

18 Groundwater and ground movement - Stage 1

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This chapter provides an assessment of the potential impact of Stage 1 on groundwater and ground movement and identifies mitigation measures to address these impacts. This chapter draws on information in Technical Paper 7 (Hydrogeology).

18.1 Secretary’s environmental assessment requirements

The Secretary’s Environmental Assessment requirements relating to groundwater and ground movement, and where these requirements are addressed in this Environmental Impact Statement, are outlined in Table 18-1.

Table 18-1: Secretary’s Environmental Assessment Requirements – Groundwater and ground movement Stage 1

Reference	Requirement	Where addressed
9. Water – Hydrology and flooding		
9.1	The existing hydrological regime for any surface and groundwater resource (including mapping, the reliance by users, and for ecological purposes) likely to be impacted, including stream orders.	Section 18.4.2
9.2	A water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration.	Chapter 19 (Soils and surface water quality – Stage 1)
9.3	Requirements for baseline monitoring of hydrological attributes	Section 18.8.2
9.4	The impact on surface and groundwater hydrology in accordance with the current guidelines, including: <ul style="list-style-type: none"> a. natural processes within rivers, wetlands, estuaries, marine waters and floodplains; b. impacts from any permanent and temporary interruption of groundwater flow; c. stormwater and wastewater management on natural hydrological attributes and the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and d. water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction. 	Section 18.6 Chapter 21 (Hydrology and flooding – Stage 1)
9.5	Flood behaviour for a range of flood events up to the probable maximum flood (taking into account sea level rise and storm intensity due to climate change) including: <ul style="list-style-type: none"> a. potential flood affectation of other properties, assets and infrastructure; b. consistency (or inconsistency) with applicable Council floodplain risk management plans; c. compatibility with the flood hazard of the land; and d. compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land. 	Chapter 21 (Hydrology and flooding – Stage 1)

Reference	Requirement	Where addressed
10. Water – Quality		
10.1	Surface and groundwater quality impacts including: <ul style="list-style-type: none"> a. identifying and estimating the discharge water quality and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment; b. identifying the rainfall event that the water quality protection measures will be designed to cope with; and c. assessing the significance of any identified impacts including consideration of the relevant ambient water quality outcomes. 	Section 18.4.2, Section 18.6.5 Chapter 19 (Soils and surface water quality – Stage 1)
10.2	Demonstrating how Stage 1 will, to the extent that the project can influence, ensure that: <ul style="list-style-type: none"> a. where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and b. where the NSW WQOs are not currently being met, activities will work toward their achievement over time; and c. justify, if required, why the WQOs cannot be maintained or achieved over time. 	Chapter 19 (Soils and surface water quality – Stage 1)

18.2 Legislative and policy context

18.2.1 National Water Quality Management Strategy

The National Water Quality Management Strategy is the adopted national approach to protecting and improving water quality in Australia. It includes specific documents relating to the protection of groundwater resources.

The primary document relevant to the assessment of groundwater risks or Stage 1 is the Guidelines for Groundwater Quality Protection in Australia (Australian Government, 2013). This document sets out a high-level risk-based approach to protecting or improving groundwater quality for a range of groundwater beneficial uses (called ‘environmental values’), including aquatic ecosystems, primary industries (including irrigation and general water users, stock drinking water, aquaculture and human consumption of aquatic foods), recreational and aesthetic values (e.g. swimming, boating and aesthetic appeal of water bodies), drinking water, industrial water and cultural values.

18.2.2 NSW Legislation

Under the *Water Management Act 2000*, water sharing plans provide the basis for equitable sharing of surface water and groundwater between water users, including the environment.

For groundwater, Stage 1 lies within the area covered by the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The Water Sharing Plan contains provisions for allocation of water to construction projects through a volume of ‘unassigned water’ or through the ability to purchase an entitlement where groundwater is available under the long-term average annual extraction limit (LTAAEL).

The LTAAEL for the Sydney Basin Central Groundwater Source is 45,915 megalitres per year, which is 25 per cent of the estimated annual recharge for the area. Under the Water Sharing Plan, there are currently 120 groundwater access licences, with a total licensed volume of 2,592 megalitres per year. As such there is up to 43,323 megalitres per year of water available under the LTAAEL.

18.2.3 NSW Policy

NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (NSW Office of Water, 2012) defines the regime for protecting and managing impacts of aquifer interference activities on NSW water resources.

The NSW Aquifer Interference Policy requires that for an aquifer interference activity (such as excavation which intercepts the aquifer) to meet the minimal impact considerations, any change in groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity. Groundwater along the alignment may potentially be used by aquatic ecosystems and primary industries to account for small-scale domestic use of groundwater, although this varies locally depending on local groundwater conditions such as quality and salinity.

The NSW Aquifer Interference Policy also provides a framework for assessing the impacts of aquifer interference activities on water resources. To assess potential impacts, groundwater sources are categorised as either highly productive or less productive, with sub-categories for different aquifers, such as alluvial, coastal sands, porous rock, and fractured rock. For each category, there are a number of prescribed minimal impact considerations relating to water table and groundwater pressure drawdown, and changes to groundwater and surface water quality.

The Sydney Basin Central Groundwater Source is declared a Less Productive Groundwater Source. Therefore, the Less Productive Minimal Impact Considerations of the NSW Aquifer Interference Policy apply with respect to Porous and Fractured Rock Water Sources. An assessment of Stage 1 against the Less Productive Minimal Impact Considerations is provided in Section 18.6.9.

NSW Groundwater Dependent Ecosystems Policy

The NSW State Groundwater Dependent Ecosystems Policy (Department of Land and Water Conservation, 2002) provides guidance on the protection and management of Groundwater Dependent Ecosystems. It sets out management objectives and principles to:

- Ensure that the most vulnerable and valuable ecosystems are protected
- Manage groundwater extraction within defined limits thereby providing groundwater flow sufficient to sustain ecological processes and maintain biodiversity
- Ensure that sufficient groundwater of suitable quality is available to ecosystems when needed
- Ensure that the precautionary principle is applied to protect groundwater dependent ecosystems, particularly the dynamics of flow and availability and the species reliant on these attributes
- Ensure that land use activities aim to minimise adverse impacts on groundwater dependent ecosystems.

18.3 Assessment approach

The assessment approach for groundwater and ground movement involved:

- A review of publicly available data and web-based information searches, including:
 - WaterNSW Groundwater Bore Database (WaterNSW, 2019)
 - NSW Water Register (WaterNSW, 2019)
 - Groundwater Dependent Ecosystems Atlas (Bureau of Meteorology, 2019)
 - Geological maps, topography and drainage maps, and soil maps.
- A review of groundwater investigations previously carried out within and around the construction footprint, where available, and review of similar assessments for previous tunnelling projects in the Sydney region, including Sydney Metro Northwest and WestConnex M4 East
- Site investigations for Sydney Metro West including installation of 55 monitoring piezometers, with Vibrating Wire Piezometers installed in 12 boreholes
- Development of a conceptual model of the existing Stage 1 hydrogeological environment to assess potential groundwater changes as a result of Stage 1 construction activities

- Identification and assessment of potential groundwater and ground movement impacts from the construction of Stage 1 using the conceptual model, including:
 - Expected changes to groundwater level, flow and quality on surrounding land uses, other groundwater users, surface water/groundwater interaction and potential impacts to groundwater dependent ecosystems
 - Effects of ground movement on nearby structures, either due to excavation or ground consolidation following groundwater drawdown
- Development of monitoring and mitigation measures to address potential groundwater impacts and ground movement.

