

**Table 13.3: Summary of nearby water features to Pegasus interchange**

| Water feature | | Distance/direction from Designation | Details |
|---|---|---|---|
| Surface water catchments | • Saltwater Creek | • n/a | • As defined on Canterbury Maps.[20]<br>• See Figure 4.5. |
| | • Taranaki Creek | • n/a | |
| Surface waters | • Waihora Stream | • Crossed by SH1 | • Nearest surface waters.<br>• Both modified by Ravenswood development. |
| | • Taranaki Stream | • Crossed by SH1 | |
| | • Taranaki Branch | • Crossed by SH1 | • Unofficial name for drain tributary. |
| Wetlands | • WC_W1_NPSFM | • Crossed by SH1 | • Part of the Waihora wetland complex of six wetlands.<br>• Details included in Section 13.4.<br>• See Figure 13.2.<br>• Wetland assessment in Appendix H.<br>• All have standing water.<br>• Wetlands W2, W3, W4, W6 receive water from stream flows, as well as overland flows and a contribution from groundwater. |
| | • WC_W2_NPSFM | • Approximately 100 m NE | |
| | • WC_W3_NPSFM | • Approximately 65 m NE | |
| | • WC_W4_NPSFM | • SE of designation | |
| | • WC_W5_NPSFM | • Within designation | |
| | • WC_W6_NPSFM | • Crossed by SH1 | |
| Springs | • At Waihora Stream | • Near to SH1 crossing | • Possible spring inflows at headwaters. |
| | • Upstream on Taranaki Creek | • 2-5 km WNW | • Sources identified upstream of Garlick Street. |

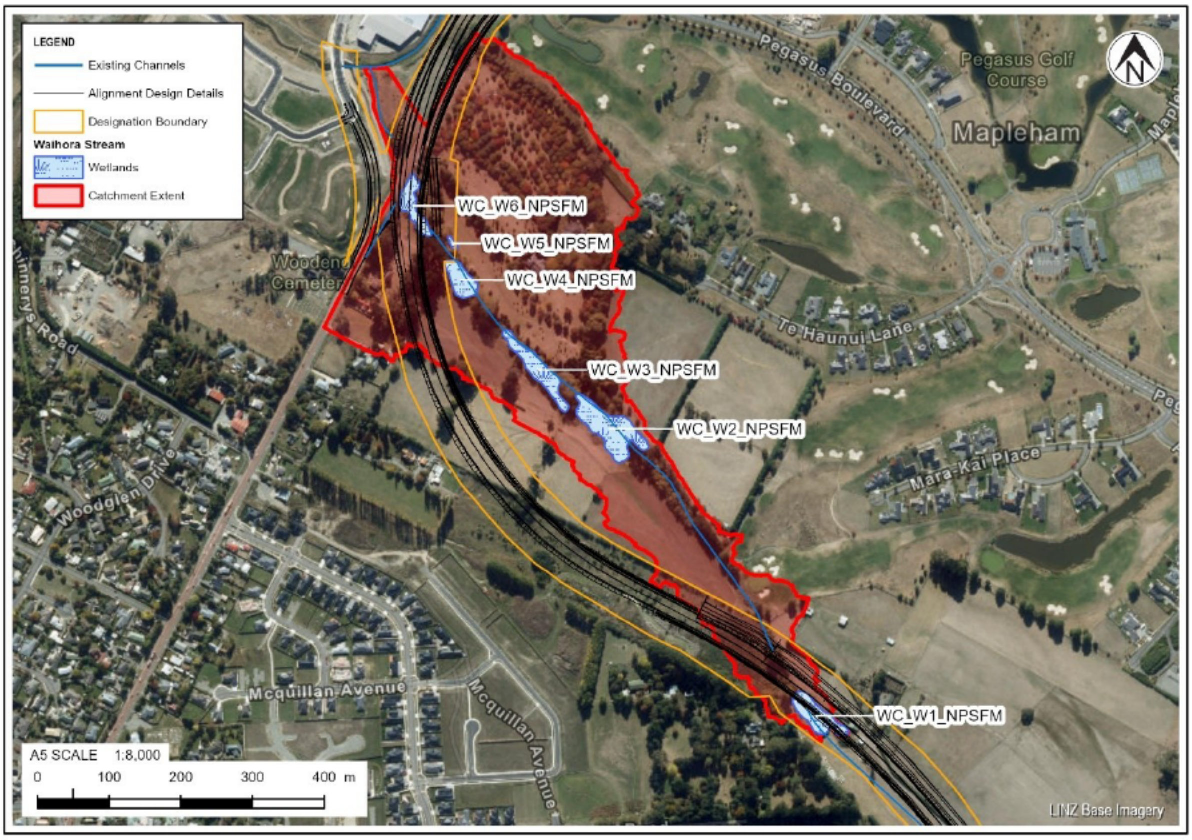



*Figure 13.2: Existing wetland extents and defined catchments at Pegasus.*

### 13.2.4 Surrounding groundwater users

Details of the bore survey are described in Section 4.6. Bores included in Table 13.4 are all bores within 400 m of the designation boundary surrounding Pegasus approach and interchange as shown in Figure 13.3.

**Table 13.4: Results of bore survey for all known bores[27] within 400 m of the designation Pegasus approach and interchange**

| Bore status | Bore use | Number of bores | Depth range (m) |
|---|---|---|---|
| Confirmed as present | Water supply purposes | 8 | 18.3 - 94 |
| | Other uses | 3 | 10.5 - 24.4 |
| Unconfirmed | Bore details not confirmed by owner | 13 | 20 - 21 |
| Unsure | Owner unsure if bore exists | 1 | 8.5 |
| Capped/sealed | n/a | 4 | 20 - 21 |

Note: Details of bore use are provided in Section 4.6.1.

Table 13.5 provides details of those bores that may be affected by the temporary and permanent activities associated with the Project. Due to the nature of the proposed activities, there will be limited effects on the surrounding bore users and only bores with the potential to take water from the shallow unconfined groundwater within approximately 20 m of the surface are included. This selected depth is to include consideration of the potential effects from the ground improvement activities.

