

GROUNDWATER AND GEOLOGY

CHAPTER SEVENTEEN

17 Groundwater and geology

This chapter provides an assessment of the potential impact on groundwater as a result of the project, and identifies mitigation measures to address these impacts. This chapter draws on information in Technical paper 7 – Groundwater.

17.1 Secretary’s environmental assessment requirements

The Secretary’s environmental assessment requirements relating to groundwater, and where these requirements are addressed in this Environmental Impact Statement, are outlined in Table 17-1.

Table 17-1 Secretary’s environmental assessment requirements – groundwater and geology

Ref.	Secretary’s environmental assessment requirements	Where addressed
17. Water- Hydrology		
17.1	The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the Framework for Biodiversity Assessment.	The existing hydrological regime is described in Section 17.3.
17.2	The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	Impacts associated with hydrology are addressed in Section 17.4.
17.2(a)	natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	Water quality impacts are addressed in Chapter 18 (Soils, contamination and water quality). Aquatic ecology is addressed in Chapter 20 (Biodiversity).
17.2(b)	impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Groundwater impacts are addressed in Section 17.4. Groundwater dependent ecosystems area addressed in Chapter 20 (Biodiversity).
17.2(c)	changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	Water quality impacts are addressed in Chapter 18 (Soils, contamination and water quality).
17.2(d)	direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Impacts associated with soils are addressed in Chapter 18 (Soils, contamination and water quality).
17.2(e)	minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	Hydrology is addressed in Chapter 21 (Flooding and hydrology).
17.2(f)	water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	Groundwater impacts are addressed in Section 17.4. Resource use is addressed in Chapter 25 (Sustainability).

Ref.	Secretary's environmental assessment requirements	Where addressed
17.3	The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Hydrology is addressed in Chapter 21 (Flooding and hydrology).
10. Socio-economic, Land Use and Property		
10.3	Assess the likely risks of the project to public safety, paying particular attention to subsidence risks, bushfire risks and the handling and use of dangerous goods.	Subsidence and settlement risk is addressed in Section 17.4.

17.2 Assessment methodology

The assessment of potential groundwater impacts involved a consideration of the existing hydrogeological environment and the effects of the project on that environment. The assessment specifically included:

- Development of a conceptual model of the hydrogeological environment with reference to geological characteristics (including rock types, permeability and storage) and available data for groundwater levels, quality and yield; existing groundwater users and extraction rates were also considered
- Establishment of expected (or target) changes to groundwater level, flow and quality with reference to the project design, estimated groundwater inflow rates and groundwater treatment strategies during both construction and operation.

The assessment then considered the potential impacts due to the expected changes to groundwater level, flow and quality on surrounding land uses, other groundwater users, and surface water / groundwater interaction. The assessment made reference to:

- Minimal harm criteria presented in the *NSW Aquifer Interference Policy* (NSW Office of Water, 2012)
- Rules of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*.

The effects of ground movement on nearby structures, either due to excavation or ground consolidation following groundwater drawdown, were also considered. This involved a screening level of assessment using accepted criteria to identify those locations where more detailed future assessment is needed.

17.3 Existing environment

17.3.1 Geological context

The project area traverses seven regional geological units identified by the *Sydney 1:100,000 Geological Sheet 9130* (Herbert, 1983). Table 17-2 presents the regional geology while Figure 17-1 shows the location of surface geological units along the project alignment. The conceptual hydrogeological model discussed later in this section includes a geological long section showing a graphical representation of the geology at different depths along the project alignment. The geological long section is provided in Appendix F.

Table 17-2 Regional geology along the project alignment

Geological unit	Description
Fill	Reclaimed areas generally adjacent to Sydney Harbour and some parklands
Holocene alluvium	Normally consolidated sediments
Pleistocene alluvium	Over-consolidated sediments (often sandy clays)
Residual soil	Derived from completely weathered siltstone and sandstone
Ashfield Shale	Black to dark-grey shale and laminite
Mittagong Formation	Interbedded shale, laminite and medium-grained quartz sandstone
Hawkesbury Sandstone	Medium to coarse-grained quartz sandstone

The proposed metro tunnels would primarily transition through Hawkesbury Sandstone with some sections of Ashfield Shale and Mittagong Formation. For a small part of the Sydney Harbour crossing, the tunnels would pass through fluvial / marine clayey-silty and clayey-sandy sediments.