18.3.1 Groundwater modelling

Groundwater models were developed for each Stage 1 construction site in the software package SEEP/W. The model was based on regional hydrogeological data, and local geotechnical and hydrogeological data recorded as part of Sydney Metro West site investigations.

Groundwater level drawdown contours were developed based on the results of multiple model cross sections (i.e. cross sections and long sections through station box, cavern and shaft excavations). The two-metre drawdown contour represents the minimal impact consideration (for groundwater level drawdown) of the NSW Aquifer Interference Policy (NSW Office of Water, 2012).

The models were used to estimate:

- Groundwater inflows to excavations and station/services facility excavations
- Groundwater level drawdown associated with construction.

Potential impacts are assessed by reviewing the predicted groundwater level drawdown due to Stage 1 against the locations and conditions of existing supply bores; groundwater dependent ecosystems; acid sulfate soils; and interpreted existing groundwater recharge, flow and surface water-groundwater behaviour.

Key assumptions in the model include:

- All cross caverns would be untanked during construction
- Excavations would be open for up to two years during construction
- The excavations are 'wished-in-place' (i.e. progressive excavation over time is not considered). This assumption results in potentially higher inflows to the excavations than would be experienced with progressive excavation, and therefore provides a conservative estimate of groundwater inflow
- The modelling is based on limited geotechnical and hydrogeological data. Where data are not available at sites, assumptions regarding ground conditions have been made.

A full list of modelling assumptions is provided in Technical Paper 7 (Hydrogeology).

18.3.2 Ground movement

The following framework was applied to assess and mitigate potential impacts of ground movement on existing buildings, tunnels, road pavements and utilities:

- Identification of the ground movement zone of influence as triggered by construction and classification of all existing buildings and infrastructure within that zone
- Risk assessment of the structures within the zone of influence against acceptance criteria and where necessary development of solutions to minimise the impact of construction on potentially critical buildings and infrastructure
- Implementation of minimisation measures (for buildings and structures classified as critical), re-assessment and review of performance.

18.4 Existing environment

18.4.1 Geological context

Topography

Stage 1 falls within the catchment of the Parramatta River and Sydney Harbour. The catchment lies to the west of the Sydney CBD within the relatively flat region of the Cumberland Plain. Elevations range from 140 metres Australian Height Datum (AHD) in the north-west of the catchment to sea level in the east. Most of the waterways are within urbanised coastal areas.

Geology

The Sydney 1:100,000 Geological Series Sheet 9130 (NSW Department of Mineral Resources, 1983) and the Parramatta 1:100,000 Geological Sheet 9030 (NSW Department of Mineral Resources, 1991) indicate that most of the Stage 1 construction footprint is underlain by geological units associated with the Wianamatta Group. Ashfield Shale underlies most of the Stage 1 construction footprint and tunnel alignment, with occurrences of Hawkesbury Sandstone and Mittagong Formation. In addition, significant areas of disturbed ground (imported fill) are known to be present within the Stage 1 footprint at Rosehill, Silverwater, Sydney Olympic Park and The Bays.

A description of the geological formations is presented in Table 18-2 and shown in Figure 18-1. The geological long section is provided in Technical Paper 7 (Hydrogeology).

Table 18-2: Geological units – Stage 1 construction footprint

Geological unit	Description	Relevant Stage 1 construction sites
Fill	Material comprising waste, emplaced material and engineered fill.	<ul style="list-style-type: none"> Silverwater services facility Clyde stabling and maintenance facility The Bays Station
Quaternary deposits (residual and alluvial soils)	Alluvial and marine sediments associated with gullies, valleys, and former drainage channels.	<ul style="list-style-type: none"> Westmead metro station Parramatta metro station Silverwater services facility Clyde stabling and maintenance facility Sydney Olympic Park metro station North Strathfield metro station Burwood North Station Five Dock Station The Bays Station
Mittagong Formation	Interbedded dark siltstone and fine-grained sandstone beds and laminae of varying thickness.	<ul style="list-style-type: none"> Westmead metro station Parramatta metro station Clyde stabling and maintenance facility Silverwater services facility Sydney Olympic Park metro station North Strathfield metro station Burwood North Station Five Dock Station
Ashfield Shale	Black to dark grey shale and laminate.	<ul style="list-style-type: none"> Westmead metro station Parramatta metro station Silverwater services facility Clyde stabling and maintenance facility Sydney Olympic Park metro station North Strathfield metro station Burwood North Station Five Dock Station
Hawkesbury Sandstone	Medium to coarse-grained quartz sandstone.	<ul style="list-style-type: none"> All Stage 1 construction sites

Note: Geological units presented in order of depth from surface.

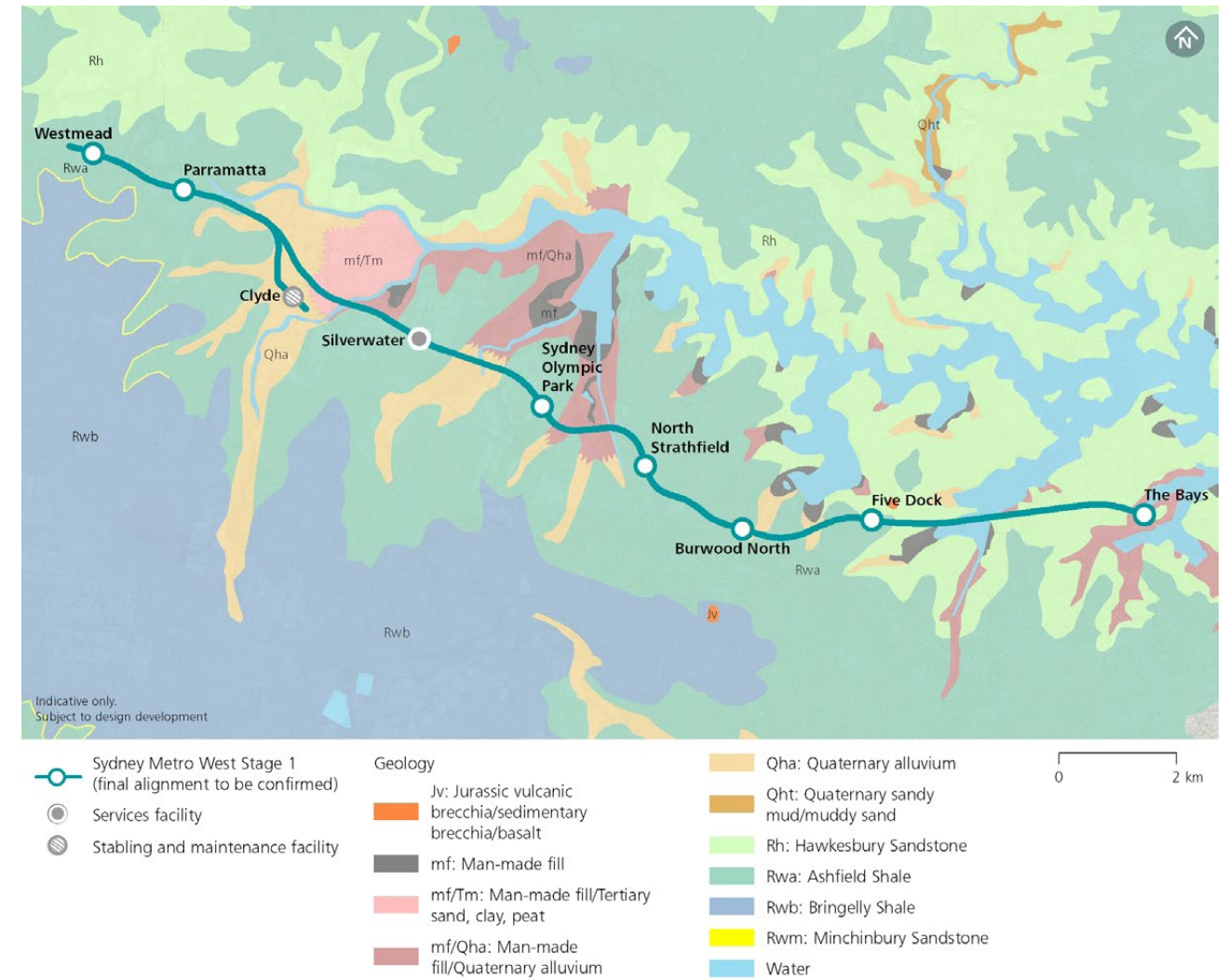


Figure 18-1: Regional geological context

Geological structural features

The geology within the Stage 1 construction footprint is crossed by several volcanic structural features such as dykes and faults that may impact groundwater flow. Dykes are bodies of rock that cut across other geological units. Faults are a fracture within rock where displacement may have occurred. Dykes and faults may provide a conduit or hydraulic barrier for groundwater inflows.