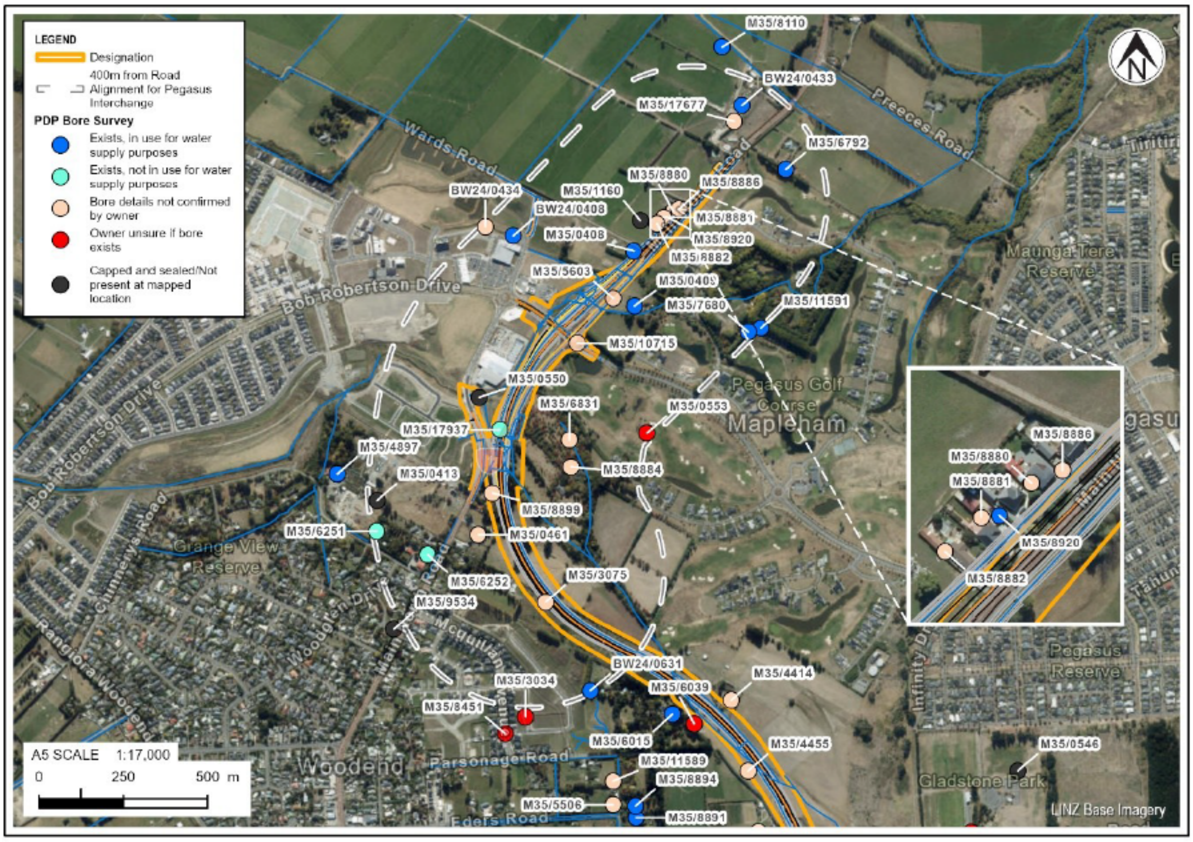



*Figure 13.3: All known bores within 400 m of the Designation surrounding Pegasus approach and interchange (source: modified from PDP Bore Use Survey[27]).*

**Table 13.5: Bores within 400 m of the designation at Pegasus approach and interchange that may be affected by the Project**

| Bore use | Number of bores | Comments |
|---|---|---|
| Shallow bores[1] (0 m – approx. 20 m depth) for water supply purposes | 13 | Includes 7 bores unknown depth & includes 1 bore at 20.5 m, 21.9 m, 22 m & 24 m depth. |
| Community drinking water bores | 0 | n/a |
| Bores within alignment requiring decommissioning | 5 | Owned by NZTA |

Note:

[1] Water supply purposes are classified as those bores from which water is actively abstracted for a defined use such as domestic, stock water supply or irrigation. Community drinking water bores are listed separately.

## 13.3 Localised conceptual hydrogeology model

Due to the relatively large area covered by Pegasus interchange, for the purposes of this report, the area is spilt into Waihora Stream crossing and Taranaki Stream crossing.

### 13.3.1 Waihora Stream area

In summary, the hydrogeological conceptual model for this area is described below and shown in Figure 13.4:

- Both the Garlick Street connection and Waihora Stream are located on a former flood channel of the Ashley River/Rakahuri with the underlying geology[3] comprising fluvial deposits of variably sorted sediments of gravel, sand, silt and clay of the Springston Formation and Riccarton/Burnham Gravels.
- Groundwater is encountered in shallow deposits between approximately 1.3 m and 2 m bgl.
- Deposits of sand and gravel are identified extending from approximately 11 - 18.5 m bgl.
- A thin silt stratum (1 m thick) at approximately 18 m depth, is inferred to form the confining layer over the Riccarton/Burnham aquifer gravels.
- Beyond the former flood channel, on raised terraces, gravel is encountered at shallow depths. The bore log of an existing piezometer M35/17937 adjacent to Waihora Stream confirms 3 m of gravel underlain by silt to 10.6 m depth.
- Groundwater dependent wetlands have formed along Waihora Stream at places where this surface water is hydraulically connected with shallow groundwater.
- Direct connection between Waihora wetland complex and Waihora Stream occurs at five out of six wetlands with hydraulic connection between stream flow and groundwater flow (discharges). Wetland WC_W5_NPSFM does not have a direct connection with Waihora Stream.
- South of wetland WC_W1_NPSFM groundwater falls below ground level. The depth to shallow groundwater is greater than 2.5 m bgl within 500 m south of this wetland.

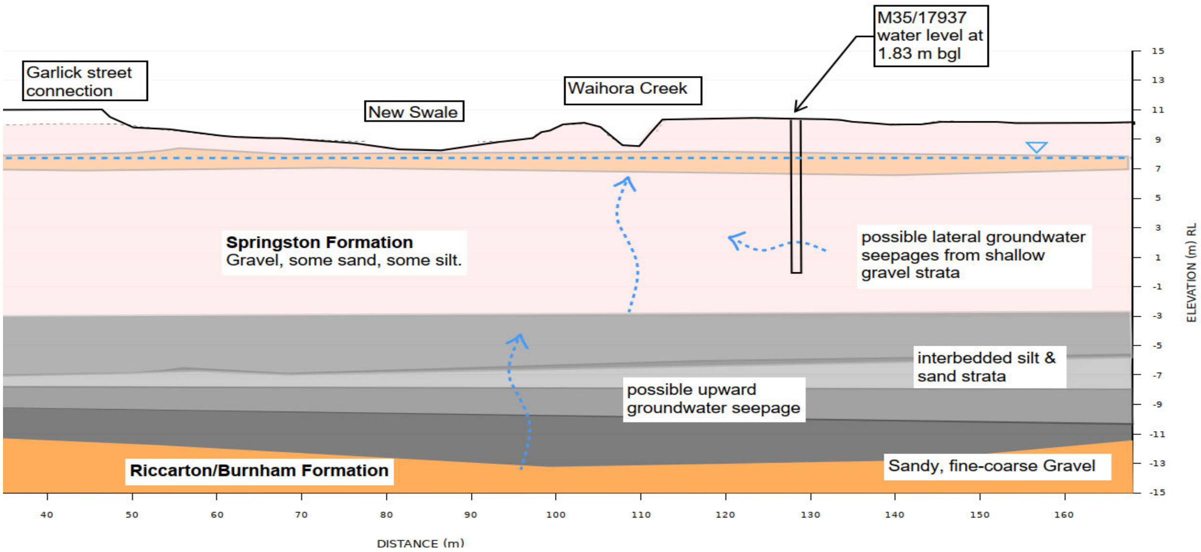



*Figure 13.4: Conceptual hydrogeological model - schematic sketch based on existing geological information (obtained from NZ Geotechnical Database (NZGD))[58].*

[58] This does not include the recent T+T site investigations.