The geological context for each construction site is described below (refer also to the geological long section in Appendix F):

- Chatswood dive site – residual soils and fill with underlying Ashfield Shale; Mittagong Formation and Hawkesbury Sandstone are below the level of the dive structure
- Artarmon substation – Ashfield Shale, Mittagong Formation and Hawkesbury Sandstone
- Crows Nest Station – fill, residual soils, Ashfield Shale, Mittagong Formation and then Hawkesbury Sandstone
- Victoria Cross Station – Hawkesbury Sandstone
- Blues Point temporary site – excavation through Hawkesbury Sandstone, with backfilling of the shaft following the completion of retrieval activities
- Barangaroo Station – extensive near surface fill and Hawkesbury Sandstone
- Martin Place Station – fill, residual soil and Hawkesbury Sandstone
- Pitt Street Station – fill, residual soil, Mittagong Formation and Hawkesbury Sandstone
- Central Station – fill, residual soil, Ashfield Shale, Mittagong Formation and Hawkesbury Sandstone
- Waterloo Station – fill, alluvium, residual soils, Ashfield Shale and Hawkesbury Sandstone
- Marrickville dive site (southern) – variable depths of fill, alluvium, residual soils and then Ashfield Shale.

In contrast to alluvium, the permeability of shale, siltstone and sandstone is generally low to very low, with the majority of groundwater flow transmitted through joints and fractures rather than via the porous nature of the material.

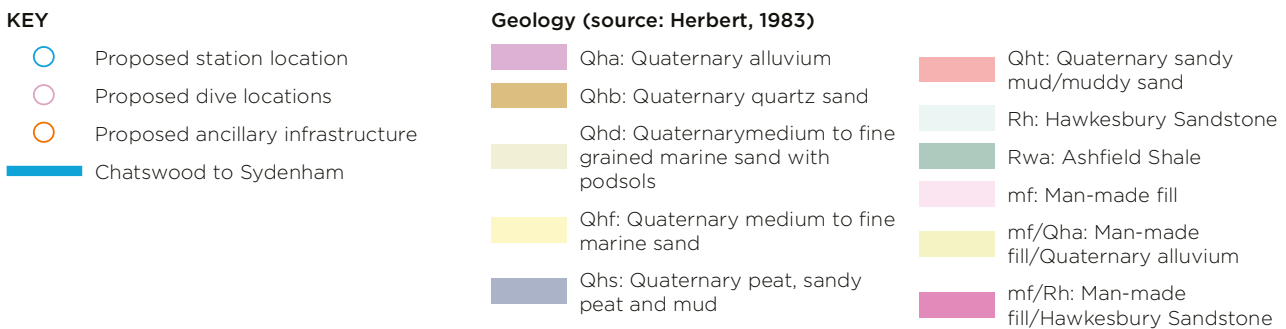
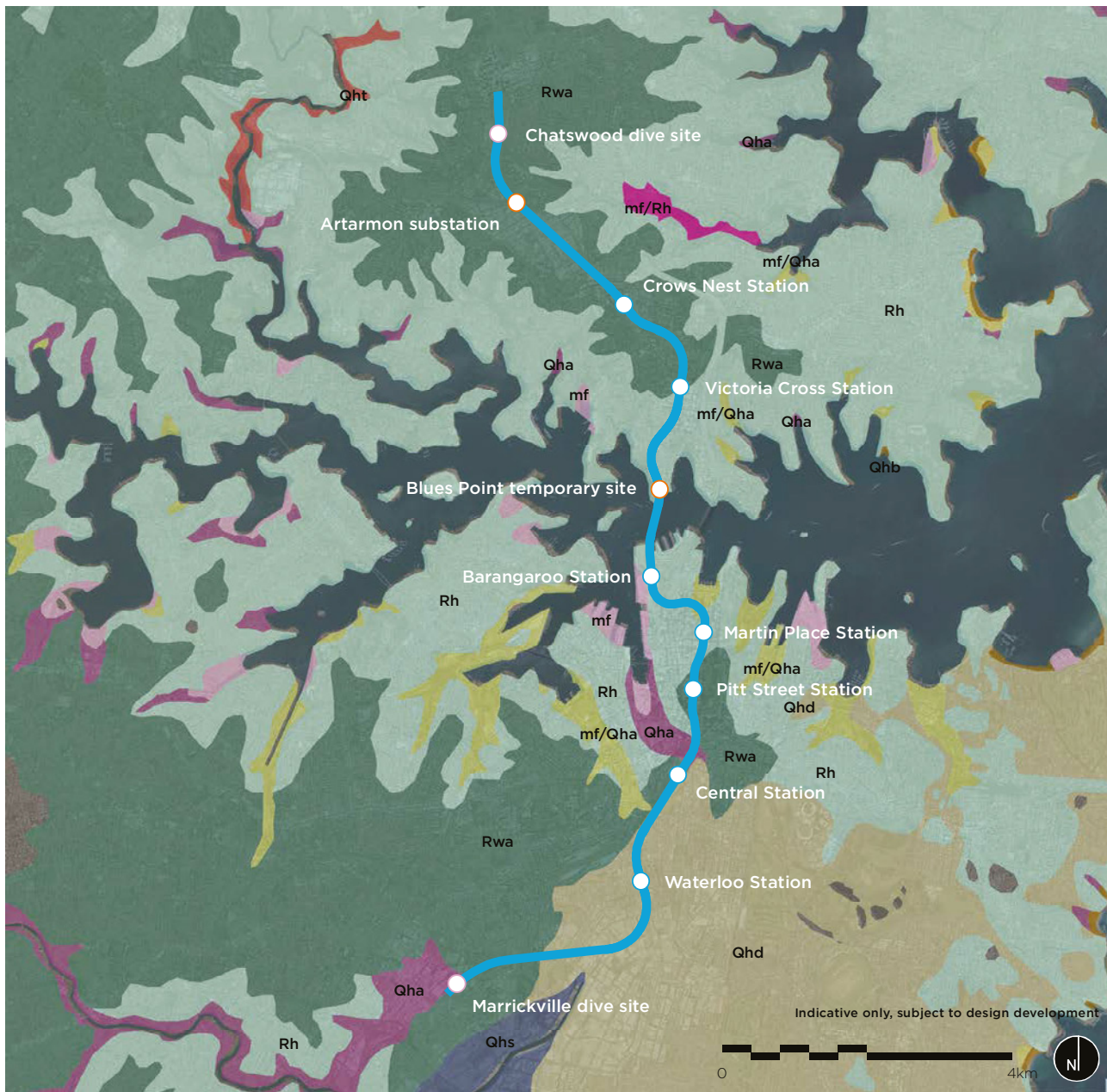