Structural features near Stage 1 include:

- Dykes within Ashfield Shale and Hawkesbury Sandstone. Dykes may be present near the construction sites for North Strathfield metro station and The Bays Station. A dyke may also be present near the tunnel alignment to the east of Five Dock Station
- Geological faults within Ashfield Shale, Mittagong Formation and Hawkesbury Sandstone. An observed fault is present near the Sydney Olympic Park metro station. Faults may also be present near the North Strathfield metro station, Burwood North Station and The Bays Station construction sites. Faults may also cross the tunnel alignment to the south and east of Sydney Olympic Park metro station construction site, to the south of North Strathfield metro station construction site and to the south of Burwood North Station construction site.

Groundwater users and extraction

A review of the WaterNSW Groundwater Bore Database (WaterNSW, 2019) and the Register of Water Approvals (WaterNSW, 2019) identified 31 registered groundwater bores located within the predicted groundwater level drawdown zone of influence during construction. These are shown in Figure 18-2 and include:

- Twenty-eight bores which are installed for monitoring purposes
- One bore which is installed for industrial purposes
- One bore which is installed for dewatering purposes
- One bore which is installed for water supply.

In addition, there are 39 Water Access Licence users within one kilometre of Stage 1.

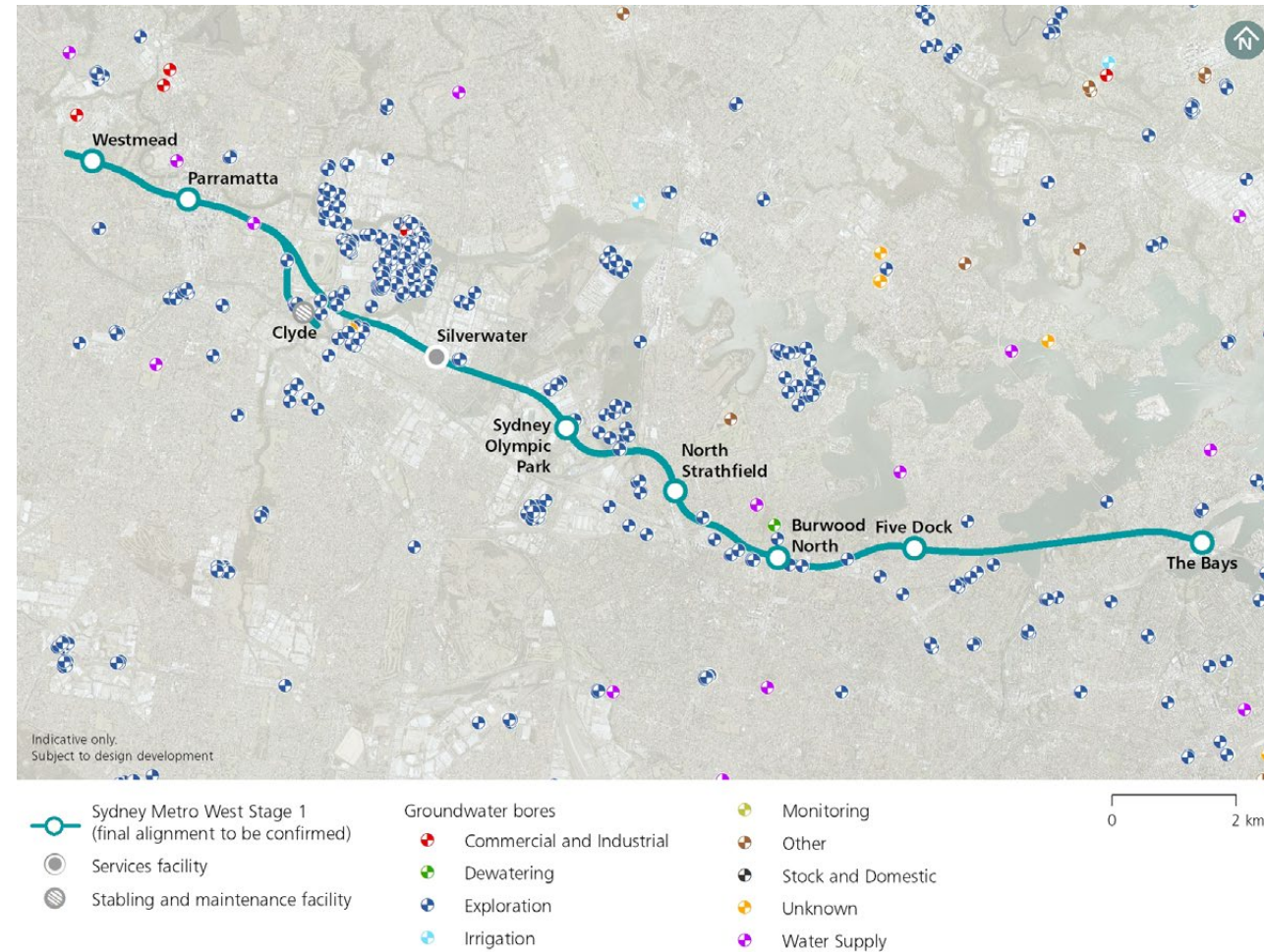


Figure 18-2: Existing groundwater bores within one kilometre of Stage 1

Groundwater dependent ecosystems

Technical Paper 10 (Biodiversity development assessment report) identifies potential groundwater dependent ecosystems located in proximity to (about one kilometre of) the Stage 1 construction sites and tunnel. These are shown in Figure 18-3.