### 13.3.2 Taranaki Stream area

In summary, the hydrogeological conceptual model for this area which includes Pegasus interchange comprises:

- The ground conditions are noticeably variable between the northern and southern side of the Pegasus interchange, separated by Bob Roberston Drive:
  - To the north shallow gravel and a deeper groundwater level approximately 3 m bgl was recorded, inferred to penetrate a former flood channel.
  - To the south, predominantly silt was observed to 6 m depth with shallower groundwater levels at between 1.3 m to 2.4 m bgl, underlain by interbedded silt and sand strata recorded to depths of approximately 18.5 m.
- The deeper interbedded sediments of sand and gravel to 18.5 m depth (approximately -10 m RL) are inferred to be the Springston Formation underlain by the Riccarton/Burnham Gravel.
- As identified at many investigation locations along the alignment, a thin silt stratum at approximately 18 to 20 m depth, is observed forming a potentially semi-confining layer over the deeper gravels, inferred to be the Riccarton/Burnham aquifer.
- The Riccarton/Burnham Gravel is assessed as a semi-confined aquifer because groundwater levels are reported in the overlying silt, forming a sub-artesian aquifer. Other investigations completed as part of the Ravenswood development[59] encountered dense gravels of the Riccarton Formation at approximately -6 to -8 m RL.
- Two deep bores, drilled each side of Bob Robertson Drive, encountered gravels between approximately 20 m and 30 m depth. Both encountered a silt stratum at approximately 30 m depth, which overlies another gravel sequence, proven to approximately 40 m. This deeper gravel sequence is considered to be the Linwood Formation.
- Groundwater levels in the confined aquifers (Riccarton/Burnham and Linwood aquifers) are artesian, although groundwater levels are usually below ground surface. No artesian flows were reported during the drilling of the deeper boreholes, but groundwater levels were close to ground surface.
- Based on the variable depth to groundwater and the elevation of Taranaki Stream, it is inferred that the stream reach within the designation at Pegasus interchange is either a neutral or losing reaching, meaning that locally, shallow groundwater does not provide recharge to baseflows in this reach.
- A schematic section of the local hydrogeology, interpreted from draft bore logs is presented in Figure 13.5.

[59] There are more than 140 geotechnical investigations available that were undertaken across the broader Ravenswood site. These support the geological interpretation for the Taranaki Stream area.

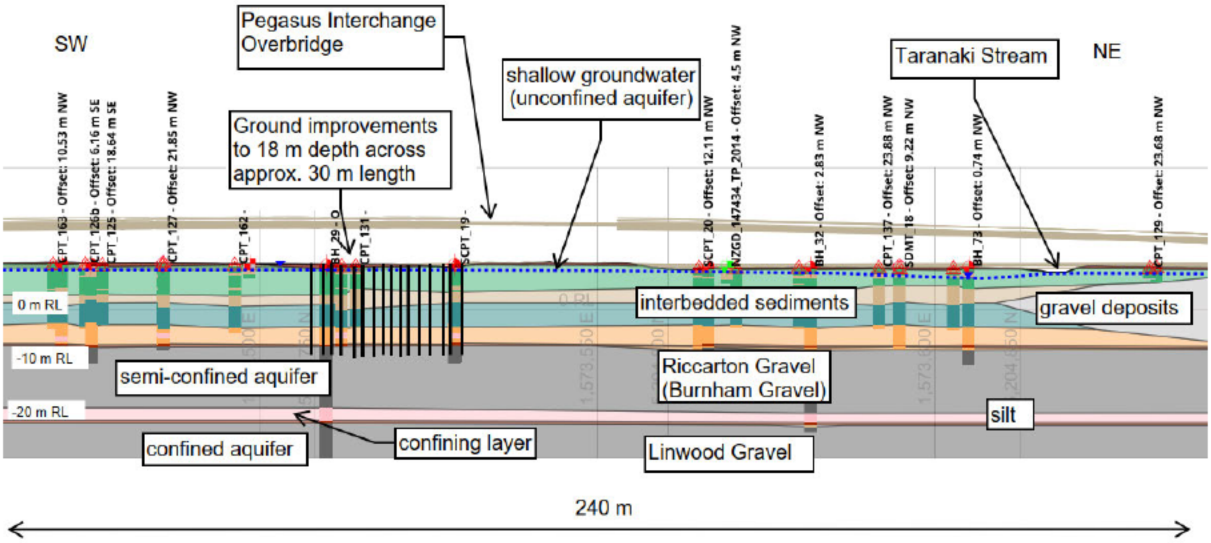



*Figure 13.5: Conceptual hydrogeological model - schematic sketch based on investigation data and draft bore logs from April – June 2025 investigations.*

## 13.4 Hydrogeological effects assessment for Pegasus interchange

### 13.4.1 Overview

The proposed activities are summarised in Table 13.6 and the assessment of effects from these activities on groundwater are provided in Sections 13.4.2 and 13.4.3. A summary of the effects including the scale of effect is included in Section 13.5.

**Table 13.6: Summary of proposed activities at Pegasus interchange**

| Proposed activities | Activity has potential to affect groundwater: | | |
|---|---|---|---|
| | Level | Quality | Flow |
| **Temporary activities during construction** | | | |
| Culvert installation | Yes | Yes | Yes |
| Ground improvements rigid inclusions | Yes | Yes | Yes |
| Embankment construction | Yes | No | Yes |
| Shallow excavations | No | Yes | No |
| Stream diversions | Yes | Yes | Yes |
| **Permanent activities during operation** | | | |
| Road embankment | No | No | No |
| Stormwater discharge | Yes | Yes | No |
| Stream restorations | No | No | Yes |

### 13.4.2 Temporary effects

#### 13.4.2.1 Culvert installations

Five culverts will be installed in the vicinity of Pegasus approach and interchange. The key excavation details for each culvert are shown in Table 13.7.

**Table 13.7: Excavation dimensions for culvert installations at Pegasus approach and interchange**

| Culvert ID | Surface water | Width (m) | Length (m) | Excavation depth range (m bgl) | | Excavation Base (m RL) |
|---|---|---|---|---|---|---|
| Culvert ID013 | Dry channel | 1.6 | 65 | 1.3 | 3.5 | 6.8 |
| Culvert ID014 | Waihora Stream | 5.5 | 70 | 1.2 | 3.5 | 6.9 |
| Culvert ID015 | Taranaki Stream | 8 | 10 | 2.2 | 3.3 | 6.0 |
| Culvert ID016 | Taranaki Stream | 4 | 90 | 1.5 | 3.2 | 6.4 |
| Culvert ID017 | Taranaki Branch | 2.3 | 55 | 1.2 | 2.2 | 5.9 |

Based on the range in depth to groundwater of approximately 1.3 m to 3 m in these areas, shallow groundwater will be encountered during the some of the culvert excavations and dewatering will be necessary to work in dry conditions.

An assessment on the dewatering effects is included in Appendix G which includes a list of assumptions used to make this assessment. The results for maximum assessed effects are presented in Table 13.8 below and the general conclusions are the same as described in the Project-wide items in Section 6.4.2.1. For that reason, these points are summarised below:

- Results are based on conservative groundwater levels, indicative excavation dimensions and anticipated dewatering duration.
- Radial drawdown effects from the dewatering are limited to local distances from the excavation.
- The maximum predicted distance from the centre of the excavation to where the amount of drawdown is estimated to be nil/less than measurable is between 50 m to 250 m and this distance is dependent on the excavation dimensions and groundwater levels (as presented in Table 13.8).
- Groundwater induced settlement effects are localised to near the excavation, they are expected to be small and are able to be mitigated thorough construction methodologies.

**Table 13.8: Summary of the maximum assessed drawdown effect from dewatering at culverts ID013, ID014, ID015, ID016 & ID017**

| Culvert ID | Surface water | Drawdown within excavation(s) (m) | Radius of drawdown extent (m) |
|---|---|---|---|
| Culvert ID013 | Dry channel | 1.2 | 250 |
| Culvert ID014 | Waihora Stream | 1.1 | 240 |
| Culvert ID015 | Taranaki Stream | 2.0 | 130 |
| Culvert ID016 | Taranaki Stream | 0.5 | 50 |
| Culvert ID017 | Taranaki Branch | 0.5 | 160 |

The groundwater effects for culvert installation are described in the following sections.

#### 13.4.2.1.1 Effects on surface waters

Stream depletion effects from the excavation dewatering are likely. It is assessed that at Waihora Stream and Taranaki Stream dewatering could result in a high stream depletion effect at both streams.

To manage these depletion effects and as part of the dewatering activity, abstracted groundwater will be discharged back into the respective surface waters just upstream of the affected reaches after suitable treatment, this will be described in the GMP. Thus, the stream flows will be mitigated and managed in a way that negate any of the depletion effects and the effects will be low.

