Project Number: W-SL001.03

Groundwater and Settlement Monitoring and Contingency Plan

10 July 2024

CONFIDENTIAL

Queen Street Wastewater Diversion Part 3 Alignment

wsp

150 YEARS IN AOTEAROA

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Revision Details

Revision	Details
R0	Draft for client and contractor review
R1	Final report to be submitted as part of S92.
R2	Revision reflecting the s92 comments and changes in the AEE
R3	Final DRAFT GSMCP
R4	Final for AC certification
R5	Draft for client review – s127 variation

Contents

List of Tables

1 Introduction

1.1 GSMCP Background

The GSMCP (R1) was completed in December 2023 and submitted as an appendix to the dewatering AEE for the resource consent application for the construction of the Part 3 works of the Queen Street Wastewater Diversion to Auckland Council. The GSMCP was independently reviewed by Council's specialist reviewer, who requested amendments based on updated total settlement analyses and the associated settlement effects assessment and shaft design changes (R2). Minor changes were made for R3.

This report has been updated in response to May 2024 changes to the construction design of the three temporary shafts. The May 2024 shaft changes did not require a re-assessment of dewatering effects as detailed in the dewatering AEE and included the following:

- Mayoral Shaft – has increased in length by approximately 1 m to the south. The estimated settlement contours towards the south has been updated, and the location of monitoring pins have been amended based on the updated settlement contours.
- Wellesley Shaft – has changed from a caisson to secant pile type and the internal diameter of the shaft has been confirmed as 3 m (from the preliminary design of 3.5 m). The extent of the settlement contours around the 3 m shaft diameter was updated and the location of monitoring pins have been updated.
- Victoria Shaft – dimensions in an east-west direction have increased (from 5 m to 7.4 m wide) and dimensions in the north-south direction have decreased from 8.8 m to 7.6 m long. The extent of the settlement contours around the new shaft has been extrapolated to the updated shaft dimensions.

1.2 Proposed Development

Watercare Services Limited ('Watercare') are proposing to upgrade the wastewater network within the upper catchment (southern) of Auckland City Centre. It has been established by WSL that the existing network does not have sufficient capacity to meet future demands. This Groundwater and Settlement Monitoring and Contingency Plan (GSMCP) applies to the Part 3 alignment of the Queen Street Wastewater Diversion. The construction along Part 3 alignment comprises:

- The pipeline (580 m) for the gravity main will be installed using trenchless methodologies.
- Three deep, temporary shafts will be required for access for the tunnelling equipment and pipes for the gravity main:
    - Victoria Shaft – at the intersection of Queen and Victoria Streets
    - Wellesley Shaft – at the intersection of Queen and Wellesley Streets
    - Mayoral Shaft – at the intersection of Queen Street and Mayoral Drive
- Local connections (engineering overflow points) to the Wellesley shaft will be installed in open trenches.

Dewatering will be required during the excavation of the temporary shafts to maintain workable and stable conditions.

1.3 Purpose

This GSMCP provides a framework to manage potential settlement generated by groundwater drawdown and deflections caused by temporary excavations on buildings, services and roading

infrastructure adjacent to the Part 3 works and to contain the groundwater level and settlement within the trigger levels stated in the plan.

The purpose of this document is to support the resource consent application to dewater during the construction of Part 3 of the Queen Street Wastewater Diversion. The final GSMCP will be prepared and implemented by the construction contractor using this document and will be submitted for certification by Auckland Council (AC).

The GSMCP is based on and should be read in conjunction with the following report prepared for the project: *Queen Street Wastewater Diversion: Part 3 Works. Assessment of Dewatering Effects Report prepared by WSP for Watercare Services Limited, updated 3 July 2024.*

1.4 Scope of Queen Street Wastewater Diversion Covered by this GSMCP

The GSMCP sets out:

- Trigger levels and maximum levels for groundwater drawdown and settlement of heritage buildings and other infrastructure associated with the Part 3 works.
- Provides appropriate measures to mitigate adverse effects (including cumulative effects) as a result of the dewatering and excavation activities involved in the early works.
- Contingency measures to be implemented should the alert or alarm levels be exceeded.

2 Proposed Construction Methodology

Settlement due to dewatering and excavation deflections may arise in the vicinity of the temporary access shafts for the tunnelling equipment for the period these shafts are open. The open trenches for the local connections to EOPs comply with Auckland Unitary Plan (AUP) standards for dewatering and diversion of groundwater and the tunnelling works are exempt based on standard E7.6.1.10(1), and these construction elements are not included in the GSMCP.

The shaft dimensions for the three shafts, denoted based on the intersecting road where the shaft is located, is summarised in Table 2-1. The proposed temporary works construction method is also indicated in the table. The post and panel shaft wall supports for Victoria shaft will be unsealed and will require 24/7 dewatering, whereas the secant pile shafts for Wellesley and Mayoral will be sealed with a base slab and will essentially be sealed upon completion of construction.

Table 2-1: Shaft dimensions

Shaft	Excavation dimension	Excavation depth (m bgl) [m RL]	Construction method
Mayoral	4.6 × 11.6 m	14.14 [13.95]	Secant pile
Wellesley	3 m radius (internal)	8.1 [6.3]	Secant pile
Victoria	7.4 × 7.6 m	7.45 [2.78	Post and panel

3 Overview of Monitoring Requirements

This section provides an overview of the monitoring and reporting required for the excavation and construction works in accordance with the consent conditions to dewater.

Temporary works, ground and building deflections and groundwater drawdown monitoring during the construction works will be undertaken to monitor whether the response of the surrounding structures remain within design tolerances and estimated range of settlement effects. This process allows for the geotechnical effects to be monitored and can act as an indication for mitigation measures to be implemented, if required.

3.1 Monitoring and Reporting Requirements

In general, monitoring is subdivided into three separate stages reflecting the separate periods of construction works. These are summarised in Table 3-1.

Table 3-1: Summary of Monitoring Stages

Pre-construction monitoring	This monitoring phase will provide baseline data against which effects resulting from the construction works can be assessed. The outcomes will form part of the input for the construction phase assessments. Pre-construction monitoring is to include: - Condition surveys and visual inspections of selected nearby buildings, including all heritage buildings, to define existing condition of the buildings. - Building and infrastructure survey points to establish a deflection baseline. - Groundwater level monitoring to establish baseline levels.
During construction monitoring	Monitoring during the construction phase will be carried out to compare movements against the set Alert and Alarm levels and enable the implementation of countermeasures in advance of potential adverse impacts occurring. Mitigation options set out in Section 6 of this GSMCP, may also be required to be implemented.
Post-construction monitoring	Where specified in the Consent, monitoring will occur until the various stages of works are completed (excavation, dewatering and construction). Post-construction measurements will be completed, once a month for three months or until the position pins is found to have stabilised and approval is given in writing by AC.