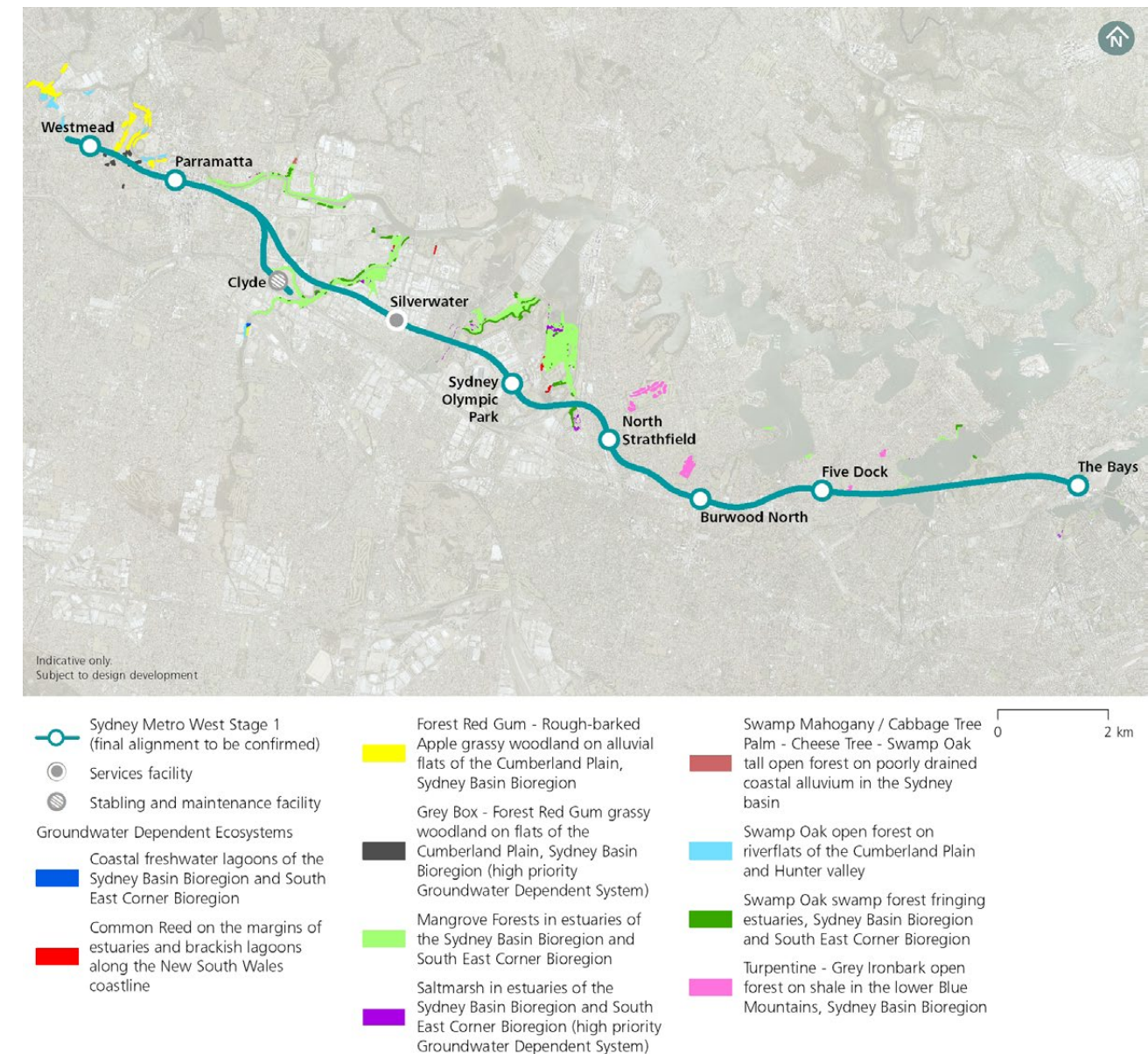


Figure 18-3: Groundwater dependent ecosystems

There are no mapped aquatic groundwater dependent ecosystems within the Stage 1 study area, however Chapter 22 (Biodiversity – Stage 1) identifies areas of high potential groundwater dependent terrestrial vegetation including:

- Saltmarsh in estuaries of the Sydney Basin Bioregion and South East Corner Bioregion
- Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion Plant Community Type (849) (a vegetation community classified as Cumberland Plain Woodland in the Sydney Basin Bioregion)
- Forest Red Gum - Rough-barked Apple grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion Plant Community Type (835) (a vegetation community classified as Cumberland Plain Woodland in the Sydney Basin Bioregion).

High priority groundwater dependent ecosystems are listed in Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources (Department of Industry, 2011). The plan lists Cumberland Plain Woodland and Coastal Saltmarsh in the Sydney Basin Bioregion as high priority groundwater dependent ecosystems. Therefore, Grey Box - Forest Red Gum woodland on the flats of the Cumberland Plain in the vicinity of Westmead metro station and Parramatta metro station construction sites, and the Saltmarsh in estuaries of the Sydney Basin Bioregion and South East Corner Bioregion in the vicinity of Sydney Olympic Park metro station and North Strathfield metro station construction sites are classified as high priority groundwater dependent ecosystems.

18.4.3 Conceptual hydrogeological model

A conceptual hydrogeological model of the existing environment has been developed for Stage 1. A conceptual hydrogeological model is a mostly qualitative description of the groundwater system, including groundwater levels, quality, inputs/outputs and a description of geology and its properties. A conceptual model allows the effect of newly introduced changes to the hydrogeological system to be understood and assessed, such as those proposed for Stage 1 construction activities. It also allows consideration of whether more detailed numerical modelling is necessary.

The conceptual hydrogeological model for Stage 1 incorporates the groundwater and geology elements described in Sections 18.4.1 and 18.4.2 and is shown graphically in Technical Paper 7 (Hydrogeology).

18.5 Avoidance and minimisation of impacts

The design development of Stage 1 has included a focus on avoiding or minimising potential groundwater impacts and ground movement. This has included:

- Tanking at Parramatta, Five Dock and The Bays stations to avoid ongoing groundwater inflow
- Tanking of tunnels to avoid ongoing groundwater inflow.

18.6 Potential impacts

18.6.1 Ground movement

The specific risk to most buildings and structures due to ground movement is considered negligible, with superficial damage to buildings unlikely. Construction of some underground sections of Stage 1 may potentially induce ground movement at the surface and below ground which could include ground settlement and lateral movement. If not adequately managed, ground movement has the potential to cause damage to infrastructure, nearby buildings and other structures.

Ground movement may occur from either the release or redistribution of stress in rock formations or from ground consolidation following the drawdown of groundwater. Typically ground movement caused by stress redistribution in rock generally occurs shortly after excavation, while consolidation settlement from groundwater drawdown can occur over a longer period.

The tunnels and many other project elements are designed as tanked structures and, therefore, long-term settlement effects associated with groundwater drawdown are not anticipated at most locations. For Stage 1, it is expected that any potential settlement associated with groundwater drawdown would be minimal as most underground excavation would be within rock that has low permeability. Some settlement could potentially occur as a result of groundwater drawdown associated with open excavations and this potential would be greatest in soft superficial surface deposits, if the perched water table is lowered.

Ground movement risk levels have been determined with reference to geotechnical conditions, distance from construction activities and building characteristics including condition and type of masonry. For the purposes of a screening assessment, the risk-based criteria outlined by the Construction Industry Research and Information Association (1996) have been used and are detailed in Table 18-6. These criteria specify the maximum settlement of the building and the maximum slope of the ground below building foundations for each risk level. A small number of buildings and structures assessed as having a risk level of two or greater would be subject to more detailed building strain assessment and would potentially require a structural assessment later in the design process.

Table 18-6: Ground movement risk levels

Risk	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, 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, possible damage to other pipelines	>1:50	>75

Preliminary settlement contours were developed for the Stage 1 corridor to identify the expected zone of influence and magnitude of induced settlement. The development of the contours considered 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).

Settlement contour intervals (namely 1mm, 3mm, 5mm, 10mm, 15mm, 20mm and 25mm) were selected to cover the expected typical range of potential ground movement. The three millimetre contour defines what is considered to be the extent of the Stage 1 influence, while the ten millimetre contour defines the point at which more detailed future assessment is required as per Table 18-6. Most of the alignment falls within the risk category one 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 risk category two. These would be subject to further assessment at later design stages, which may include building strain and structural assessment to address settlement related risks.