The closest natural inland wetlands to the culverts; 013 and 014 are WC_W4_NPSFM at the edge of the designation and WC_W3_NPSFM, located 180 m southeast to culvert 013 at the nearest point. These wetlands are hydraulically connected with Waihora Stream and supported by groundwater baseflows. Therefore, it is assessed that the dewatering at these culverts close to and on Waihora Stream could result in a high stream depletion effect on wetlands; WC_W4_NPSFM and WC_W3_NPSFM. Management of these depletion effects is the same as for the overall stream depletion, as described above. Wetlands WC_W6_NPSFM and WC_W5_NPSFM will be lost during construction (see Section 13.4.2.2.2.)

There are no natural inland wetlands close to culverts: 015, 016 and 017. However, there are three other wetlands located close to the designation at Pegasus interchange, these wetlands are shown in the Site Plan and Environmental Features (Volume 4C). Wetland GC_W1_LWRP is located approximately 125 m southeast of culvert: 015 and approximately 75 m southwest of culvert: 016. At these distances, which are the closest measurements to the culvert excavations, the radial drawdown extent from culvert: 016 does not reach this wetland.

However, the assessed radial drawdown from culvert: 015 overlaps with Wetland GC_W1_LWRP by the order of 5 m. The wetland borders a pond which is likely to buffer the effect of any drawdown on the wetland through surface water recharge. It is also noted that the assessed drawdown radius assumes that steady state drawdown conditions are achieved during dewatering. These conditions are unlikely to be achieved over the duration of the dewatering.

Another wetland, not fully assessed at this stage is wetland GS_W2, located at the northern end of the Project alignment. This wetland is approximately 360 m northeast of culvert: 017. The effects of dewatering will not be measurable at this distance and the assessed effects are negligible.

Wetland GS_CW1_RMA is a constructed wetland located approximately 45 m west of culvert ID:013 and approximately 80 m southwest of culvert ID:014. Whilst the radial drawdown extent could reach this wetland, because it is a constructed wetland and its primary water source is expected to be stormwater. On this basis, the effects on groundwater levels at this wetland will be negligible.

The volume and rate of discharge will be determined by the Contractor. Due to low flows in these surface waters, the discharge rate could be greater than the stream flows and this will be managed to ensure that flooding does not occur at downstream locations and to manage erosion/scour effects from the discharge. It is expected that discharge to Waihora Stream will ultimately go the ground.

#### 13.4.2.1.2 Effects on other groundwater users

The nearest groundwater users to the culvert excavations are summarised in Table 13.9. The closest groundwater users to excavations for culverts; 013, 014 and 017 are located within the radius of influence of the dewatering.

**Table 13.9: Nearest groundwater users to each culvert installation at Pegasus approach and interchange**

| Culvert ID | Surface water | Bore ID | Bore depth (m) | Distance/ direction | Bore within the predicted radius of drawdown extent (distance)* | Address |
|---|---|---|---|---|---|---|
| Culvert ID013 | Dry channel | M35/0432 | 19.7 | 175 m E | Yes (250 m) | 1188 Main North Road |
| Culvert ID014 | Waihora Stream | M35/0432 | 19.7 | 180 m SE | Yes (230 m) | 1188 Main North Road |
| Culvert ID015 | Taranaki Stream | M35/0409 | 21.9 | 260 m E | No (130 m) | 1250 Main North Road |
| Culvert ID016 | Taranaki Stream | M35/0409 | 21.9 | 90 m E | No (50 m) | 1250 Main North Road |
| Culvert ID017 | Taranaki Branch | M35/0408 | 18.3 | 70 m N | Yes (160 m) | 5 Wards Rd |

Note: * The distance reported in this table is the maximum predicted distance from the centre of the excavation to where the amount of drawdown is estimated to be nil/less than measurable.

The same bore/groundwater user from bore M35/0432 is assessed to potentially be affected by dewatering at both culvert 013 and 014 by a similar amount of drawdown. In reality, the amount of drawdown expected at this bore will be much less than the amount predicted at the edge of the excavation. This bore is much deeper than the proposed excavation depths. Whilst the screened interval of this bore is not recorded, it is likely to be taking water from the deeper aquifer and it is assessed that the effect on this groundwater user from the short-term dewatering will be negligible.

Bore M35/0408 is assessed to potentially be affected by dewatering at culvert 017. For the same reasons described above, it is assessed that the effect on this groundwater user from the short-term dewatering will be negligible.

#### 13.4.2.1.3 Effects on drinking water supply source water (cDWPZ)

The nearest cDWPZ (WDC bore M35/0225) is located approximately within 780 m west of culvert 013 excavation on Chinnerys Road. Further review of this bore indicates that it is most likely not in use due to the relatively new residential at Ravenswood Subdivision overlying the indicative bore location. It is understood that this bore was previously a backup bore for emergency use[60]. Therefore, the potential drawdown effect on this bore does not exist.

Another cDWPZ (WDC bore M35/10908) is located approximately within 850 m southeast of culverts 013, 014, 016 excavation. These cDWPZ will not be affected by the dewatering activities. The overall effect on groundwater users is assessed to be negligible. In addition, as described in Section 12.4.2.4, the effects on groundwater quality are also assessed as negligible.

#### 13.4.2.1.4 Effects on groundwater quality

The effects on groundwater quality will be limited to increased sediment loading in the water at the base of the excavation. Mobilisation of suspended sediment will be restricted and will be removed by the pumping of groundwater as part of the dewatering. These overall effects are described in the Project-wide items in Section 6.4.2.1.3. and the discharge water quality at the point of discharge will

[60] WDC (December 2019) Woodend Pegasus Water Safety Plan 2019. Ref: WAT-05-23-03/ TRIM 191023148220.

be managed by the Contractor through specification in the GMP. Overall, the effects on groundwater quality is expected to be a low effect.

#### 13.4.2.1.5 Effects of discharge water quality at point of discharge

Dewatering will generate water to discharge. These overall effects are described in the Project-wide items in Section 6.4.2.1.4. and TSS at the point of discharge will be managed by the Contractor through specification in the GMP with the intention of meeting the discharge water quality requirements. On this basis, the overall, the effects on groundwater quality will be negligible.

#### 13.4.2.1.6 Effects on groundwater flow

The construction of the culverts and the backfilling of areas where stream diversion is proposed, has the potential to result in changes to the groundwater flow. At these locations, groundwater flows may locally track around the in-ground structures (culverts) and flow along the former stream location. Based on the scale of the construction activities, this could result in a very localised, negligible effect.

To reduce the potential effect for changes to groundwater flow around the new culverts, the contractor could limit the amount of granular backfill around the culvert construction and/or install seepage dams at intervals along the culvert alignment, such detail will be provided in the GMP.

To reduce the potential effect, for the backfilling of stream diversion areas, the contractor should match the backfill with material of similar permeabilities to the material removed, as described in the GMP.

### 13.4.2.2 Earthworks

#### 13.4.2.2.1 Effects on groundwater

Minor, shallow excavation activities will occur for the formation of the road embankment and for creation of shallow footings for the MSE abutment walls. Some of these excavations are expected to be within 1 m above the local unconfined groundwater level, although groundwater is typically deeper than 1.5 m from the surface. However, if groundwater is encountered, these excavations will not require dewatering as placement of the backfill material can be completed in a wet excavation. With the exception of ground improvements, for the embankment construction, there will be no excavation of any confining layer.