Figure 17-1 Regional geology

17.3.2 Groundwater

Groundwater levels

The groundwater level along most of the project alignment is between 10 to 30 metres below ground level. Local shallow groundwater within residual soils is anticipated at two to five metres below ground level. A detailed review of data on groundwater levels along the project alignment is included in Technical paper 7 – Groundwater.

Groundwater quality

Groundwater that flows into existing underground structures in Sydney is generally high in iron, may contain manganese, may contain contaminants, has a relatively high salinity (as total dissolved salts) and a slightly acidic pH. Typical characteristics from existing tunnel projects in Sydney include:

- Energy Australia cable tunnel – iron 110 milligrams per litre; total dissolved solids 10,000 milligrams per litre; pH 5.9
- Sydney Harbour Tunnel – iron 40 milligrams per litre
- Epping to Chatswood Railway – iron 90 milligrams per litre; total dissolved solids 1300 milligrams per litre average to 6000 milligrams per litre; pH 5.9
- Cross City Tunnel – iron 50 milligrams per litre.

Groundwater is expected to be brackish within Ashfield Shale with neutral pH. Groundwater within Mittagong Formation and Hawkesbury Sandstone is expected to be fresh to brackish with neutral pH and slightly elevated levels of iron and manganese. The concentration of dissolved metals and nutrients in the Ashfield Shale, Mittagong Formation and Hawkesbury Sandstone, including residual soils, is expected to be naturally very low. Organic compounds are not naturally associated with Ashfield Shale, Mittagong Formation or Hawkesbury Sandstone.

Salinity of groundwater in the Ashfield Shale ranges between 269 and 493 milligrams per litre as total dissolved solids and pH ranges between 4.9 and 5.1. Groundwater quality testing conducted as part of the design process has found the Ashfield Shale to be fresher than expected, presumably reflecting leaching of salts from the formation.