18.6.2 Groundwater levels

During tunnel construction, tunnel boring machines would progress through Ashfield Shale, Mittagong Formation and Hawkesbury Sandstone and would place a pre-cast segmental tunnel lining as tunnelling progresses. Groundwater level drawdown due to the tunnels is not likely to be significant as the tunnels would be tanked almost immediately following tunnelling and given the relatively low hydraulic conductivity and storativity (i.e. a measure of the capacity of the aquifer to release groundwater) of the rock and the short timeframe over which an unlined excavation would be open in the tunnels.

The impacts of cross passage construction on groundwater are not likely to be significant as the tunnel cross passages have a relatively small footprint and may be open for a short period of time prior to being waterproofed.

Estimates of groundwater level drawdown from the current water level as a result of Stage 1 excavation at each construction site have been developed and are provided in Technical Paper 7 (Hydrogeology). Further discussion of predicted groundwater inflows and potential impacts are provided in the sections below.

18.6.3 Groundwater inflows and local flow regime

Excavations at Stage 1 construction sites would act as groundwater sinks, causing the surrounding groundwater to flow towards the excavations. Some excavations would be tanked (i.e. sealed) during construction, which would prevent groundwater from flowing into the excavation. Other excavations would be untanked (i.e. the excavation would not be sealed and groundwater would flow to the excavation across both soil and rock horizons). Whether an excavation is untanked or tanked would influence the actual groundwater inflow rates at each of the construction sites where excavations would occur.

Rock in the vicinity of water-bearing geological features such as faults, dykes and joint swarms has the potential to have relatively high hydraulic conductivity (i.e. ability of groundwater to pass through the pores and fractures in the rock). Identification of such features would be carried out, and significant water-bearing features would be grouted prior to excavation, to reduce the potential for relatively high groundwater inflows to the excavations.

The inflow rates in Table 18-7 provide indicative maximum inflows at both one and two years after excavation to address the requirements of the NSW Aquifer Interference Policy and the Water Sharing Plan.

Excavations would change the direction of existing groundwater flow regime, causing groundwater to flow towards the excavation. There is a potential for contaminants within the groundwater to be mobilised towards the excavation sites, at some locations, particularly near Clyde, Silverwater, Sydney Olympic Park, North Strathfield and The Bays. It is expected that all potential groundwater contamination identified can be managed to acceptable levels with the implementation of appropriate management measures and/or remediation (refer to Chapter 20 (Contamination - Stage 1)).

Table 18-7: Predicted maximum groundwater inflows at Stage 1 construction sites

Construction site	Construction design	Predicted inflow rate (litres/second)		Predicted inflows (megalitres)	
		One year after excavation	Two years after excavation	One year after excavation	Two years after excavation
Westmead metro station	Untanked excavation Tankered crossover cavern ¹	1.5	1.5	54	46
Parramatta metro station	Tanked (soil) Untanked (rock)	2.7	2.7	89	85
Clyde stabling and maintenance facility	Tanked (soil) Untanked (rock)	0.5	0.8	38	40
Silverwater services facility	Untanked	0.3	0.3	11	10
Sydney Olympic Park metro station	Untanked	0.4	0.4	13	12
North Strathfield metro station	Untanked	0.4	0.4	22	12
Burwood North Station	Untanked excavation and shaft Tankered crossover cavern ¹	3.1	2.8	117	91
Five Dock Station	Untanked	1.7	1.7	64	53
The Bays Station	Tanked (soil) Untanked (rock)	10.1	10.1	319	320

Note 1: For the purpose of modelling, these are assumed to be untanked, however would later be tankered

18.6.4 Groundwater recharge

Groundwater recharge is the downward movement of water to the water table (i.e. the saturated part of the geological layer).

Soils are recharged by rainfall and localised irrigation, as well as incidental runoff from impervious surfaces. When rock layers are exposed at surface, there can be direct recharge of the rock aquifers, with transmission primarily through rock joints. Recharge to the rock aquifers elsewhere is by downward percolation through soils.

Table 18-8 discusses the potential impacts on groundwater recharge at each Stage 1 construction site. At most sites, there would potentially be very little change from pervious to impervious surfaces and therefore potential impacts to groundwater recharge would be low.

Table 18-8: Potential impacts on groundwater recharge

Construction site	Potential impacts on groundwater recharge
Westmead metro station	Stage 1 would increase the proportion of impervious areas through the site establishment and excavation which could potentially reduce recharge rates within the footprint of the construction site. The proposed construction site is small relative to the local catchment, and the net impact on regional recharge is not likely to be significant.
Parramatta metro station	Almost all the proposed construction site is currently impervious. Stage 1 would therefore not reduce recharge rates near the site.
Clyde stabling and maintenance facility	About 30 per cent of the construction site is currently pervious. Stage 1 is likely to reduce the groundwater recharge rate in the vicinity of the construction site. This would potentially reduce the groundwater baseflow to Duck Creek and A'Becketts Creek.
Silverwater services facility	Most of the proposed construction site area appears to be pervious and Stage 1 may therefore potentially reduce recharge rates. The proposed construction site is small relative to the local catchment area, and the net impact on regional recharge is not likely to be significant.
Sydney Olympic Park metro station	Most of the proposed construction site is currently impervious. Therefore, Stage 1 would not reduce recharge rates near the construction site.
North Strathfield metro station	Most of the proposed construction site area appears to be pervious and Stage 1 may therefore potentially reduce recharge rates. At a regional scale, the contribution of potential recharge from the site is likely to be minor, and changes to groundwater recharge from the conversion of the site to an impervious area are likely to be minor to negligible.
Burwood North Station	Almost all the proposed construction site is currently impervious. Stage 1 would not reduce recharge rates near the site.
Five Dock Station	Almost all the proposed construction site is currently impervious. Stage 1 would not reduce recharge rates near the site.
The Bays Station	Almost all the proposed construction site is currently impervious. Stage 1 would not reduce recharge rates near the site.

18.6.5 Groundwater quality

Groundwater inflow would be collected and treated during construction via temporary water treatment plants so that discharged water quality is compliant with the ANZECC/ARMCANZ (2000) and ANZG (2018) guideline values and/or meets the requirements of the relevant environment protection licence for Stage 1 prior to entering the local stormwater system.

Existing contaminated groundwater could be mobilised by groundwater drawdown resulting from Stage 1 construction activities. Potential migration of existing contaminants could impact the beneficial uses of groundwater in nearby areas. This may cause volatile contaminants to come into contact with underground structures, creating a risk of vapour intrusion to underground structures. Both risks could impact groundwater users, the health and safety of construction workers, groundwater disposal options and, potentially other drained structures in the areas.

It is possible that saline water could be drawn into the fresh groundwater at Parramatta, Clyde, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock and The Bays. Groundwater supply for primary industries/ industrial/drinking water and sites with groundwater-dependent cultural or spiritual values have not been identified in areas where this potential impact could occur. Based on this, potential saline water intrusion in this area is not likely to impact on the environmental values of the aquifers. Further discussion is provided in Technical Paper 7 (Hydrogeology).

Further information relating to soils and surface water, and contamination are provided in Chapter 19 and Chapter 20 respectively.

18.6.6 Groundwater users

Potential impacts to groundwater users due to groundwater level drawdown during construction were identified at two locations. These are summarised in Table 18-9. No impacts were identified at other locations.