Shallow excavations into groundwater are likely for the stream diversion channels at Waihora Stream and Taranaki Stream. These excavations can be completed as a wet excavation, and no dewatering will be required. There is a potential effect on groundwater quality during wet excavations. These overall effects are described in the Project-wide items in Section 6.4.2.3 and the discharge water quality at the point of discharge will be managed by the Contractor through specification in the GMP.

There will be shallow excavations for the stormwater bio-retention basin near to culvert 014. These excavations will be in natural ground but are expected to be dry excavations. Stormwater swales will be excavated into the road embankment as dry excavations.

In summary, while there could be some excavation within 1 m of and into groundwater it is assessed that excavations in the vicinity of Pegasus interchange are expected to have low effects on shallow groundwater and negligible effect on groundwater receptors.

#### 13.4.2.2.2 Effects on Wetlands

There is the potential for effects to occur on the Waihora Stream wetland complex (natural inland wetlands) and their associated catchments from the temporary activities. These potential effects include changes to groundwater and surface catchments from the associated earthwork activities.

An assessment on the quantified loss of these six wetlands has been completed with full details in Appendix H. Table 13.10 provides a summary of the potential loss of the wetland areas and catchments during construction.

**Table 13.10: Summary showing temporary loss of wetland areas and catchments**

| Wetland ID | Works within 10 m? | Temporary loss of wetland extent | Temporary loss of wetland catchment | Mitigation required to reduce level of effect? |
|---|---|---|---|---|
| WC_W1_NPSFM | Yes | 100 % | N/A | N/A |
| WC_W2_NPSFM | No | None | 26 % | Yes, see EcIA (Volume 3I) |
| WC_W3_NPSFM | No | None | 48 % | |
| WC_W4_NPSFM | No | 2 % | 75 % | |
| WC_W5_NPSFM | Yes | 79 % | 24 % | |
| WC_W6_NPSFM | Yes | 100 % | N/A | N/A |

Note: the loss of the catchment is N/A when there is a total loss to the wetland extent. This is covered in the permanent effects (Section 13.4.3).

It is assessed that the effects on wetlands associated with construction activities is a:

- High effect at wetlands WC_W1_NPSFM and WC_W6_NPSFM with total loss to the wetland extents based the works will occur within all of the wetlands since they are crossed by the road and designation. This loss is also a permanent loss and this is discussed in Section 13.4.3.
- Moderate effects at wetland WC_W2_NPSFM, WC_W3_NPSFM, and WC_W4_NPSFM
- High effect at wetland WC_W5_NPSFM with almost a total loss to the wetland extent based on the works will occur within all most of the wetland extent and catchment since it is in the designation.

These level of effects are conservative because there will be continued stream flows to the wetland extents from Waihora Stream which has a contribution of flow from Taranaki Stream. This means the calculated loss of the catchment areas may not result in the scale of reduction as reported in Table 13.10.

At wetlands WC_W2_NPSFM, WC_W3_NPSFM, WC_W4_NPSFM and WC_W5_NPSFM mitigation to reduce the temporary level of effect to low is restricted by the designation crossing of the wetland catchment area, as shown in Figure 13.2. Recommendations are provided in the EcIA (Volume 3I).

#### 13.4.2.2.3 Filling

**Effect on groundwater recharge and water levels**

Temporary filling activities and associated stockpiling of material could result in effects on groundwater with potential changes to local groundwater recharge, levels and flows. The overall effects are the same as described in the Project-wide items in Section 6.4.2.3.2. and there are no location specific groundwater effects at this location. The overall effect on the groundwater environment from the temporary filling is negligible and thus the effect on groundwater receptors is negligible.

#### 13.4.2.3 Ground improvements

##### 13.4.2.3.1 Effects on groundwater

Installation of rigid inclusions to 18 m depth will intercept the shallow unconfined groundwater and are likely to reach the semi-confined groundwater of the Riccarton/Burnham aquifer over the southeast embankment footprint of the Pegasus interchange overbridge.

**Mixing of groundwater from different aquifers**

The overall effects are the same as described for Cam River bridge in Section 8.4.2.2 where there is the potential for mixing of groundwater from different aquifers.

it is assessed that ground improvements in the vicinity of Pegasus interchange are expected to have a low effect on the mixing of groundwater over the localised area of the ground improvements.

**Groundwater flow and level**

The resulting ground improvement area is likely to have effects on groundwater flows and levels, whilst these effects may be initiated during the construction works, overall, they will have a permanent effect and they are described in Section 13.4.3.

**Groundwater quality**

There is the potential for temporary localised changes to groundwater quality to occur due to the ground improvement works. The overall effects are the same as described for Cam River bridge in Section 8.4.2.2. where the use of concrete in rigid inclusions could result in localised increases to the pH level of groundwater and cause a rise in groundwater temperature. Increased turbidity in shallow groundwater may also occur as a result of the temporary construction work activities.

Taranaki Stream is the nearest ecological receptor for groundwater to discharge into from the Pegasus interchange ground improvement works. These effects are the same as provided in Section 8.4.2.2. and it is assessed that the temporary effect on groundwater quality during the construction of ground improvements in the vicinity of Taranaki stream is low.

The wetlands are located away from the ground improvement works and these are assessed not to be affected by any change in the groundwater quality.

##### 13.4.2.3.2 Effects on other groundwater users

The nearest groundwater user to the designation is bore M35/0409 approximately 60 m to the southeast at 1250 Main North Road with a bore depth of 21.9 m depth. The depth of the neighbouring bore is similar to the temporary activities and likely penetrates the Riccarton/Burnham aquifer. The activities could result in increased turbidity in shallow groundwater induced during the ground improvements/vibrations, however, the extent of these effects are likely not to be observed at the nearby groundwater user and the assessed effect on water quality at the nearby bore is a negligible effect.

### 13.4.3 Permanent effects

#### 13.4.3.1 Road embankment

As described in Section 3.9, the road embankments could result in effects on groundwater with potential changes to the local regime. These overall effects are described in the Project wide items in Section 6.4.3.1 and there are no location specific groundwater effects at this location. The overall effect on the groundwater environment from the road embankments is assessed as negligible and therefore the effect on groundwater receptors will be negligible.

#### 13.4.3.1.1 Effects on Wetlands

There is the potential for effects to occur on the Waihora Stream wetland complex and their associated catchments on a permanent basis. These changes are compared with the existing (pre-construction) setting. Table 13.11 provides a summary of the potential loss of the wetland areas and catchments with the scale of effect, full details are provided in Appendix H.

**Table 13.11: Summary showing permanent loss of wetland areas and catchments**

| Wetland ID | Permanent loss of wetland extent | Permanent loss of wetland catchment | Mitigation required to reduce level of effect? | Permanent scale of effects |
|---|---|---|---|---|
| WC_W1_NPSFM | 100 % | N/A | See EcIA (Volume 3I) | |
| WC_W2_NPSFM | None | 18 % | Yes | Low |
| WC_W3_NPSFM | None | 36 % | Yes | Low |
| WC_W4_NPSFM | None | 59 % | Yes | Low |
| WC_W5_NPSFM | None | None | None | Negligible |
| WC_W6_NPSFM | 100 % | N/A | See EcIA (Volume 3I) | |

It is assessed that the permanent effects on wetlands WC_W1_NPSFM and WC_W6_NPSFM will be a total loss to the wetland extents as these wetlands will be crossed by the road alignment.

The key points, applicable to the remaining four wetlands in the Waihora Stream wetland complex are:

- There will be no direct effect on the wetland extents.
- The road operation will not occur within 10 m of any of the wetlands.
- There are changes to the wetland catchments. The effects are reduced when compared with the temporary effects because part of the catchment used during construction i.e. the area within the designation that does not include the road footprint, will be returned to its previous condition e.g. by removal of the haul road and stock piling.
- Stream flows will be maintained and provide a water contribution to these wetlands on a permanent basis.