The monitoring required during each stage is summarised in Table 3-2.

Table 3-2. Summary of Monitoring Requirements

Monitoring Type	Construction Stage	Minimum Measurement Frequency	Measurement Accuracy	Reporting Requirement to AC, unless otherwise stated	Relevant GSMCP Sections
Groundwater monitoring	Baseline (pre-construction)	Once for a four-week period before commencing dewatering in monitoring boreholes placed near affected parties.	+/- 10 mm	Bimonthly for routine monitoring. Within 2 working days of any alert trigger level exceedances.	Section 4
	Excavation dewatering (during construction)	Twice weekly for all monitoring boreholes until completion of dewatering. Daily, should the Groundwater Alert Trigger level be exceeded			
	Post-construction dewatering	Weekly for the first month after dewatering has stopped and monthly thereafter. Monitoring must continue for three months after the completion of dewatering, if monitoring levels are stable, or until stable measurements are demonstrated and written approval is provided by AC for certification.			
Building Condition Surveys (BCS)	Baseline (pre-construction)	A pre-construction condition survey is to be carried out on all buildings identified relevant to this GSMCP (subject to approval of the property owner), no more than six months prior to the commencement of dewatering. Refer Table 5-2 to Table 5-4.	Not applicable	Within 15 working days to the relevant property owner and AC.	Section 5.2.1
	Excavation dewatering (during construction)	Weekly visual inspections with photographic evidence of the surrounding ground and external facades of buildings identified, from the commencement of excavation/dewatering, or within one week of the completion of works for shorter duration activities. This is to record any deterioration or further cracking after pre-construction conditions. Additionally, visual inspections with photographic evidence will be undertaken at intermediate intervals during construction if requested by the building or structure owner, following observation of cracking.		A record is to be maintained of the time, date and any observations for each inspection. This record is to be maintained and submitted to AC at two monthly intervals or upon reasonable request from the AC Representative. Results are to be included in the bi-monthly	
	Post-construction dewatering	A post-construction condition survey shall be carried out between six and twelve months after completion of dewatering/excavation.			

				monitoring report to Council	
Ground Surface and Building Monitoring	Baseline (pre-construction)	Each ground settlement and building movement monitoring mark shall be surveyed and recorded at least three times prior to the commencement of excavation / dewatering to establish a baseline elevation.	Horizontal and vertical accuracy of at least ±2 mm, or as otherwise achieved by precise levelling during baseline phase.	To be compiled and submitted to AC prior to the commencement of dewatering.	Section 5.2.2
	Excavation dewatering (during construction)	- Weekly		A record is to be maintained of the time, date and any observations for each survey, and submitted to AC at two monthly intervals.	
	Post-construction dewatering	Monthly for six months.			
Retaining wall monitoring	Baseline (pre-construction)	Twice	Horizontal and vertical accuracy of at least ±2 mm, or as otherwise achieved by precise levelling during baseline phase.	To be compiled and submitted to AC prior to the commencement of excavation.	Section 5.2.3
	Excavation dewatering (during construction)	Retaining wall survey pins shall be surveyed and recorded at: - An average of each 2 metres depth excavation, at a minimum of once weekly; or - When changes to the propping system are being carried out; and - At a minimum frequency of weekly intervals from the commencement of dewatering.		A record is to be maintained of the time, date and any observations for each survey, and submitted to AC at two monthly intervals.	
	Post-construction dewatering	Fortnightly			

3.2 Roles and responsibilities

The key management roles for each organisation in relation to groundwater and settlement management during the construction of the project are outlined in Table 3-3. Monitoring details and records shall be submitted to the Engineer by those indicated as responsible.

Table 3-3: Specific roles and responsibilities.

Organisation	Role	Responsibilities
Water Services Limited (Watercare)	Consent Holder and Project Manager	- Overall responsibility for project compliance and performance in relation to environment, quality assurance and incident management. - Obtaining new or altered consents required during construction (if any).
	Health and Safety Manager	- Compliance with Health & Safety and incident management.
Construction Contractor	Project Manager	- Overall responsibility for site management. - Review and adoption of the Construction and Environmental Management Plan (CEMP), including relevant sub-plans (e.g., this GSMCP).
	Environment and Sustainability Manager	- On-site compliance with consent conditions and other requirements and tracking compliance information. - Reviewing and reporting on environmental performance. - Inspection of works to assess compliance with the GSMCP including monitoring. - Implementation of the GSMCP including monitoring, interpretation and reporting. - Inspections, auditing and checking of environmental management practices and procedures. - Report to AC changes to construction techniques or natural environmental changes which require alterations to existing consents or new resource consents. - Prepare, review and update the overall Site Management Plan (CEMP) and relevant Sub-Plans (including GSMCP). - Facilitate and oversee environmental monitoring. Update and maintain the environmental portion of the Project Risk Register. - Training of all staff including subcontractors.
Subcontractors	Project and Site Engineers	- Development, management and procedures, including incorporating sustainability requirements. - Review and interpret monitoring observations and trends to the relevant members of the construction team. - Identify and respond to alert and manage contingency measures. - Overseeing subcontractors.
	Site Managers	- Adherence to the GSMCP
Independent	Asset Condition Engineer	- Undertake asset dilapidation surveys where exposed, by an independent suitably qualified Chartered Professional Engineer.

4 Proposed Groundwater Monitoring Plan

4.1 Introduction

Groundwater level monitoring of piezometers positioned near buildings/structures that may be affected will be conducted. The purpose of the groundwater monitoring is to confirm that water table changes are controlled to be within the set Alert and Alarm Levels.

It is proposed that groundwater levels are monitored at the locations presented in Table 4-1, to establish the initial baseline conditions, pre-excavation conditions with dewatering arrangement turned on and continue throughout and beyond the end of the construction process. This section of the proposed GSMCP presents the groundwater monitoring methodology including instrumentation types, trigger levels and recording and reporting requirements.