Salinity of the Mittagong Formation ranges between 265 to 350 milligrams per litre as total dissolved solids and pH ranges between 4.7 and 5.6. Groundwater quality testing for the Mittagong Formation has also found it to be fresher than is expected, with pH slightly more acidic.

Salinity in the Hawkesbury Sandstone ranges between 147 and 574 milligrams per litre as total dissolved solids, while pH is near-neutral and ranges between 5.2 and 6.8. Groundwater quality testing for Hawkesbury Sandstone has found it to be fresher than is expected.

Default water quality trigger criteria for freshwater and marine ecosystems are provided in *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000a). Measured groundwater quality, with the exception of pH, meets the ANZECC 95th percentile default trigger values for marine environments, with treatment (minor) required to meet ANZECC 95th percentile default trigger values for freshwater in relation to pH.

Groundwater users and extraction

There is limited groundwater use near the project alignment due to the presence of low permeability shale, siltstone and sandstone. A search of the NSW Water Register was carried out to identify existing users and extraction rates. The search identified four sites where there is an approval as Basic Rights to extract groundwater, and therefore do not need a Water Access Licence. The expected take, as a basic right, is minor and is presumed to be less than one megalitre per year.

There are also two sites that hold Water Access Licences; both are located in the adjacent Botany Sands Groundwater Source. The remaining groundwater extraction sites do not hold a Water Supply Work Approval and therefore are assumed to be inactive and not taking groundwater. Table 17-3 summarises the NSW Water Register search results.

Table 17-3 Groundwater users and extraction

Location	ID	Approval type	Work type	Estimated extraction	Approx distance to excavation
Chatswood Oval	GW107757	Water Supply Work, Inactive	Bore	N/A	275 m
	GW029731	Water Supply Work, Inactive	Bore	N/A	215 m
St Leonards TAFE	GW072478	Basic Rights (Domestic), Inactive	-	N/A	265 m
Private Well near St Leonards Station	GW108224	Basic Rights (Domestic)	Bore	<1 ML/y	330 m
Shore School	GW107764	Basic Rights (Domestic)	Collector system	<1 ML/y	60 m
Redfern Park	GW071907	Water Supply Work	Bore	12 ML/y	440 m
Private Spear near Waterloo Station	GW106192	Basic Rights (Domestic)	Spearpoint	<1 ML/y	140 m
Industrial Water Supply, Bourke Road	GW017342 GW017684	Water Supply Work, Inactive	Bore	N/A	N/A
Erskineville Oval	GW110351	Water Supply Work	Bore	10 ML/y	445 m
Private Spear in Alexandria	GW111164	Basic Rights (Domestic)	Spearpoint	<1 ML/y	70 m

Groundwater inflows to existing tunnels

Measured inflows in existing drained tunnels in Sydney are summarised in Table 17-4 and indicate that that long term inflow into ‘drained’ tunnels is one litre per second per kilometre (consistent with applicable approval conditions) and typical design standards.

Table 17-4 Measured inflows in existing Sydney tunnels

Project tunnel	Length (km)	Diameter (m)	Maximum rock cover (m)	Dominant rock type	Measured inflow (L/s/km)
Northside storage	20	6	90	Hawkesbury Sandstone	0.9
Epping to Chatswood Rail Line	13	7.2 (twin)	60	Hawkesbury Sandstone	0.9
M5 East	3.9	8 (twin)	4 to 60	Hawkesbury Sandstone	0.8
Eastern Distributor	1.7	12 (double deck)	40	Hawkesbury Sandstone	1.0
MetroGrid	3.5	2	10 to 40	Narrabeen Group	0.8
Cross City Tunnel	2.1	8 (twin)	53	Hawkesbury Sandstone	<3
Lane Cove Tunnel	3.6	9 (twin)	60	Hawkesbury Sandstone	<3

Conceptual hydrogeological model

A conceptual hydrological model is a mostly qualitative and often pictorial description of a project in the context of the groundwater system, including groundwater levels, quality, inputs / outputs and a description of the soils and rocks and their properties. A conceptual model allows the effect of newly introduced changes to the hydrogeological system to be understood and assessed. It also allows consideration of whether a more detailed numerical modelling is necessary. The key elements of the conceptual hydrological model for the project are described in the preceding sections and are shown graphically in Technical paper 7 – Groundwater.