Table 18-9: Potential impacts to groundwater users due to groundwater level drawdown

Construction site	Bore ID/use	Potential impact
Westmead metro station	GW108378 - Commercial/ industrial	At two years after Stage 1 excavation, it is estimated that groundwater level drawdown at this bore would be four metres. This does not satisfy the minimal impact considerations of the NSW Aquifer Interference Policy. Given the depth of the bore, and an assumed groundwater table of about 20 metres below ground surface, the available water column in the bore would be reduced by about two per cent. Based on this, groundwater supply is not likely to be affected at this bore due to Stage 1.
Burwood North Station	GW305646 - Water Supply	It is estimated that groundwater level drawdown at this bore would be two metres at two years after Stage 1 excavation. Two metres is at the limit of minimal impact considerations as per the NSW Aquifer Interference Policy (NSW Office of Water, 2012), and considering that the modelling is conservative, it is unlikely that this bore would be impacted. The bore is not listed as active however a site inspection could confirm the viability of this bore. If it is viable, the bore would be monitored throughout construction and make good measures implemented if a loss of yield were to occur.

18.6.7 Groundwater dependent ecosystems

The tunnel alignment would pass within 500 metres of groundwater dependent ecosystems in the suburbs of Westmead, Parramatta, Clyde, Silverwater and Sydney Olympic Park. Given the tunnel would be tanked (sealed), the groundwater level drawdown is likely to be insignificant and potential impacts to groundwater dependent ecosystems due to tunnel excavation are not expected.

For high priority groundwater dependent ecosystems (associated with Cumberland Plain Woodland) near Westmead and Parramatta, the likelihood of these ecosystems being impacted by the groundwater level drawdown associated with Stage 1 is low. The groundwater level drawdown in the sandstone induced by station excavation is not likely to cause direct groundwater level drawdown within these geological units.

Negligible impacts are expected at the saltmarsh estuaries near Sydney Olympic Park metro station and North Strathfield metro station construction sites as these sites are located outside of the impacted groundwater zone.

Potential saline water intrusion into groundwater is not likely to impact groundwater dependent ecosystems. Groundwater dependent ecosystems that have been identified in the vicinity of potential saline water intrusion (see Section 18.6.5) are tolerant of saline groundwater.

Further discussion on potential impacts to groundwater dependent ecosystems is provided in Chapter 22 (Biodiversity - Stage 1).

18.6.8 Interactions of groundwater with surface water

Interactions between surface water and groundwater due to tunnelling activities are not expected due to the depth of tunnels. However, it is not known whether groundwater at surface construction sites may potentially contribute to baseflow of nearby surface water bodies, based on the current level of site investigations. Notwithstanding, several locations have been identified where there is potential for interaction between groundwater and surface water to be affected due to groundwater drawdown. These potential interactions of groundwater with surface water are summarised in Table 18-10.

Additional site investigation at the locations of the creeks would be required to confirm the existing baseflow contribution to these creeks. This would include investigation of ground conditions, groundwater levels, and stream flows. Further assessment of the potential change in baseflow due to Stage 1 would be undertaken based on the findings of the investigation.

Table 18-10: Potential interactions of groundwater with surface water

Construction site	Surface water bodies near the construction site	Potential impact
Westmead metro station	Domain Creek and Toongabbie Creek	It is possible that groundwater level drawdown could result in reduced groundwater flow towards the creeks, and ultimately reduced baseflow to the creeks. However, as baseflows are likely to be a minor component of streamflow, the significance of this potential change is likely to be low. Therefore it is considered unlikely that a reduction in stream flow would occur that could impact the groundwater dependent ecosystem; Forest Red Gum - Rough-barked Apple grassy woodland.
Parramatta metro station	Clay Cliff Creek Parramatta River	Clay Cliff Creek is a concrete lined channel and is not likely to receive groundwater baseflow. Stage 1 excavation at Parramatta metro station construction site is not likely to reduce baseflow contributions to streams.
Clyde stabling and maintenance facility	A'Becketts Creek and Duck Creek	It is possible that groundwater level drawdown due to excavation of the shaft and dive could potentially reduce baseflow contribution and reduce stream flows to A'Becketts Creek and Duck Creek. However, as baseflows are likely to be a minor component of streamflow, the significance of this change in flows is likely to be low. If there is existing groundwater baseflow contribution to A'Becketts Creek and Duck Creek, then Stage 1 has the potential to reduce that baseflow contribution and reduce stream flows. Stage 1 could potentially cause reduced baseflow to A'Becketts Creek and Duck Creek due to groundwater level drawdown, and the reduced groundwater recharge caused by converting pervious ground to impervious ground at the Sydney Speedway. A potential reduction in stream flow could impact the groundwater dependent ecosystem; Mangrove Forests located along Duck Creek. Other aquatic ecosystems could also potentially be impacted if baseflows are reduced (which is considered unlikely). Potential groundwater level drawdown at Duck Creek is likely to be negligible. However, a proportion of the inflows to the shaft may be indirectly sourced from the waters of Duck Creek which may leak into the underlying and adjacent ground, and potentially migrate towards the shaft excavation. However, the significance of this impact is likely to be low, due to negligible groundwater drawdown.

Construction site	Surface water bodies near the construction site	Potential impact
Sydney Olympic Park metro station	Haslams Creek, the Mason Park wetlands, Bicentennial Park wetlands and the Brickpit	<p>It is possible that groundwater level drawdown at distance from these surface water bodies could result in reduced groundwater flow towards the surface water bodies, which could potentially mean receiving reduced baseflow. Reduction in stream flow may impact groundwater dependent ecosystem; Common Reed, Swamp Oak swamp forest, Mangrove Forests and Saltmarsh located along Haslams Creek and in the Bicentennial Park wetlands and the Mason Park wetlands.</p> <p>The potential impact on Haslams Creek is likely to be low as baseflows are likely to be a minor component of creek stream flow, and the groundwater modelling undertaken is conservative. For the Bicentennial and Mason Park wetlands, groundwater baseflows are likely to be a minor component of water contributing to the wetland systems, therefore the potential impact is likely to be low. Rainfall and tidal flows from the Parramatta River are likely to be the dominant source of water for the wetland systems.</p>
North Strathfield metro station	Powells Creek, the Mason Park wetlands, Powells Creek Reserve and Bicentennial Park	<p>It is possible that groundwater level drawdown could result in reduced groundwater flow towards the creek, and ultimately reduced baseflow to the creek. However, as baseflows are likely to be a minor component of streamflow, the significance of this potential impact is likely to be low. If a reduction in stream flow occurred it could impact groundwater dependent ecosystem; Common Reed, Swamp Oak swamp forest, Mangrove Forests and Saltmarsh. Other aquatic ecosystems could also likely be impacted if baseflows are reduced.</p>
Burwood North Station	St Lukes Park Canal and Barnwell Park Canal	<p>Surface water-groundwater interaction is not likely to be affected by groundwater level drawdown. Groundwater is not likely to contribute to these waters as they are concrete-lined channels. The potential naturalisation of these channels by Sydney Water would modify the banks of the channels but would retain the concrete-lining at the base and centre-line of the channels.</p>
Five Dock Station	Barnwell Park Canal and Iron Cove Creek	<p>Groundwater is not likely to contribute to these waterways as they are concrete-lined channels. The naturalisation of these channels by Sydney Water would modify the banks of the channels but would retain the concrete-lining at the base and centre-line of the channels. Connection between surrounding groundwater and the concrete-lined channel is not likely, and groundwater level drawdown is not likely to affect groundwater interaction with these surface waterways. Water from Kings Bay may also be indirectly drawn into the groundwater to the south of the bay causing intrusion of saline water into groundwater (see Section 18.6.5).</p>
The Bays Station	White Bay	<p>A proportion of inflow to the station excavation is likely to be indirectly sourced from White Bay, as bay waters could be drawn into the groundwater system. Therefore, it is possible that the excavation could cause intrusion of saline water into groundwater (see section 18.6.5).</p>

18.6.9 Policy compliance

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 Stage 1 does not require a licence/ approval under the *Water Management Act 2000*, 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 18-11).