4.2 Monitoring Plan

The monitoring network will comprise new monitoring piezometers for Mayoral and Victoria shafts near the heritage buildings to assess whether the dewatering effects are within the estimated range of dewatering levels. Proposed locations are listed in Table 4-1 and shown on the monitoring plans in Appendix A. These locations have been chosen so that they are located within the construction support area for the Mayoral and Victoria shafts for ease of access and within the distance of maximum drawdown that may result in settlement effects on the heritage buildings. The existing shallow monitoring piezometer PZ06-S can be used for groundwater level monitoring of the Wellesley shaft. The existing data from the monitoring at this location can be used to define exact trigger levels.

Table 4-1. Proposed monitoring well details

Monitoring well ID	Potentially affected structure	Depth (m bgl)	Screened interval (m bgl)	Distance to shaft edge (m)
M_PZ01 (5 m from edge of shaft)	Auckland Sunday School Union Building (325 Queen St)	15	10-15	5
PZ06_S	Civic Theatre (corner of Queen Street and 269-287 Wellesley Street West)	8	5-8	11
V_PZ02 (5 m from edge of shaft)	John Court's Building (former), now Farmers	8	5-8	5

Exact locations are to be confirmed for each potentially affected location by the Contractor in consultation with WSP. Additional monitoring piezometers may be required during the course of the construction if excavations change from the proposed locations and dimensions. Should any of the monitoring bores be damaged and become in-operable during construction works, then AC is to be informed and a new monitoring bore is to be drilled at an appropriate nearby location.

4.3 Monitoring Methodology

It is proposed that groundwater levels are monitored using automatic pressure transducers set at 15-minute intervals. The specified monitoring frequency in Table 3-2 refers and is considered the minimum frequency (i.e., monitoring intervals should not be greater than 15-minutes and data downloads as specified for the different construction stages) at which the data is retrieved and processed. Telemetered systems that can relay monitoring data back to the office without having to go onsite to retrieve necessary data, should be considered. Telemetered systems can provide real time data at specified intervals for continuous surveillance and is optimal where space is limited and have the advantage of monitoring the loggers' operational status. All levels will be recorded to a minimum accuracy of +/-10 mm.

4.4 Groundwater Trigger Levels

Groundwater drawdown as a result of the project works has been modelled by WSP and is used to set the groundwater trigger levels. Only a single trigger level per monitoring point is proposed because the settlement itself will be measured and any mitigation or contingency will be based on those. The alert trigger will provide a flag that groundwater responses to the construction works are nearing estimated and that such groundwater responses may be close to having implications for surface settlement.

The trigger levels will be set as the lowest groundwater level considering seasonal variation, plus a dewatering drawdown as per Table 4-2. Confirmation of the exact groundwater trigger levels requires completion of the baseline readings and identification of the lowest seasonal groundwater level. The longer-term monitoring from the existing piezometers at the Mayoral (PZ01_S and PZ01_D) and Victoria (PZ09) shafts may be applicable to establish seasonal low if the data correlate well with the dedicated monitoring well water levels.

Table 4-2. Proposed alert groundwater levels for monitoring piezometers.

Monitoring well	Relative alert level (m RL)	Relative alert level (m bgl)	Comment
M_PZ01 (Mayoral)	Season low (m RL) – 2.0 m	Season low (m bgl) + 2.0 m	To verify groundwater drawdown does not exceed estimated drawdown at the Mayoral shaft. Drawdown level is based on the Best-Case scenario dewatering model (WSP, 2023). The existing monitoring piezometers are inside the shaft excavation and will be decommissioned.
PZ06_S (Wellesley)	Season low (m RL) – 2.0 m	Season low (m bgl) + 2.0 m	To verify groundwater drawdown does not exceed estimated drawdown at the Wellesley shaft. Drawdown level is based on the Best-Case scenario dewatering model (WSP, 2023).
V_PZ02 (Victoria)	Season low (m RL) – 3.0 m	Season low (m bgl) + 3.0 m	To verify groundwater drawdown does not exceed estimated drawdown at the Victoria shaft. Drawdown level is based on the Best-Base scenario dewatering model (WSP, 2023). The existing piezometer at Victoria shaft is too far away (16 m) from the shaft to provide meaningful drawdown monitoring.

If the Alert levels are reached, the actions outlined in Section 6 shall be carried out.

5 Proposed Settlement Monitoring Plan

5.1 Introduction

The settlement monitoring plan provides advanced warning that the ground behaviour is beginning to deviate from estimations and provides sufficient time for mitigation or rectification works to be identified and implemented.

The proposed settlement monitoring requirements are the minimum to be implemented and the Contractor must adapt/adopt and update the settlement monitoring plan as the works progress.

5.2 Monitoring Plan

The settlement monitoring will use visual inspections, ground movement and building markers, as well as retaining wall pins for monitoring the area around the shaft excavations. The proposed methodology is detailed below, but generally comprises the following:

- Pre-construction monitoring to determine existing conditions and baseline measurements.
- Monitoring during construction around active works areas at a higher frequency to determine actual ground movements and compare with assumptions as the works progress.
- Post-construction monitoring continued until potential ground movements have stabilised and no further potential for damage remains.

A set of preliminary plans showing the proposed location of monitoring points are included in Appendix A. These plans will be updated with as-built locations following installation of the monitoring points and their pre-construction survey.

5.2.1 Condition Surveys and Visual Inspections

Pre- and post-construction condition surveys will be undertaken on all assets (buildings, utilities, roads) determined to be susceptible to damage by the settlement assessment. During construction additional visual inspections shall be undertaken with additional condition surveys performed as required by this plan.

5.2.1.1 Methodology

The inspections and subsequent evaluations will be undertaken and reported on by a qualified chartered engineer and shall include:

- *For all inspections, approval from the asset owner shall be acquired.*
- *Type and arrangement of foundations.*
- *Condition of the existing asset including any pre-existing damage and the type of damage (e.g., aesthetic, serviceability impact).*
- *Susceptibility of the asset to further damage from ground movement.*
- *Review of proposed alarm and alert trigger levels to confirm they are appropriately set.*
- *Photographic evidence of the above.*

The sites to be surveyed are the heritage buildings near the Mayoral, Wellesley and Victoria shafts, as well as some other nearby buildings:

- *Auckland Sunday School Union Building at 323-327 Queen Street*
- *The Civic Theatre at the corner of Queen Street and 269-287 Wellesley Street West*
- *John Court's Building (former) at 210 Queen St*
- *329 Queen Street*

- *290 Queen Street*
- *205 Queen Street/20 Victoria Street West*
- *203a Queen Street.*

The proposed extent of the condition surveys is summarised in Table 5-1

Table 5-1: Extent of condition surveys for buildings.