17.4 Potential impacts

17.4.1 Changes to groundwater levels

The metro tunnels would be tanked (designed to inhibit the inflow of groundwater, typically using concrete lining and waterproofing membrane), so limited to negligible change is expected to groundwater levels as a result of their construction.

Cross passages, mined station caverns, and the Artarmon substation would be tanked. There is no change expected to groundwater levels associated with these elements.

Cut-and-cover stations, with the exception of Barangaroo and Waterloo, would be drained structures and would have an ongoing inflow of groundwater.

There is also the potential for off-site impact at station excavations during construction. The target changes are presented in Table 17-5. The target changes to groundwater levels generally aim to keep the project related changes to within natural variation of groundwater level encountered in the past. They were determined as follows:

- The two metre drawdown criteria from the *NSW Aquifer Interference Policy* (NSW Office of Water, 2012) (which applies, cumulatively, at nearby water supply works) was adopted as a general guide for changes at surrounding land uses
- Recognising that the contribution of drawdown to subsidence in hard rock is minor to negligible, a four metre drawdown was allocated to project activity at depth
- Where masonry structures (rather than slab on ground structures) are located near to the station shafts, a 0.5 metre drawdown target was adopted for residual soils and a one metre target was adopted for Ashfield Shale and Mittagong Formation. For nearby commercial premises or high rise residential premises (which will have foundations to competent rock) the adopted target changes are less conservative (four metres).

Table 17-5 Target change to groundwater level at surrounding land uses

Location	Design	Target Change (metres)
Chatswood dive site (northern)	Piled retained wall, drained	<0.5 (residual soil), <2.0 (Ashfield Shale)
	Tunnels with segmental lining	<4.0 (assuming deep foundations), otherwise <2.0
Artarmon substation	Shaft (assumed drained)	<0.5 (residential in the vicinity)
Crows Nest Station	Drained station shaft	<1.0 (residual soil), <2.0 (Ashfield Shale and Mittagong Formation)
	Drained station	<2.0 (Mittagong Formation)
	Tunnels with segmental lining	<2.0 (Hawkesbury Sandstone)
Victoria Cross Station	Drained station shaft	<1.0 (residual soil), <4.0 (assuming deep foundations), otherwise <2.0
	Tanked station cavern	<1.0 (residual soil), <4.0 (assuming deep foundations), otherwise <2.0
	Tunnels with segmental lining	<1.0 (residual soil), <4.0 (assuming deep foundations), otherwise <2.0
Blues Point temporary site	Drained shaft during construction, backfilled following construction.	<0.5 (residual soil), <2.0 (Hawkesbury Sandstone)
Harbour crossing	Tunnels with segmental lining.	N/A (no change presented since, by design, groundwater inflow must be negligible)
Barangaroo Station	Tanked station shaft	<1.0 (residual soil), <2.0 (Hawkesbury Sandstone)
	Tanked station cavern	<2.0 (residential in the vicinity)
	Tunnels with segmental lining	<2.0 (residential in the vicinity)
Martin Place Station	Drained station shaft	<1.0 (residual soil), <4.0 (assuming deep foundations), otherwise <2.0
	Tanked station cavern	<4.0 (assuming deep foundations), otherwise <2.0
	Tunnels with segmental lining	<4.0 (assuming deep foundations), otherwise <2.0
Pitt Street Station	Drained station shaft	<1.0 (residual soil), <2.0 (Mittagong Formation), <4.0 (assuming deep foundations), otherwise <2.0 (Hawkesbury Sandstone)
	Tanked station cavern	<4.0 (assuming deep foundations), otherwise <2.0
	Tunnels with segmental lining	<4.0 (assuming deep foundations), otherwise <2.0
Central Station	Drained station shaft	<1.0 (residual soil), <2.0 (residential in the vicinity) (Mittagong Formation, Hawkesbury Sandstone)
	Drained station cavern	<2.0 (residential in the vicinity)
	Tunnels with segmental lining	<2.0 (residential in the vicinity)
Waterloo Station	Tanked station cavern	<0.5 (fill / Aeolian sand), <2.0 (Ashfield Shale), <2.0 (residential in the vicinity) (Hawkesbury Sandstone)
Marrickville dive site (southern)	Piled retained wall, drained	<0.5 (residual soil), <2.0 (due to stormwater channel)

Project related excavation would be located at a sufficient distance from groundwater users and, therefore, no change in groundwater level is expected at these extraction sites.