Mitigation measures to address the scale of effects are provided in the EcIA (Volume 3I).

### 13.4.3.2 Ground improvements

As described in 8.4.3.2, the resulting ground improvement area at the localities of the rigid installations are likely to have a lower permeability following improvement due to the filling with concrete over a small, localised area. The effects are described in Section 8.4.3.2 and in addition, the specific localised effects on the Taranaki Stream are similar to those of the Cam River/Ruataniwha, where the effect of the ground improvements, and the potential to form a barrier to groundwater flows. However, this stream reach is not dependent on groundwater flows and the effects on the Taranaki Stream are assessed as negligible.

Based on the surface water/groundwater interaction assessment[12] at Taranaki Stream, and as described in Section 4.4, groundwater flows along this reach of the stream are likely to be neutral or a losing reach. Therefore, the potential changes to groundwater flow and levels on the surface water are unlikely to be measurable. In addition, these effects are expected to be temporary and groundwater flows and levels are expected to equilibrate once pore water pressures have dissipated. Overall, it is assessed that ground improvements in the vicinity of Pegasus interchange are expected to have low temporary effects on shallow groundwater flow and level over the localised area of the permanent ground improvements and negligible effect on groundwater receptors.

As described in the Section 8.4.3.2, the permanent long-term effects on groundwater quality are negligible.

#### 13.4.3.3 Stormwater retention, drainage and cut-off drains

The effects from the stormwater systems at Pegasus interchange on groundwater are described in the Project wide items (Section 6.3.4.2). The overall effect on the groundwater environment from the stormwater systems are assessed as negligible.

## 13.5 Summary of effects

A summary of the temporary and permanent effects on groundwater from the activities at Pegasus interchange, principally comprising overbridge construction, ground improvements, culvert installation and stormwater systems are provided in Table 13.12 and Table 13.13. Mitigation to reduce/minimise these effects is provided where the scale of effect is greater than 'low'.

**Table 13.12: Temporary groundwater effects from activities at Pegasus approach and interchange**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Culvert installation | Stream depletion on Waihora & Taranaki Streams | Low | - | - |
| | Groundwater levels on wetlands WC_W3_NPSFM & WC_W4_NPSFM | Low | - | - |
| | Groundwater levels on other wetlands | Negligible | - | - |
| | Well interference | Negligible | - | - |
| | Groundwater quality on receptors | Low | - | - |
| Ground improvements (rigid inclusions) | Groundwater level & flow (mixing aquifers) | Low | - | - |
| | Groundwater quality on receptors | Low | - | - |
| | Groundwater users | Negligible | - | - |
| Embankments & earthworks | Overall groundwater | Negligible | - | - |
| | Loss of wetland catchment to WC_W2_NPSFM, WC_W3_NPSFM, WC_W4_NPSFM | Low | Refer to EcIA (Volume 3I) | |

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| | Loss of wetland extent & catchment to WC_W5_NPSFM | High | | |
| Earthworks (shallow excavations) | Overall groundwater | Negligible | - | - |
| | Groundwater quality on receptors | Negligible | - | - |

**Table 13.13: Permanent groundwater effects from activities at Pegasus approach and interchange**

| Works activity | Issue/effect | Scale of effect | Potential mitigation to reduce level of effect | Level of effect after mitigation |
|---|---|---|---|---|
| Road embankment | Overall groundwater on receptors | Negligible | - | - |
| | Loss of wetland extent & catchment to WC_W1_NPSFM & WC_W6_NPSFM | High | Refer to EcIA (Volume 3E) | |
| | Loss of wetland extent & catchment to WC_W2_NPSFM, WC_W3_NPSFM & WC_W4_NPSFM | Low | | |
| | Loss of wetland extent & catchment to WC_W5_NPSFM | Negligible | | |
| All Ground improvements | Groundwater quality on receptors | Negligible | - | - |
| | Groundwater level & flow (mixing aquifers) | Negligible | - | - |
| Stormwater | Overall groundwater | Low | - | - |

# 14 Mitigation, management, and monitoring

## 14.1 Overview

This section provides a high-level overview of proposed mitigation, management and monitoring that will be set out in the GMP. The follow headings cover those topics identified in this hydrogeological assessment and further topics will be expanded on in the GMP and also covered by other technical assessments.

### 14.1.1 Bore decommissioning

Bores will be decommissioned in accordance with ECan Guidelines[1] with bore casing removed prior to filling and sealing of the bore (where practical) by NZTA and in advance of the Construction Works in each area. Bore decommissioning will be completed by backfilling with suitable material to ensure bores will be:

- Sealed to prevent vertical mixing of groundwater between aquifers.
- Permanently confine groundwater in the aquifer to the position that it originally occurred.
- Sealed to prevent any contaminants and surface water from entering the bore.

### 14.1.2 Management during ground improvement works

Ground improvement works covers the installation of piles, rigid inclusions and stone columns. Examples of standard controls for the management of potential groundwater effects during the installation of the piles and ground improvements to be included in the GMP could include:

- Site management and controls including practices to ensure no surface contaminants can enter the probe holes during installation.
- Information on drilling of the pile holes and auger techniques for installation of rigid inclusions.
- Management of confined aquifer and artesian pressures and methods of control.
- Control of any bore flushing and management of the drilling fluids.
- Installation procedures for the mixing and placement of concrete.
- Measures such as documented grout volumes.
- Control, collection and treatment of displaced water from the piles/ground improvements with protocols for correct disposal.
- Potential inspection of a test rigid inclusion to ensure integrity of the grout and groundwater monitoring at different depths.
- Safe clean work practises, cleaning equipment in controlled areas away from surface waters.
- Erosion and sediment controls incorporating minimisation of sedimentation and contaminant discharge for the site works, especially at the edge of Cam River/Ruataniwha and Taranaki Stream.
- Provision of contingency measures.

These procedures will provide management to reduce the effects on aquifer mixing, control of artesian groundwater conditions (if encountered) and limit effects on groundwater quality.

In addition, for the installation of stone columns at William Street interchange, the GMP will include additional management methods to reduce the potential effects of mixing groundwater between aquifers at a specific location(s) and to reduce upward groundwater flows, if these are anticipated. A control will include an item to the similar effect of:

- To reduce the potential effects at the spring-fed pond, stone columns filled with a lower permeability material (subject to the design of the Engineer).

### 14.1.3 Excavation within 1 m of groundwater

Examples of standard controls for the management of potential groundwater effects during shallow excavations close to groundwater to be included in the GMP could include:

- Site management and controls including practices to ensure no surface contaminants can enter the excavations.
- Erosion and sediment controls incorporating minimisation of sedimentation and contaminant discharge (if groundwater is intercepted) for the site works.
- Safe clean work practises, cleaning equipment in controlled areas away from exposed waters.
- Visual inspections to monitor groundwater levels and quality before, during, and after excavation.
- Management plan to deal with groundwater if encountered (see dewatering management).
- Provision of contingency measures.