Building type	Condition survey extent
Heritage and non-piled/shallow foundations: - Auckland Sunday School Union Building at 323-327 Queen Street - The Civic Theatre at the corner of Queen Street and 269-287 Wellesley Street West - John Court's Building (former) at 210 Queen St - 329 Queen Street	Condition survey - inside (if accessible) on the ground floor levels - outside on the ground floor level - on the building fronts facing the excavations.
Non-heritage and piled/deeper foundations: - 290 Queen Street - 205 Queen Street/20 Victoria Street West - 203a Queen Street.	Condition survey - outside on the ground floor level - on the building fronts facing the excavations.

Pre-construction

The details and photographs of the pre-construction condition surveys, as outlined above, shall be recorded and submitted to AC before the commencement of works. If access to the property cannot be reasonably obtained, this shall be reported to AC and an alternative monitoring option implemented for the duration of the project or until access can be obtained.

During construction

Visual inspections of the structure and surrounding ground of the assets identified in the pre-construction survey shall be performed if requested by the building or structure owner. Additional inspections may be required as part of the contingency measures associated with the ground movement trigger levels.

A record shall be kept of the visual inspections, including time and date, asset inspected, and any observations made. The result of the inspection shall be compared against the pre-construction condition surveys to determine if any damage has occurred.

Post-construction

A post-construction inspection will be completed for each asset at the later of either the completion of the project works or six to 12 months after completion of the dewatering/construction or as otherwise agreed with the owner. In addition to the details recorded in the pre-construction inspection, the survey should note whether any additional damage has occurred to the structure and the probable cause of such damage. If damage or other type of deterioration has occurred to any building or structure as a result of the construction works, remedial actions shall be taken immediately and in accordance with the GSMCP.

5.2.2 Ground surface and building monitoring

The purpose of the ground surface and building monitoring is to confirm that actual settlements are within the estimated settlement range, as a precautionary measure. Settlement estimations were within the negligible damage category. Trigger levels are based on the estimated settlements.

5.2.2.1 Methodology

Ground movement and building pins will be installed in all directions around the shaft excavations, at the approximate locations indicated on the plans in Appendix A for the Mayoral, Wellesley and Victoria Street shafts. The locations were selected as follows:

- *Movement pins on the sidewalk near the heritage buildings where the estimated settlement is highest, with at least two pins along the building fronts closest to the excavation to allow for differential settlement to be determined if required.*
- *Building pins on the heritage buildings near the excavation where the estimated settlement is highest, with at least two pins on the building fronts closest to the excavation to allow for differential settlement to be determined if required.*
- *Movement pins on the street corners away from the shaft, just off the roadside.*
- *The pins should be placed to allow for ease of access for pre and post construction monitoring.*

The location of monitoring pins has been updated based on the changes in shaft dimensions.

Pre-construction

Existing levels will be determined for each marker by at least three baseline surveys taken prior to any of the construction works commencing. The surveys shall record both the vertical and horizontal positions of the marker. Additional pre-construction monitoring may be required if any pre-existing ground movements are identified by the initial surveys. The existing levels will be recorded and submitted to AC for approval before beginning the works.

During construction

Markers at the shaft locations shall be surveyed once a week for one month immediately from the start of the construction. Thereafter, if there are three consecutive measurements where no or very little (<2 mm) movement is observed then monitoring can move to once a month for all ground and building settlement markers within 20 m of excavations during excavation. Alternatively, weekly measurements shall continue for another month.

The results of the surveys shall be recorded in a database and compared against the baseline levels. During excavation, and until movements have stabilised, AC shall be provided with the results of the daily monitoring and a summary report of the ground movement, with interpretation, in a monthly report.

Post-construction

Following completion of the construction works, surveying of the markers shall be continued monthly for three months or until the position of the pins is found to have stabilised and approval is given in writing by AC.

5.2.3 Shaft retaining structure monitoring

The purpose of the retaining structure monitoring is to confirm that actual movement deflections remain within the estimated range. Trigger levels are based on the estimated deflections.

The retaining wall pins will be installed along the panel walls closest to the heritage buildings, at the approximate locations indicated on the plans for the Mayoral, Wellesley and Victoria Street shafts in Appendix A.

5.2.3.1 Methodology

Monitoring can only be conducted once the panel and post retaining structure has been completed. Markers shall be surveyed weekly from the time that the temporary shafts have been completed, prior to the start of the tunnelling. The results of the surveys shall be recorded in a database and compared against the estimated levels. AC shall be provided with the results of the daily monitoring and a summary report of the ground movement, with interpretation, in a monthly report.

5.2.4 Monitoring of Utilities and Infrastructure

The shaft excavations will be undertaken in proximity to various existing underground services including water, wastewater, stormwater, electricity, gas and telecommunications. These services are constructed of different materials to various standards, at different depths and locations, and as such may have varying tolerances to deformation. Therefore, settlement trigger levels shall be based on the condition of the current asset and its tolerance to deformation. The asset owners shall be consulted to establish deformation tolerances of the given assets, and the associated monitoring requirements.

Prior to construction a pre-condition survey shall be undertaken on assets that are accessible. The survey may comprise a CCTV condition assessment for up to 30 m from the excavation, carried out by adequately qualified professional personnel, and shall include the following but are not limited to:

1 Existing levels of aesthetic damage.
2 Existing levels of serviceability damage.
3 Existing levels of structural damage.
4 Existing top of pipe RL (GPS).
5 Photographic/video evidence of (1), (2), and (3) above.

If the total or differential Alarm limits are reached during construction close to the pipe (less than 20 m), a post-construction survey will be done within six months of completion of construction activity covering the items detailed above.

A copy of the pre- and post-construction survey report shall be forwarded to AC within 15 working days of completing the reports along with a certificate from the Chartered Surveyor or Chartered Professional Engineer who has certified that the survey has been completed in a professional manner and is an accurate assessment of the condition of the structure concerned.

The proposed ground movement markers will be used for the underground services. If the trigger levels are exceeded, the actions outlined in Section 6 shall be carried out.