Table 18-11: Minimal harm assessment

Minimal harm considerations	Assessment
Water table	
<p>1. Less than or equal to ten per cent cumulative variation in the water table, allowing for typical climatic ‘post-water sharing plan’ variations, 40 metres from any:</p> <p>a. High priority groundwater dependent ecosystem; or</p> <p>b. High priority culturally significant site; listed in the schedule of the relevant water sharing plan.</p> <p>A maximum of a two-metre cumulative decline at any water supply work.</p>	<p>High priority groundwater dependent ecosystems (terrestrial vegetation) include the Grey Box - Forest Red Gum woodland on the flats of the Cumberland Plain near Westmead metro station and Parramatta metro station construction sites, and the Saltmarsh in estuaries of the Sydney Basin Bioregion and South east Corner Bioregion near Sydney Olympic Park metro station and North Strathfield metro station construction sites.</p> <p>Groundwater level drawdown is not predicted at the location of these ecosystems, except for the Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain to the east of Westmead metro station construction site. However, this ecosystem grows in clay alluvium and this geological unit is likely to be of relatively low permeability, with a potential perched water table present (which may be temporary) upon which these groundwater dependent ecosystems may intermittently rely. The groundwater level drawdown in the sandstone induced by station excavation is not likely to cause direct groundwater level drawdown within a potential perched aquifer in the clay alluvium. The likelihood of this ecosystem being impacted by the groundwater level drawdown associated with Stage 1 is therefore low.</p> <p>The Greater Metropolitan Regional Groundwater Sources Water Sharing Plan does not list any high priority culturally significant in the vicinity of Stage 1.</p> <p>Groundwater modelling has estimated a groundwater level drawdown of two metres at two years after excavation at water supply bore GW305646, and four metres at two years after excavation at water supply bore GW108378. This does not satisfy the minimal impact considerations of the NSW Aquifer Interference Policy. However, the available water column in bore GW108378 would be reduced by Stage 1 by about two per cent. Based on this, groundwater supply is not likely to be affected at this bore due to Stage 1.</p> <p>At bore GW305646, site inspection would be carried out to confirm the current viability of this bore. If viable, the bore would be monitored throughout construction. Make good measures would be implemented if a loss of yield were to occur.</p>

Minimal harm considerations	Assessment
<p>2. If more than ten percent cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any:</p> <p>a. High priority groundwater dependent ecosystem; or</p> <p>b. High priority culturally significant site; listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister's satisfaction that the variation would not prevent the long-term viability of the dependent ecosystem or significant site.</p> <p>If more than a two-metre decline cumulatively at any water supply work, then make good provisions should apply.</p>	<p>Item (1) responses apply. Mitigation measures to address impacts have been identified (see Section 18.8).</p>
Water pressure	
<p>1. A cumulative pressure head decline of not more than a two-metre decline, at any water supply work.</p>	<p>Mitigation measures to address potential impacts at bore GW305646 have been identified (see Section 18.8).</p>
<p>2. If the predicted pressure head decline is greater than consideration (1) above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline would not prevent the long-term viability of the affected water supply works unless make good provisions apply.</p>	<p>Mitigation measures to address potential impacts at bore GW305646 have been identified (see Section 18.8).</p>
Water quality	
<p>1. 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>Where contaminated groundwater, saline groundwater, or acid sulfate soils are present within the groundwater level drawdown zone of influence, Stage 1 has the potential to alter the groundwater quality from the contaminant/saline water sources to the excavations. If there is a beneficial use in this zone, then this beneficial use could be lowered.</p> <p>If this process occurs, this requirement of the Aquifer Interference Policy would not be satisfied and mitigation measures have been identified (see Section 18.8).</p>
<p>2. If consideration (1) is not met then appropriate studies would need to demonstrate to the Minister's satisfaction that the change in groundwater quality would not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.</p>	<p>Water supply works (WaterNSW-registered groundwater bores) are not expected to be impacted by groundwater quality changes induced by Stage 1.</p> <p>Changes to groundwater quality near the groundwater dependent ecosystems due to Stage 1 are not expected.</p>

Minimal harm considerations	Assessment
Additional considerations	
<p>Any advice provided to a gateway panel, the Planning and Assessment Commission or the Minister for Planning on a State significant development or State significant infrastructure would also consider the potential for:</p> <ul style="list-style-type: none"> Acidity issues to arise, for example exposure of acid sulfate soils Water logging or water table rise to occur, which could potentially affect land use, groundwater dependent ecosystems and other aquifer interference activities. <p>Specific limits would be determined on a case-by-case basis, depending on the sensitivity of the surrounding land and groundwater dependent ecosystems to waterlogging and other aquifer interference activities to water intrusion.</p>	<p>Where the presence of acid sulfate soils and potential groundwater level drawdown within those soils is confirmed, an acid sulfate soils management plan would be developed for Stage 1 to reduce the risks associated with oxidation/activation of acid sulfate soils (refer to Chapter 19 (Soils and surface water quality - Stage 1)).</p> <p>The risk of water logging or water table rise is assessed to be negligible due to Stage 1 excavation works.</p>

Consistency with Water Sharing Plan rules

All groundwater and surface water in the Stage 1 construction footprint is managed through the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The Water Sharing Plan provides rules to manage and allocate the groundwater resource, including specific rules on taking groundwater near high priority groundwater dependant ecosystems, groundwater dependent culturally significant sites, sensitive environmental areas, and near licenced bores. The groundwater source relevant to Stage 1 is the 'Sydney Basin Central'. While Stage 1 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 18-12).

Table 18-12: Compliance with Water Sharing Plan rules

Rule	Assessment
Part 7 - Rules for granting access licences	A water access licence is not required for Stage 1.
Part 8 - Rules for managing access licences	A water access licence is not required for Stage 1.
Part 9 - Rules for water supply work approvals	<p>The <i>Water Management Act 2000</i> requires that a water supply work approval is obtained for groundwater ingress to tunnels, stations and services facilities.</p> <p>The approval process would determine distance restrictions to minimise interference between water supply works.</p> <p>In the case of Stage 1, the water supply works include the excavations and permanently drained structures, including the station boxes, shafts, dives and services facilities.</p>
Part 9 - 39 Distance restrictions to minimise interference between water supply works	While some of the distance restrictions identified in Part 9 - 39 are not satisfied, water supply bores (approved water supply works that are reported to supply water) would not be adversely impacted.
Distance restriction from an approved water supply work nominated by another access licence is 400 metres	Stage 1 sites lie within 400 metres of approved water supply works under other access licences.
Distance restriction from an approved water supply work for basic landholder rights only is 100 metres	Stage 1 sites lie within 100 metres of approved water supply works for basic landholder rights.