### 14.1.4 Dewatering management

Management and controls for dewatering activities will be included as a chapter in the GMP. This chapter will cover all aspects relating to the specific procedures, methodology and management of water when dewatering activities are completed. It is envisaged that the following items will be covered in this management document:

- Visual inspections to monitor groundwater levels and quality before, during, and after excavation.
- Visual monitoring at surface waters and wetlands where identified.
- Monitor excavation water quality continuously and avoid discharging dirty water.
- Controls on volume/pumping rate of discharge water as to not cause downstream effects (e.g. flooding, scour).
- Considerations on the excavation size where appropriate for long culvert lengths such as at Culvert: 016.
- Management of discharge quality, e.g. pre-treatment of the water may be required to remove TSS and/or other contaminants.
- Descriptions on the details on dosing rates and flocculant treatment methods.
- Provision for the use of settlement tanks, sediment retention ponds, or discharge to land where feasible.
- Placement of discharge water at specified locations such as into streams just upstream of the affected reaches where direct hydraulic connection is identified, or to ground where effects on wetlands could be observed.
- Provision for installation of barriers such as the use of trench shields or temporary sheet piling to limit groundwater inflows.
- Adoption of suitable pumping rates/screen sizing can be used to manage some volumetric loss to reduce the effects of dewatering induced ground settlements.

- Options for dewatering methods and provision of contingency measures.
- Consideration of timing and staging of the dewatering activities if necessary.
- Additional broad items associated with dewatering activities that are commonly provided in management documents.

In addition, where activities are completed at Gladstone landfill, any discharge of dewatering water from landfill will be subject to controls and procedures for the management discharge which will be provided in the Contaminated Site Management Plan.

#### 14.1.5 Ancillary activities

The GMP will outline activities within the construction support areas (CSA). Appropriate environmental management controls will be put in place within the CSA around certain possible activities such as the storage of hazardous construction materials will not occur within the cDWPZ.

## 15 Summary and conclusions

### 15.1 Overview

This hydrogeological assessment evaluates the potential temporary and permanent effects associated with the construction works at SH1, and its future operation. It covered the potential effects on groundwater levels, flow, quality, and how changes effect groundwater receptors such as surface waters, wetlands and groundwater users including bores with community drinking water protection zones (cDWPZ). This report integrates findings from site investigations, hydrogeological conceptual modelling, and published regional data to assess both temporary and permanent effects on groundwater receptors.

All assessments have applied a conservative approach to the evaluation of groundwater effects based on the 30 % detailed design, and for this reason, they provide a conservative assessment of the effects. Groundwater effects have been evaluated using a source-pathway-receptor approach to identify the groundwater receptors.

The overall findings of the assessments in relation to works activities or permanent features and the groundwater effects are tabulated in Tables 15.1 and 15.2. The key findings of this assessment as reported in Sections 6 to 13 are set out below. Technical assessments to support these findings are included in the Appendices G to I.

### 15.2 Temporary effects on groundwater

Most of the identified effects are temporary, occurring during the construction works and the majority of these effects on groundwater receptors are assessed as negligible. The following list of key findings on the temporary effects includes a summary on the measures proposed to limit the effects (where required):

- Some of the **earthworks activities** are shown to have an effect on wetlands because the construction activities will be within the wetland extents and/or catchments. This will result in:
  - A temporary partial loss to wetlands at some locations; Quarry Lakes QP_W1_NPSFM, Fullers Road FR_W4_NPSFM, Waihora WC_W2 to W5_NPSFM.

  Recommendations/mitigations to address these effects are provided in the EcIA (Volume 3I).
- Groundwater drawdown effects at **17 culvert locations** have been assessed. The radial extent of the drawdown has been determined to evaluate the potential effects on groundwater

receptors such as surface waters and wetlands. The dewatering activities at individual excavations are of short duration (up to 30 days) and this will result in:

- A low effect for culvert excavations at Rossiters, Wilsons and McIntosh Drains and Waihora and Taranaki Streams, where the direct stream depletion effect is managed by discharge of water arising from dewatering activities back to the surface water.
- A negligible effect at other culvert excavations, due to the limited radial extent being localised and this limits the effects on groundwater receptors.

- At specific locations, where **piling and/or ground improvements** are proposed e.g. Cam River bridge, Williams Street interchange, Pegasus interchange and Woodend Beach Road, there will be short-term low to moderate effects on groundwater. These temporary effects are related to the:
  - Potential mixing of aquifers by penetration of the deeper semi-confined or confined aquifer.
  - Groundwater quality from the installation of concrete piles and/or ground improvements.

  These effects will be very localised and can be reduced through management and controls that will be provided in GMP.
- The temporary **surface water take** from Quarry Lakes will result in temporary changes to groundwater which are assessed to have a low effect on one wetland and negligible effects on other groundwater receptors.
- Other activities at Quarry Lakes including the **dynamic compaction** are assessed to have negligible effects on groundwater receptors.
- Construction options for the **landfill works at Gladstone landfill** provide a range of potential effects from negligible to low on groundwater receptors. . Based on the findings of the recent investigations, if excavation and dewatering were to occur (Option 1 or 3) it is expected to pose a low level of effect because groundwater will only be encountered towards the base of the excavation and no exceedances of the DWSNZ MAVs or the ECan water quality limits for groundwater were recorded. The groundwater discharged to land during any landfill dewatering will be the same groundwater as that adjacent to the landfill and is expected to be of similar water quality. Additional controls will be provided in the Contaminated Sites Management Plan (**CSMP**) and GWP to manage the rates of dewatering and disposal of dewatering discharge.
- Ancillary activities include consideration of storage of hazardous construction materials at **construction storage areas** (CSA) and the potential effect on groundwater receptors, in particularly the CSA at Lineside interchange located within a cDWPZ. Appropriate environmental management controls, included in the GMP, will be put in place to control these activities to limit the level of effect on groundwater receptors to negligible.

**Table 15.1: Summary of temporary effects**

| Works activity | Issue/effect(s) | Scale of effect | Mitigation to reduce effects |
|---|---|---|---|
| **Project-wide activities (Table 6.5)** | | | |
| **Culvert installation** | Stream depletion | Low | - |
| | Well interference & groundwater quality on receptors | Negligible | - |
| | Ground settlement | Low | - |

| Works activity | Issue/effect(s) | Scale of effect | Mitigation to reduce effects |
|---|---|---|---|
| Construction of stormwater drainage | Overall groundwater | Low | - |
| Earthworks | Overall groundwater | Negligible | - |
| Construction storage area | Groundwater quality on cDWPZ | Negligible | - |
| SH1 upgrade activities (Table 7.5) | | | |
| Culvert installation | Stream depletion (on drains) | Low | - |
| | Well interference & groundwater quality on receptors | Negligible | - |
| Shallow excavations | Overall groundwater | Negligible | - |
| Construction storage areas | Groundwater quality on cDWPZ | Negligible | - |
| Cam River Bridge (Table 8.7) | | | |
| Ground improvements (rigid inclusions) | Groundwater quality, level & flow (mixing aquifers) | Low | - |
| | Overall groundwater on receptors | Negligible | - |
| Foundation piling | Groundwater quality, level & flow (mixing aquifers) | Low | - |
| | Overall groundwater on receptors | Negligible | - |
| Embankments | Overall groundwater | Negligible | - |
| Shallow excavations | Overall groundwater | Negligible | - |
| Williams St interchange (Table 9.8) | | | |
| Ground improvements (rigid inclusions & stone columns) | Groundwater level & flow (mixing aquifers & artesian groundwater) | Moderate | Ref. Section 8.4.2.2.1 & 9.4.2.3.1 |
| | Overall groundwater quality | Low | - |
| | Overall groundwater on receptors | Negligible | - |
| Embankments & earthworks | Overall groundwater | Negligible | - |
| Culvert installation | Overall groundwater | Negligible | - |
| Shallow excavations | Overall groundwater | Negligible | - |
| Quarry Lakes (Table 10.14) | | | |
| Culvert installation | Overall groundwater on receptors | Negligible | - |
| Earthworks | Overall groundwater on receptors | Negligible | - |
| | Loss of wetland extent & catchment to QP_W1_NPSFM | Moderate | Refer to EcIA (Volume 3I) |
| | Loss to wetland extent & catchment to QP_W4_NPSFM, BR_W1 to W4_NPSFM | Negligible | |