5.3 Monitoring trigger levels

Two trigger levels are set for all settlement monitoring points:

- Alert: Measured settlements are still within normal levels but are approaching those predicted (≥ 70%) in the settlement assessment. Alert levels for estimated settlement less than damage levels (10 mm) have been set to 70% of damage levels (i.e., 7 mm).
- Alarm: Measured settlements have reached those predicted. Alert levels for estimated settlement less than damage levels (10 mm) have been set to the damage levels (i.e., 10 mm).

Details of the trigger levels for all monitoring points are provided in Table 5-2 to Table 5-4. Note that these trigger levels are preliminary only and are to be revised following the installation of the monitoring points, the conditions surveys and following any changes in the design. Note that the estimated settlement for Mayoral and Victoria shafts is based on two and three sets of settlement

analysis, using different ground conditions for the heritage buildings hence the trigger levels differ with distance for the different scenarios.

Table 5-2: Mayoral shaft: Estimated settlement and trigger levels for monitoring locations.

Marker ID[1]	Distance to shaft edge (m)	Maximum estimated settlement (mm)	Trigger level (mm) - Ground		Trigger levels – differential settlement		Justification for marker locations
			Alert	Alarm	Alert	Alarm	
M-G1	5.3	6.7	7	10	1:1,000	1:700	Differential settlement monitoring with M-G3 – closer to 323-327 Queen St
M-G2	5	12	7	10	1:1,000	1:700	Ground settlement monitoring near northern corner of 323-327 Queen St
M-G3	8.5	<5	7	10	1:1,000	1:700	Differential settlement monitoring 329 Queen St.
M-G4	5.8	5	7	10			
M-G5	10	3.2	7	10	1:1,000	1:700	Differential settlement monitoring with M-G2.
M-G6	15.7	<5	7	10	1:1,000	1:700	Settlement monitoring on opposite side of shaft where groundwater heave is likely
Marker ID	**Distance to shaft edge (m)**	**Maximum estimated settlement (mm)**	**Trigger level (mm) - Building**		**Trigger levels – differential settlement**		**Justification for marker locations**
			Alert	Alarm	Alert	Alarm	
M-B1	5.9	6.7	7	10	1:1,000	1:700	Marker on the column of 323-327 Queen St as per s92 recommendation
M-B4	29	<2.2	7	10	1:1,000	1:700	Marker on the column of 323-327 Queen St as per s92 recommendation
M-B5	35	<2.2	7	10	1:1,000	1:700	Marker on the column of 323-327 Queen St as per s92 recommendation
M-B9	23	<2.2	7	10	1:1,000	1:700	New marker on the column of 323-327 Queen St as per s92 recommendation
M-B2	5.7	6.7	7	10	1:1,000	1:700	Markers to monitor differential settlement at 323-327 Queen St
M-B3	8.2	5	7	10			
M-B6	7.2	10	7	10	1:1,000	1:700	New marker added to assess differential settlement for building 329 Queen St
M-B8	10	3.2	7	10			
M-B7	15	2.2-3.2	7	10	1:1,000	1:700	Settlement monitoring at 329 Queen St

[1] The markers are denoted by prefix M for Mayoral shaft, W for Wellesley shaft, V for Victoria shaft, G for ground movement markers, B for building movement markers, and RW for retaining wall markers.

Marker ID	Distance to shaft edge (m)	Maximum estimated settlement (mm)	Trigger level (mm) – Retaining Wall		Trigger levels – differential settlement		Justification for marker locations
M-RW1	0	6	7	10	-	-	Retaining Wall markers moved to the middle of each retaining wall – M-RW4 newly added on the southern wall
M-RW2	0	6	7	10	-	-	
M-RW3	0	6	7	10	-	-	
M-RW4	0	6	7	10	-	-	

Table 5-3: Wellesley shaft: Estimated settlement and trigger levels for monitoring locations.

Marker ID	Distance to shaft edge	Maximum estimated settlement (mm)	Trigger level (mm) - Ground		Trigger levels – differential settlement		Justification for marker locations
			Alert	Alarm	Alert	Alarm	
W-G1	5	12	8	12	1:450	1:350	Differential settlement monitoring 290 Queen St – closest building to shaft
W-G2	10	8	7	10			
W-G3	5	12	8	12	1:450	1:350	Differential settlement monitoring 290 Queen St – closest building to shaft
W-G4	12	<8	7	10			
W-G5	17	<8	7	10	1:1,000	1:700	Settlement monitoring for 300 Queen St
W-G6	20	<8	7	10	1:1,000	1:700	Settlement monitoring for 265 Queen St
W-G7	30	<5	7	10	1:1,000	1:700	Settlement monitoring for heritage building at 269-287 Wellesley St
W-G8	29	<5	7	10	1:1,000	1:700	
W-G9	29	<5	7	10	1:1,000	1:700	Settlement monitoring for 265 Queen St
Marker ID	**Distance to shaft edge**	**Maximum estimated settlement (mm)**	**Trigger level (mm) - Building**		**Trigger levels – differential settlement**		**Justification for marker locations**
			Alert	**Alarm**	**Alert**	**Alarm**	
W-B1	11	8	7	10	1:1,000	1:700	Settlement monitoring heritage building at 290 Queen St
W-B3	20	5	7	10	1:1,000	1:700	
W-B2	10	8	7	10	1:1,000	1:700	Settlement monitoring heritage building at 290 Queen St
W-B4	20	5	7	10	1:1,000	1:700	
W-B5	40	2	7	10	1:1,000	1:700	Settlement monitoring heritage building at 269 Queen St
W-B6	40	2	7	10	1:1,000	1:700	
Marker ID	**Distance to shaft edge**	**Maximum estimated settlement (mm)**	**Trigger level (mm) – Retaining Wall**		**Trigger levels – differential settlement**		**Justification for marker locations**
W-RW1	0	11	8	11	-	-	Retaining Wall markers added to the middle of each retaining wall
W-RW2	0	11	8	11	-	-	
W-RW3	0	11	8	11	-	-	
W-RW4	0	11	8	11	-	-	

Table 5-4: Victoria shaft: Estimated settlement and trigger levels for monitoring locations