17.4.2 Ground movement

Ground movement (or settlement) refers to a localised lowering of the ground level due to construction activities. It can affect nearby buildings and other structures. Movement typically results from either the release or redistribution of stress in rock formations during tunnelling and excavation, or from ground consolidation following the drawdown of groundwater (during construction and / or operation). Movement caused by stress redistribution in rock generally occurs shortly after excavation, while consolidation settlement from groundwater drawdown can occur over a longer period of time.

For the project, a majority of the underground excavation would be within rock that has low permeability, and it is therefore expected that settlement associated with groundwater drawdown would be minimal. Some settlement could occur as a result of groundwater drawdown associated with open excavations and this would be greatest in soft superficial surface deposits, if the perched water table is lowered. The tunnels and many other project elements are designed as tanked structures (refer to Table 17-5) and, therefore, long-term settlement effects associated with groundwater drawdown are not anticipated at most locations.

The specific risk to buildings and structures due to ground movement depends on geotechnical conditions, distance from construction activities and building characteristics including condition and type of masonry. However, for the purposes of a screening assessment the risk-based criteria in Table 17-6 have been used (Construction Industry Research and Information Association, 1996). These criteria specify the maximum settlement of the building and the maximum slope of the ground below building foundations for each risk level. Buildings and structures assessed as having a risk level of two or greater would be subject to more detailed building strain and potentially a structural assessment later in the design process.

Table 17-6 Ground movement risk levels

Risk Level	Description	Maximum slope of building	Maximum settlement of building (mm)
1	Negligible – superficial damage unlikely	<1:500	<10
2	Slight – possible superficial damage which is unlikely to have structural significance	1:500 to 1:200	10 to 50
3	Moderate – expected superficial damage and possible structural damage to buildings, and possible damage to relatively rigid pipelines	1:200 to 1:50	50 to 75
4	High – expected structural damage to buildings, expected damage to rigid pipelines, and possible damage to other pipelines	>1:50	>75

The assessment of potential ground movement included consideration of the following construction activities:

- Tunnelling
- Mining (station caverns and adits, ventilation caverns and cross passages)
- Open-cut and trough excavation from the surface using conventional excavation techniques (station excavations, ventilation shafts and dive sites).

For the whole of the project alignment, three millimetre, five millimetre and ten millimetre ground movement contours were developed. The three millimetre contour defines what is considered to be the extent of the project's influence, while the ten millimetre contour defines the point at which more detailed future assessment is required as per Table 17-6. Most of the project alignment falls within the three millimetre contour and is therefore considered to have a negligible ground movement risk, with superficial damage to buildings unlikely. Small areas at station sites and dive sites are within the ten millimetre contour and may require future building strain and structural assessment to address settlement related risks.

17.4.3 Groundwater inflows

Groundwater inflows were estimated as part of the design process. The inflow rates in Table 17-7 provide indicative maximum construction related dewatering estimates (after initial works) as well as maximum operational inflows that may be expected (with drained project elements). Actual inflows would be lower with many project elements proposed to be tanked.

The annual inflow from the Sydney Basin Central Groundwater Source has been conservatively estimated (assuming drained conditions for all project elements) at 372 megalitres per year.

Table 17-7 Estimated groundwater inflows along the project alignment

Location	Predicted maximum inflow (litres/s)
Crows Nest Station	0.12
Victoria Cross Station	0.78
Barangaroo Station	2.86
Martin Place Station	1.97
Pitt Street Station	2.86
Central Station	0.03 (excluding existing seepage)
Waterloo Station	2.86
Tunnels and cross passages	0.319
Total (litres/s)	11.8 ¹

¹ To determine the capacity of the water treatment plant a maximum permissible inflow of 12.5 litres per second has been assumed consistent with Metro Northwest, with a further 2.5 litres per second allowance for additional volumes of water (for example water used fire suppression).