| Works activity | Issue/effect(s) | Scale of effect | Mitigation to reduce effects |
|---|---|---|---|
| Dynamic compaction | Overall groundwater on receptors | Negligible | - |
| Lake infilling | Overall groundwater on receptors | Negligible | - |
| Water take | Overall groundwater on receptors | Negligible | - |
| | Groundwater effects on wetland QP_W2_LWRP | Low | - |
| Woodend Beach Rd (Table 11.11) | | | |
| Culvert installation | Overall groundwater on receptors | Negligible | - |
| Ground improvements (stone columns) | Groundwater level & flow (mixing aquifers) | Low | - |
| | Groundwater quality on receptors | Negligible | - |
| Earthworks | Overall groundwater on receptors | Negligible | - |
| | Loss of wetland extent & catchment to FR_W1_NPSFM, FR_W2_NPSFM & FR_W3_NPSFM | Negligible | Refer to EcIA (Volume 3I) |
| | Loss of wetland extent & catchment to FR_W4_NPSFM | Low | |
| Shallow excavations | Overall groundwater on receptors | Negligible | - |
| Gladstone Rd (Table 12.9) | | | |
| Landfill works | Groundwater flow & level on receptors | Negligible | - |
| | Groundwater quality on receptors | Low | Ref. Section 12.4.2.1 |
| | Groundwater level effect on wetland FA_W2_NPSFM, | Negligible | Refer to EcIA (Volume 3I) |
| Culvert installation | Overall groundwater on receptors | Negligible | - |
| Earthworks | Overall groundwater on receptors | Negligible | - |
| Shallow excavation | Overall groundwater on receptors | Negligible | - |
| Pegasus approach and interchange (Table 13.12) | | | |
| Culvert installation | Stream depletion on Waihora & Taranaki Streams | Low | - |
| | Groundwater levels on wetlands WC_W3_NPSFM & WC_W4_NPSFM | Low | Refer to EcIA (Volume 3I) |
| | Groundwater levels on other wetlands and well interferences | Negligible | - |
| | Groundwater quality on receptors | low | - |
| Ground improvements (rigid inclusions) | Groundwater level & flow (mixing aquifers) | Low | - |
| | Groundwater quality on receptors | Low | - |
| | Groundwater users | Negligible | - |
| Embankments & earthworks | Overall groundwater | Negligible | - |
| | Loss of wetland catchment to WC_W2_NPSFM, WC_W3_NPSFM, WC_W4_NPSFM | Low | Refer to EcIA (Volume 3I) |
| | Loss of wetland extent & catchment to WC_W5_NPSFM | High | |

| Works activity | Issue/effect(s) | Scale of effect | Mitigation to reduce effects |
|---|---|---|---|
| Earthworks (shallow excavations) | Overall groundwater on receptors | Negligible | - |

## 15.3 Permanent effects on groundwater

Permanent effects on groundwater receptors that will occur either for a short-term or long-term over the operational life of SH1 are limited and fewer than the number of temporary effects. Most of these effects on groundwater receptors are assessed as negligible. The following list of key findings on the permanent effects includes a summary on the measures proposed to limit the effects (where required):

- The **road embankment** will have a permanent effect on the wetland extents and/or catchments on the following:
  - Permanent loss to wetlands at Cam River CR_W2_NPSFM, Waihora WC_W1_NPSFM & WC_W6_NPSFM (High effect).
  - Permanent partial loss to wetland catchments at some locations; Cam River CR_W1_NPSFM, Fullers Road FR_W4_NPSFM, Waihora WC_W2 to W4_NPSFM. (low effect).

  Recommendations and mitigations to address these effects are provided in the EcIA (Volume 3I). This includes the creation of an ecological enhancement and wetland offsetting area at Quarry Lakes.

  Other assessed effects on the presence of the road embankment on groundwater levels, flow and quality are negligible.
- Subject to the findings of the current investigations, if **landfill compaction** (Option 2) were selected, the permanent effects of the compaction on groundwater will be negligible.
- The **ground improvements** comprising **stone columns** supporting the overbridge structures at Williams Street interchange and Woodend Beach Road will have a low scale of effect on groundwater (mixing of aquifers). These effects will be very localised and have a negligible effect on groundwater receptors.
- The **stormwater system** including swale, cut-off drains and bio-retention basins and systems will have a low scale of effect on groundwater from stormwater discharges. This determined level of effect is conservative until further discharge details can be obtained. However, the overall effect on groundwater receptors is assessed as negligible.

**Table 15.2: Summary of permanent effects**

| Permanent feature | Issue/effect(s) | Scale of effect | Mitigation to reduce effects |
|---|---|---|---|
| Project-wide activities (Table 6.6) | | | |
| Road embankment | Overall groundwater | Negligible | - |
| Stormwater drainage | Overall groundwater | Low | - |
| Cam River Bridge (Table 8.8) | | | |
| Ground improvements | Groundwater quality, level & flow on receptors | Negligible | - |
| Williams St interchange (Table 9.9) | | | |

| Permanent feature | Issue/effect(s) | Scale of effect | Mitigation to reduce effects |
|---|---|---|---|
| All ground improvements | Groundwater level & flow (mixing aquifers & artesian groundwater) | Low | - |
| | Overall groundwater quality, level and flow on receptors | Negligible | - |
| | Loss of wetland extent & catchment to CR_W1_NPSFM | Low | Refer to EcIA (Volume 3I) |
| | Loss of wetland extent & catchment area to CR_W2_NPSFM | High | |
| Quarry Lakes (Table 10.15) | | | |
| Road embankment | Loss of wetland extent & catchment to QP_W1_NPSFM & QP_W4_NPSFM | Negligible | Refer to EcIA (Volume 3I) |
| Wetland offset | Overall groundwater | Negligible | - |
| Woodend Beach Rd (Table 11.12) | | | |
| Ground improvements (stone columns) | Groundwater level & flow (mixing aquifers) | Low | - |
| | Groundwater quality on receptors | Negligible | - |
| Road embankment | Overall groundwater on receptors | Negligible | - |
| | Loss of wetland extent & catchment to FR_W1_NPSFM, FR_W2_NPSFM & FR_W3_NPSFM | Negligible | Refer to EcIA (Volume 3I) |
| | Loss of wetland extent & catchment to FR_W4_NPSFM | Low | |
| Gladstone Rd (Table 12.10) | | | |
| Landfill compaction | Overall groundwater | Negligible | - |
| Pegasus approach and interchange (Table 13.13) | | | |
| Road embankment | Loss of wetland extent & catchment to WC_W1_NPSFM & WC_W6_NPSFM | High | Refer to EcIA (Volume 3I) |
| | Loss of wetland extent & catchment to WC_W2_NPSFM, WC_W3_NPSFM & WC_W4_NPSFM | Low | |
| | Loss of wetland extent & catchment to WC_W5_NPSFM | Negligible | |
| All ground improvements | Groundwater quality on receptors | Negligible | - |
| | Groundwater level & flow (mixing aquifers) | Negligible | - |

# 16 Applicability

This report has been prepared for the exclusive use of our client New Zealand Transport Agency Waka Kotahi, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that NZ Transport Agency Waka Kotahi will submit this report as part of an application under the Fast-Track Approvals Act 2024 and the appointed panel will use this report for the purpose of assessing that application.

This report has been prepared in accordance with the Tonkin & Taylor Ltd (T+T) sub consultancy agreement to "Belfast to Pegasus Motorway & Woodend Bypass pre-implementation & MSQA Professional services contract number 11320", dated 20 May 2025.

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