Marker ID	Distance to shaft edge	Maximum estimated settlement (mm)	Trigger level (mm) - Ground		Trigger levels – differential settlement		Justification for marker locations
			Alert	Alarm	Alert	Alarm	
V-G1[2]	6	20	14	20	1:1,000	1:700	Differential settlement monitoring 210 Queen St – John's Court heritage building
V-G3	10	17	12	17			
V-G2	5	20	14	20	1:1,000	1:700	Differential settlement monitoring 210 Queen St – John's Court heritage building
V-G4	10	17	12	17			
V-G5	9	17	12	17	1:1,000	1:700	Settlement monitoring for 214 Queen St
V-G6	20	13	9	13	1:1,000	1:700	Settlement monitoring for 205 Queen St
V-G7	19	13	9	13	1:1,000	1:700	Settlement monitoring for 203 Queen St
Marker ID	**Distance to shaft edge**	**Maximum estimated settlement (mm)**	**Trigger level (mm) - Building**		**Trigger levels – differential settlement**		**Justification for marker locations**
			Alert	**Alarm**	**Alert**	**Alarm**	
V-B1	7.5	11	7	10	1:1,000	1:700	Differential settlement monitoring at heritage building 210 Queen St
V-B3	10	8	7	10			
V-B2	7	8	7	10	1:1,000	1:700	Differential settlement monitoring at heritage building 210 Queen St
V-B4	10	11	7	10			
V-B5	20	6	7	10	1:1,000	1:700	Settlement monitoring heritage building at 210 Queen St
V-B6	20	6	7	10	1:1,000	1:700	
V-B7	33	11	7	10	1:1,000	1:700	Settlement monitoring at 205 Queen St
V-B8	34	11	7	10	1:1,000	1:700	
V-B9	32	11	7	10	1:1,000	1:700	Settlement monitoring at 203 Queen St
V-B10	30	11	7	10	1:1,000	1:700	
Marker ID	**Distance to shaft edge**	**Maximum estimated settlement (mm)**	**Trigger level (mm) – Retaining Wall**		**Trigger levels – differential settlement**		**Justification for marker locations**
V-RW1	0	6	7	10	-	-	Retaining Wall markers added to the middle of each retaining wall
V-RW2	0	6	7	10	-	-	
V-RW3	0	6	7	10	-	-	
V-RW4	0	6	7	10	-	-	

The following trigger levels are set for monitoring of infrastructure.

- Alert – total ground settlement measured at any ground marker exceeding 50 mm.
- Alarm – total ground settlement measured at any ground marker exceeding 70 mm.
- Alert – differential settlement calculated between two adjacent markers exceeding 1:300
- Alarm – calculated differential settlement between two adjacent markers exceeding 1:200.

[2] Trigger levels set for ground markers at Victoria shaft based on settlement at ground surface from settlement analysis for Victoria shaft west. Building markers based on settlement at foundation level of buildings.

6 Response, Mitigation and Contingency Plan

6.1 Groundwater

Dewatering of the excavations is expected and planned for as a part of the construction works. Groundwater monitoring will be used to confirm the groundwater levels are behaving as estimated in the modelling. Settlement monitoring will be used to determine the implementation of mitigation and contingency actions required to prevent asset damage, hence only an alert level for groundwater monitoring has been set.

The following actions will be taken:

- The Contractor will notify and advise the Engineer of any exceedance of the groundwater Alert trigger level within 24 hours. The notification will include an assessment of the risk of settlement and asset damage and proposed response actions.
- The frequency of groundwater reporting and settlement monitoring at the location of the exceedance will be increased to daily.

6.2 Settlement and Building Damage

The settlement monitoring will be used to confirm that any ground movement is within the expected estimation of effects (negligible). In the unlikely event that this envelope is exceeded, the response and mitigation measures, outlined in sections 6.2.1 to 6.2.3 below for each monitoring method will be implemented, as well as the following general responses as a minimum:

- The Contractor must notify and advise the Engineer of any exceedance of trigger levels within 24 hours. The notification will include an assessment of the risk of settlement and building damage and proposed response actions.
- An assessment of the potential for damage, or damage, will be undertaken by a qualified engineer and submitted with a methodology for mitigation of the settlement risk, or repair of the damage and timeframes.

6.2.1 Building Damage

The Assessment of Settlement Effects has not identified any buildings with building damage criteria greater than negligible, which is consistent with a less than minor effect. As such, damage to buildings is highly unlikely and not expected in this project. The shafts are in proximity to heritage buildings, and the building monitoring is essential to establish early warning systems against significant damage. Thus, if a building is found to have been damaged as a result of the construction works, either from a post-construction building survey or one requested during construction, AC will be immediately notified as per the above. Should building repairs be required, these will be undertaken at the cost of the consent holder as soon as practicable. The timing and extent of repairs may vary depending on the building owner's requirements.

6.2.2 Utility and Infrastructure Damage

If trigger levels, in particular differential settlement trigger levels are exceeded at monitoring points related to utilities or infrastructure, the Contractor will immediately notify the Engineer and the utility provider. A condition survey will be undertaken to determine the level and extent of any damage. Should the survey find that damage has occurred as a result of the construction works, the Contractor will notify the Engineer and propose a methodology to repair the damage and prevent further damage.

6.2.3 Settlement

The trigger levels for all monitoring locations provided within this plan are to be confirmed by the Contractor prior to taking possession of the Site. Trigger levels are based on the expected movements calculated in the design and do not necessarily imply potential for damage to occur if they are exceeded. These trigger levels are an initial estimate of effects and the Contractor may adopt more rigorous levels if needed by asset condition surveys or because of further developments or changes in the design. At least 10 working days prior to adopting any change in trigger levels the Contractor will submit to the Engineer the change in trigger levels for review.

Reponses to ground settlement depend on the level of trigger exceeded as follows.

“Alert” exceedance level means the ground behaviour is still within the design expectations but is approaching the estimated settlement. In the event of an alert exceedance the following steps shall be taken:

- Notify Council within 24 hours.
- Re-measure all monitoring stations within 20 m of the affected monitoring location to confirm the extent of apparent movement. Re-measure all these monitoring stations every two days until the written report has been submitted to Council.
- Submit a written report, prepared by the SQEP to the Council within five working days of the alert Level exceedance.
- Prepare to institute mitigation measures in consultation with the consultants. These may include measures to reduce dewatering, increase the stiffness of the support measures etc.