17.4.4 Groundwater quality management

During construction, collected groundwater (and other tunnel water) would be treated at temporary water treatment plants at tunnel boring machine support sites (Chatswood, Barangaroo and Marrickville dive sites) and it is likely that temporary water treatment plant would be deployed at each station excavation and service facility prior to disposal of the treated groundwater to stormwater. Tunnelling using tunnel boring machines and roadheaders is unlikely to cause flows into the water table and therefore contamination of groundwater is not expected.

The quality of this discharged water during construction and operation is considered in Chapter 18 (Soils, contamination and water quality). During construction, groundwater inflows would be treated to meet the requirements of an environmental protection licence issued to the project, which are anticipated to be:

- pH – 6.5 to 8.5
- Total suspended liquids – less than 50 milligrams per litre
- Oil and grease – none visible.

During operation, groundwater collected from drained station excavations and caverns would be transferred to a centralised water treatment plant prior to disposal to stormwater. For operation, the project would be designed to achieve a maximum water discharge quality equivalent to the 90 percent protection level specified for freshwater ecosystems in accordance with ANZECC guidelines (ANZECC / ARMCANZ, 2000a). The discharge water quality level would be determined in consultation with the NSW Environment Protection Authority during detailed design, taking into consideration the current water quality of the receiving watercourse.

17.4.5 Interaction between surface water and groundwater

From the Chatswood dive site to Sydney Harbour, the alignment of the project would generally coincide with the topographic ridgeline. Aside from local shallow water tables within residual soils, the groundwater level within the Mittagong Formation and Hawkesbury Sandstone is expected to be encountered at depth. Therefore, interaction between surface water and groundwater is not expected.

For the Sydney Harbour crossing, segmental lining of the metro tunnels would prevent interaction between surface water and groundwater.

Between the harbour crossing and Central Station, the alignment would be essentially north-south and parallel to the topographic ridgeline after slewing eastward from Barangaroo Station to Martin Place. Interaction between surface water and groundwater is not expected at Barangaroo, Martin Place, Pitt Street and Central Station. All stormwater would be diverted around station excavations to prevent ingress to tunnels. Due to the proximity of Barangaroo to Sydney Harbour and the presence of remediated land, Barangaroo Station would be a tanked structure to prevent groundwater inflows. Similarly, Waterloo Station would be a tanked structure and would prevent groundwater inflows.

The Marrickville dive site is located adjacent to an existing lined stormwater channel and, accordingly, there is no anticipated interaction between surface water and groundwater at this location as surface water infiltration would be minimal.

17.4.6 Consistency with minimum harm criteria

The *Water Management Act 2000* includes the concept of ensuring ‘no more than minimal harm’ for both the granting of water access licences and the granting of approvals. While the project does not require a licence / approval under the *Water Management Act*, the minimal harm criteria in the *NSW Aquifer Interference Policy* (NSW Office of Water, 2012) have been used for the purposes of assessment (refer to Table 17-8).

Table 17-8 Minimal harm assessment

Minimal harm consideration	Assessment
Water table	
<p>Less than or equal to a 10 per cent cumulative variation in the water table, allowing for typical climatic ‘post-water sharing plan’ variations, 40 metres from any:</p> <p>High priority groundwater dependent ecosystem or High priority culturally significant site listed in the schedule of the relevant water sharing plan.</p> <p>OR</p> <p>A maximum of a two metre water table decline cumulatively at any water supply work.</p>	<p>There are no high priority groundwater dependent ecosystems or high priority culturally significant sites in the vicinity of the project.</p> <p>The expected project related drawdown, cumulative, at any water supply work, is less than a two metres.</p>
Water pressure	
<p>A cumulative pressure head decline of not more than a two metre decline, at any water supply work.</p>	<p>The expected decline in groundwater elevation due to the project would be less than a two metres at any water supply work.</p>
Water quality	
<p>Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity</p>	<p>The project, due to groundwater inflows being captured and discharged, whether locally during construction or transmitted to centralised water treatment plant during operation, would not change groundwater quality beyond 40 metres from the activity.</p>

17.4.7 Consistency with Water Sharing Plan rules

The *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* provides rules for granting access licences, managing access licences, water supply works approvals and access licence dealings. While the project does not require a licence and / or approval under the *Water Management Act 2000*, these rules have been used for the purposes of assessment (refer to Table 17-9).

Table 17-9 Compliance with Water Sharing Plan rules

Rule	Assessment
Part 9 – 39: Distance restrictions to minimise interference between water supply works-	
Distance restriction from an approved water supply work nominated by another access licence is 400 metres	There are no water supply works nominated by another access licence within 400 metres of a project excavation.
Distance restriction from an approved water supply work for basic landholder rights only is 100 metres	There is a spear point adjacent Waterloo Station, however, this is more than the 100-metre distance restriction. The spear point is installed into the Botany Sands Groundwater Source and it is expected that the station excavation at Waterloo would hydraulically isolate this water source from the station excavation.
Distance restriction from the property boundary is 50 metres	The station excavations would not comply with the 50-metre distance restriction with respect to property boundaries. However, this is considered acceptable given the highly developed state of the project alignment and that there are no water supply works nearby.
Distance restriction from an approved water supply work nominated by a local water utility or major utility access licence is 1000 metres	There are no local or major water utilities near the station excavations.
Distance restriction from a Department observation bore is 200 metres	The station excavations would be more than 200 metres from a Department (NSW Office of Water) observation bore (monitoring piezometer).
Relevant rules from Part 9 – 40 to 44 of the Water Sharing Plan	
Part 9 – 40: Rules for water supply works located near contamination sources	Barangaroo Station would be adjacent to a declared remediation site under the <i>Contaminated Land Management 1997</i> . Accordingly, all elements of the station excavation and cavern would be tanked to isolate the station from the surrounding groundwater environment.
Part 9 – 41: Rules for water supply works located near sensitive environmental areas	The station excavations would not be within: <ul style="list-style-type: none"> ● 200 metres of a high priority groundwater dependent ecosystem ● 40 metres of a lagoon or any third order or higher order stream ● 40 metres of a first or second order stream ● 100 metres of the top of an escarpment.
Part 9 – 42: Rules for water supply works located near groundwater dependent culturally significant sites	The station excavations would not be located within 200 metres of a groundwater dependent culturally sensitive site.
Part 9 – 44: Rules for water supply works located within distance restrictions	This rule does not apply because the project would comply with distance restrictions.

17.5 Mitigation measures

The mitigation measures that would be implemented to address potential groundwater and geology impacts are listed in Table 17-10.

Table 17-10 Mitigation measures – groundwater and geology

Reference	Mitigation measure	Applicable location(s) ¹
GWG1	<p>A detailed geotechnical model for the project would be developed and progressively updated during design and construction. The detailed geotechnical model would include:</p> <ul style="list-style-type: none"> ○ Assessment of the potential for damage to structures, services, basements and other sub-surface elements through settlement or strain ○ Predicted changes to groundwater levels, including at nearby water supply works. <p>Where building damage risk is rated as moderate or higher (as per the CIRIA 1996 risk-based criteria), a structural assessment of the affected buildings / structures would be carried out and specific measures implemented to address the risk of damage.</p> <p>With each progressive update of the geotechnical model the potential for exceedance of the following target changes to groundwater levels would be reviewed:</p> <ul style="list-style-type: none"> ○ Less than 2.0 metres – general target ○ Less than 4.0 metres – where deep building foundations present ○ Less than 1.0 metre – residual soils ○ Less than 0.5 metre – residual soils (Blues Point) (fill / Aeolian sand). <p>Where a significant exceedance of target changes to groundwater levels are predicted at surrounding land uses and nearby water supply works, an appropriate groundwater monitoring program would be developed and implemented. The program would aim to confirm no adverse impacts on groundwater levels or to appropriately manage any impacts. Monitoring at any specific location would be subject to the status of the water supply work and agreement with the landowner.</p>	All
GWG2	<p>Condition surveys of buildings and structures in the vicinity of the tunnel and excavations would be carried out prior to the commencement of excavation at each site.</p>	All

¹ STW: Surface track work; CDS: Chatswood dive site; AS: Artarmon substation; CN: Crows Nest Station; VC: Victoria Cross Station; BP: Blues Point temporary site; GI: Ground improvement works; BN: Barangaroo Station; MP: Martin Place Station; PS: Pitt Street Station; CS: Central Station; WS: Waterloo Station; MDS: Marrickville dive site; Metro rail tunnels: Metro rail tunnels related – not related to other sites (eg TBM works); PSR: Power supply route.

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