“Alarm” exceedance means the ground behaviour has now reached the estimated settlement and any further movement may be beyond the design limits; note that asset damage is still not expected at this level. In the event of an alarm exceedance the following steps shall be taken:

- Initiate a “stop work”.
- Notify the council within 24 hours of the Alarm Level exceedance and provide details of measurements taken.
- Implementation of all measures required for an alert exceedance if not already in place.
- The works will be assessed by a Chartered Professional Engineer to identify the reasons for the ground movements and reconsider the design assumptions.
- Undertake a condition survey by a SQEP or suitably qualified building surveyor or any building or structure located adjacent to any monitoring station where the Alarm Level has been exceeded.
- The Chartered Professional Engineer will recommend and oversee the implementation of mitigation measures such as additional ground support (e.g., additional struts or anchors and / or recharge wells) to reduce further movements and prevent asset damage. The engineer may also propose additional monitoring instrumentation be installed at the affected area.
- A report will be prepared by the Chartered Professional Engineer and submitted to the Engineer within one week of the alarm exceedance being identified. The report will include analysis of all relevant monitoring data and comparison with the initial design, details of the mitigation measures implemented and the estimated risk of further ground movements and of asset damage.
- Submit a written report, prepared by the SQEP, to the Council, on the results of the condition surveys, mitigation measures implemented and any remedial works and/or agreements with affected parties within five working days of recommencement of works.

7 GSMCP Review

The Contractor will review this plan at least quarterly or to reflect any material changes that occur throughout the course of the project in regard to site conditions, ground conditions or construction methodology. This plan and any reviews will be approved in accordance with the Contractors internal governance process. The reviews shall take into consideration:

- Compliance with resource consent conditions, the GSMCP and material changes to these plans;
- Any changes to construction methodology;
- Key changes to roles and responsibilities within the project;
- Changes in industry best practice standards;
- Results of monitoring and reporting procedures associated with the management of adverse effects during construction;
- Any comments or recommendations received from AC regarding the GSMCP;
- Any unresolved complaints and any response to the complaints and remedial action taken to address the complaint as required by the relevant resource consent conditions.
- All affected parties will be notified of the review and any material changes proposed. Any material change proposed shall also be subject to an independent peer review and will be submitted to the Engineer for review.

A copy of the operative GSMCP document and subsequent revisions will be kept for the Project Records and marked as obsolete. Each new/updated revision of the GSMCP documentation will be issued with a revision number and date to eliminate obsolete GSMCP documentation being used.

Appendix A
Monitoring Site Plans – Mayoral, Wellesley and Victoria shafts

PROJECT

Watercare Services Limited
Auckland
Queen Street Wastewater Diversion - Part 3

WSP Auckland
Level 3, The Westhaven
100 Beaumont Street
Auckland 1010
+64 9 353 7375

FIGURE

Mayoral shaft - GSMCP monitoring locations and layout

PROJECT NUMBER	REVISION DATE	REVISION
W-SL001.03	10 July 2024	R1

ATTRIBUTION

LEGEND

LEGEND
- Proposed monitoring piezometer

Settlement monitoring
- Ground movement markers
- Building movement markers
- Retaining wall pins

Part 3 Alignment
- Pipeline
- Mayoral Shaft

P3-P4 connector
- P3-P4 pipeline
- Greys shaft

AC Geomaps Underground Services
- Water Pipe
- Stormwater Pipe
- Building Footprints_polygon
- Heritage

SCALE

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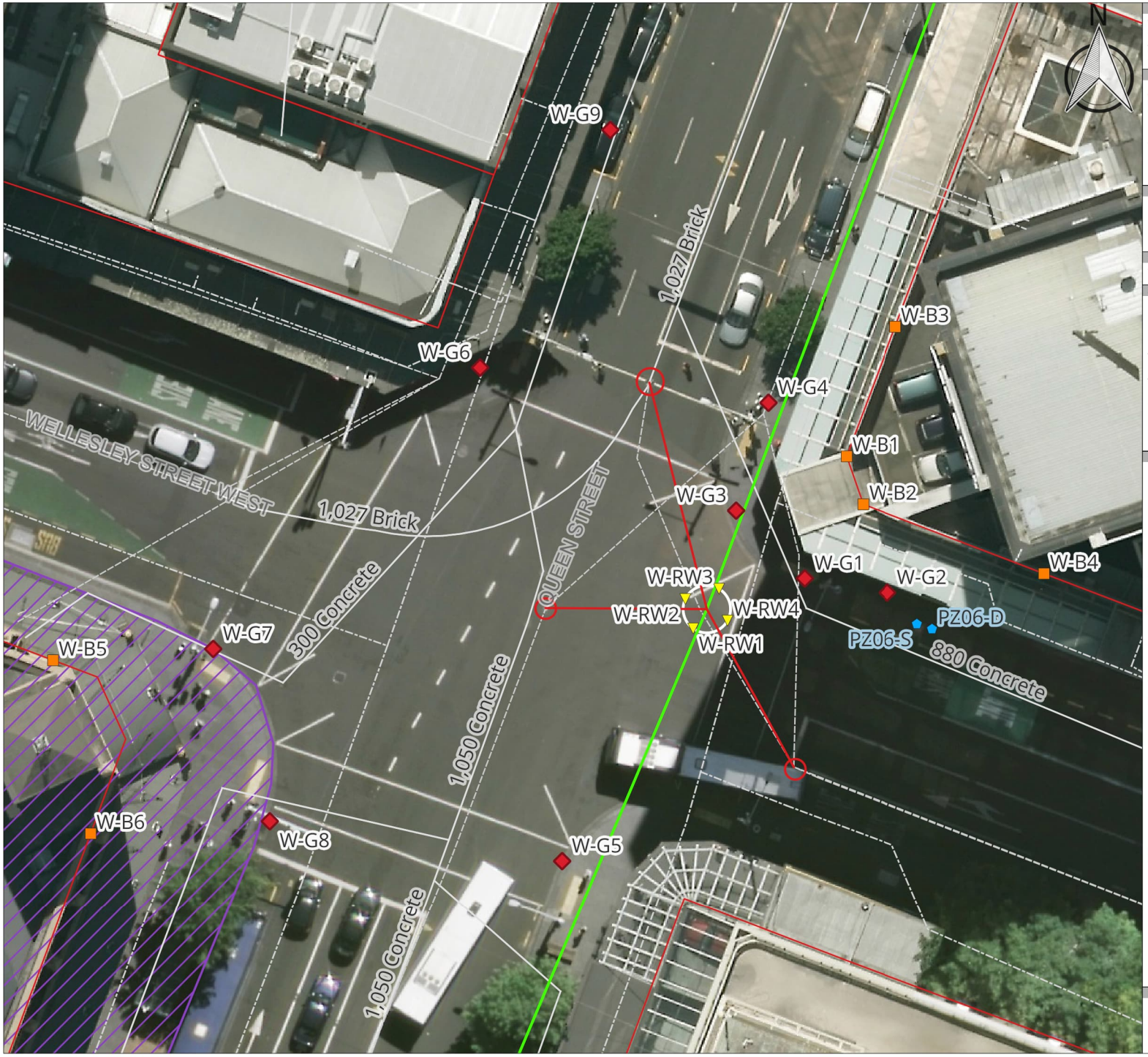

PROJECT

Watercare Services Limited
Auckland
Queen Street Wastewater Diversion - Part 3

WSP Auckland
Level 3, The Westhaven
100 Beaumont Street
Auckland 1010
+64 9 353 7375

FIGURE

Wellesley shaft - GSMCP monitoring locations and layout

PROJECT NUMBER	REVISION DATE	REVISION
W-SL001.03	10 July 2024	R1

ATTRIBUTION

LEGEND

LEGEND
- Piezometers

Settlement monitoring
- Ground movement markers
- Building movement markers
- Retaining wall pins

Part 3 Alignment
- EOP
- Pipeline
- Wellesley shaft

AC Geomaps Underground Services
- Water Pipe
- Wastewater Pipe
- Stormwater Pipe
- Building Footprints_polygon
- Heritage

SCALE

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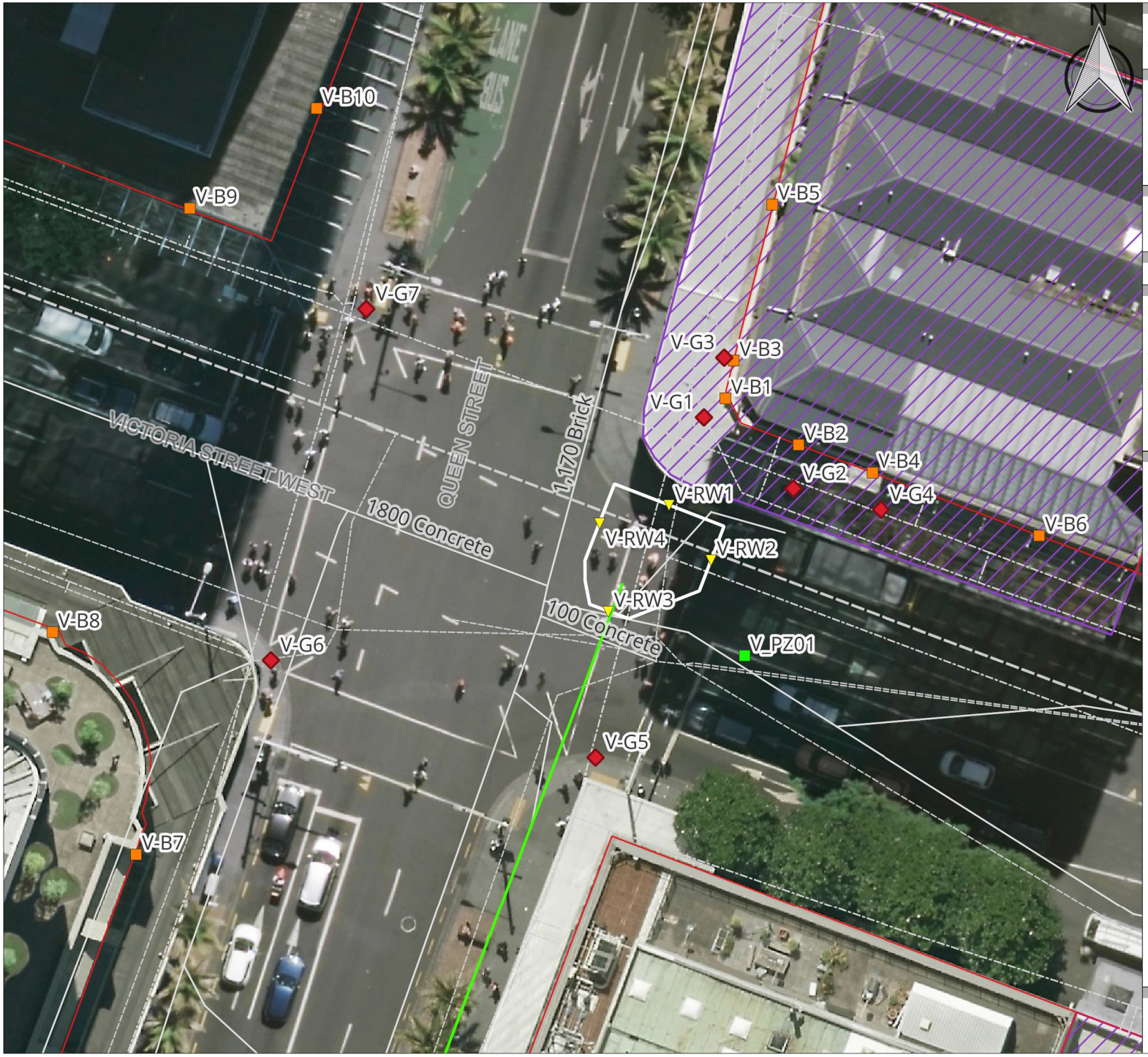

PROJECT

Watercare Services Limited
Auckland
Queen Street Wastewater Diversion - Part 3

WSP Auckland

Level 3, The Westhaven
100 Beaumont Street
Auckland 1010

+64 9 353 7375

FIGURE

Victoria shaft - GSMCP monitoring locations and layout

PROJECT NUMBER	REVISION DATE	REVISION
W-SL001.03	10 July 2024	R1

ATTRIBUTION

LEGEND

LEGEND

- Proposed monitoring piezometer

Settlement monitoring

- Ground movement markers
- Building movement markers
- Retaining wall pins

Part 3 Alignment

- Pipeline

AC Geomaps Underground Services

- Water Pipe
- Wastewater Pipe
- Stormwater Pipe
- Building Footprints_polygon
- Heritage

SCALE

0 10 20 m

wsp

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