Rule	Assessment
Distance restriction from the property boundary is 50 metres	Stage 1 sites lie within 50 metres of property boundaries.
Distance restriction from an approved water supply work nominated by a local water utility or major utility access licence is 1000 metres	Water supply works nominated by a local water utility or major utility access licence were not identified within 1000 metres of the Stage 1 sites.
Distance restriction from a Department observation bore is 200 metres	Observation bores/monitoring piezometers operated and maintained by WaterNSW were not identified within 200 metres of the Stage 1 sites. While some of the distance restrictions identified in Part 9 – 39 are not satisfied, water supply bores (approved water supply works that are reported to supply water) would not be adversely impacted.
Part 9 – 40 Rules for water supply works located near contamination sources	Construction sites with the potential for contaminated groundwater include Westmead metro station, Parramatta metro station, Clyde stabling and maintenance facility, Silverwater services facility, Sydney Olympic Park metro station, Burwood North Station and The Bays Station. Restrictions on water supply works approvals would apply to Stage 1 where construction dewatering and permanent drainage infrastructure for Stage 1 are near ground contamination. Refer to Chapter 20 (Contamination - Stage 1) for information on contamination.
Part 9 – 41 Rules for water supply works located near sensitive environmental areas	Stage 1 sites with the potential to induce groundwater level drawdown are not located within 100 metres of a high priority groundwater dependent ecosystem listed in Schedule 4 of the relevant Water Sharing Plan, or within 40 metres of the top of the high bank of a lagoon or any third order or higher order stream, or within 100 metres of the top of an escarpment. The Stage 1 excavations lie greater than 40 metres from first or second order streams.
Part 9 – 42 Rules for water supply works located near groundwater dependent culturally significant sites	Groundwater-dependent culturally sensitive sites have not been identified within 100 metres of the Stage 1 sites.
Part 9 – 44 Rules for water supply works located within distance restrictions	Stage 1 sites that do not comply with the above distance restrictions could have limitations on groundwater take under the Water Sharing Plan. However, with implementation of the mitigation measures, it is expected that such limitations would not be required.
Part 10 – Access licence dealing rules	As per response to Part 7.

18.7 Cumulative impacts

Potential cumulative impacts were considered for assessment based on the likely interactions of Stage 1 with other projects and plans that met the adopted screening criteria. The approach to assessment and the other projects considered are described further in Appendix G (Cumulative impacts assessment methodology – Stage 1).

Potential cumulative groundwater impacts include:

- Overlapping of groundwater drawdown associated with the excavation of individual Stage 1 stations and shafts. This could potentially occur in areas where the drawdown extends to the adjacent excavation impact; for example at North Strathfield, Burwood North and Five Dock
- Existing and proposed infrastructure with drained excavations/structures near to the Stage 1 excavations, including building basements and excavations associated with the WestConnex M4 East and the Western Harbour Tunnel and Beaches Link.

Based on the groundwater assessment provided in the Environmental Impact Statement for the WestConnex (M4 East) project (WestConnex Delivery Authority, 2015), the WestConnex (M4 East) tunnels are predicted to induce groundwater level drawdown in the vicinity of North Strathfield metro station, Burwood North Station and Five Dock Station construction sites. The Environmental Impact Statement for the WestConnex (M4 East) project predicted long term (steady state) drawdown only and does not present predicted drawdowns during WestConnex (M4 East) construction or in the early years of operation. The predicted drawdown for Stage 1 of Sydney Metro West indicates that there may be cumulative drawdown in some areas in the vicinity of North Strathfield metro station and Five Dock Station construction sites due to WestConnex (M4 East) and Stage 1, and that this cumulative drawdown could be several metres greater than that predicted for Stage 1 alone. The drawdown predicted in the vicinity of Burwood North Station construction site due to WestConnex (M4 East) is significantly greater than the drawdown predicted due to Stage 1.

Based on the predicted groundwater level drawdown due to the WestConnex (M4 East) tunnels, the potential impacts to potential acid sulfate soils, groundwater dependent ecosystems, groundwater users (domestic supply bores) and contaminant migration that have been identified due to the Stage 1 excavations for North Strathfield metro station, Burwood North Station and Five Dock Station construction sites may have already occurred (at least partially) due to the existing excavation of the WestConnex (M4 East) tunnels.

The groundwater assessment provided in the Environmental Impact Statement for the WestConnex M4-M5 Link project (WestConnex Delivery Authority, 2017), which includes the Rozelle Interchange, does not predict long term (steady state) groundwater level drawdown for the WestConnex M4-M5 Link that lies within the predicted zones of groundwater level drawdown due to Stage 1. Based on this, the WestConnex M4-M5 Link tunnels are not expected to contribute cumulative impacts to Stage 1.

The Environmental Impact Statement for the Western Harbour Tunnel and Warringah Freeway Upgrade (Roads and Maritime Services, 2019) shows that the tunnels associated with this project lie to the west of The Bays Station construction site. Groundwater modelling results reported for this project indicate that it is likely to cause groundwater level drawdown in the vicinity of The Bays Station construction site. Based on the predicted groundwater level drawdown at the end of tunnel construction for the project, an additional groundwater level drawdown of up to three metres would be expected at The Bays Station construction site. This drawdown would be additive to the drawdown induced by Stage 1. The potential impacts of this cumulative drawdown and their significance are not expected to differ from those predicted for Stage 1 alone.

18.8 Management and mitigation measures

18.8.1 Approach to management and mitigation

Groundwater issues would be managed in accordance with Sydney Metro's Construction Environmental Management Framework which is described in Chapter 27 (Synthesis of the Environmental Impact Statement).

The Construction Environmental Management Framework requires the preparation of a Groundwater Management Plan and includes the following groundwater management objectives:

- Reduce the potential for drawdown of surrounding groundwater resources
- Prevent the pollution of groundwater through appropriate controls
- Reduce the potential impacts on groundwater dependent ecosystems.

18.8.2 Mitigation measures

The mitigation measures that would be implemented to address potential groundwater and ground movement impacts are listed in Table 18-13.

Table 18-13: Mitigation measures – groundwater and ground movement

Reference	Impact/issue	Mitigation measure	Applicable location(s) ¹
GW1	Loss of groundwater available to existing groundwater (bore supply) users	Site inspection would be carried out on private domestic supply bore GW305646 to confirm the current viability of that bore. If found to be viable, the bore would be monitored throughout construction. Make good measures would be implemented if a loss of yield were to occur.	BNS
GW2	Potential reduced baseflow to Toongabbie Creek, Domain Creek, A'Becketts Creek, Duck Creek, Haslams Creek, Powells Creek and the Mason Park wetlands, Bicentennial Park wetlands, Brickpit and Powells Creek Reserve	A review of additional geotechnical and hydrogeology data would be undertaken to confirm the geological and groundwater conditions and determine, based on these local conditions, whether predicted groundwater drawdown from Stage 1 is likely to occur in the vicinity of these creeks. Where the additional data review shows local conditions and predicted groundwater drawdown are likely to cause surface water-groundwater interaction, then additional site investigations (in accordance with GW3) would be undertaken for those creeks or surface water bodies.	WMS, CSMF, SOPMS, NSMS
GW3	Potential reduced baseflow to Toongabbie Creek, Domain Creek, A'Becketts Creek, Duck Creek, Haslams Creek, Powells Creek and the Mason Park wetlands, Bicentennial Park wetlands, Brickpit and Powells Creek Reserve Requirements for baseline monitoring of hydrological attributes	Additional site investigations would be carried out at creeks or surface water bodies where the additional data review in GW2 shows there is a likely surface water / groundwater interaction. This would involve baseline monitoring of creek flows (streamflow gauging) prior to construction, and baseflow streamflow analysis to confirm the existing groundwater baseflow contribution to streamflow for each creek. Where a significant reduction in baseflow is predicted due to Stage 1, design responses would be implemented at station and shaft excavations to reduce potential baseflow loss.	WMS, CSMF, SOPMS, NSMS
GW4	Requirements for baseline monitoring of hydrological attributes Migration of contaminants in groundwater and reduction in beneficial uses of aquifers	Monitoring of groundwater levels and quality at the site area would occur before, during and after construction. This would also include monitoring of potential contaminants of concern. Groundwater level data would be regularly reviewed during and after construction by a qualified hydrogeologist.	WMS, PMS, CSMF, SSF, SOPMS, NSMS, BNS, FDS, TBS

Reference	Impact/issue	Mitigation measure	Applicable location(s) ¹
GW5	Ground movement and settlement	A detailed geotechnical model for Stage 1 would be developed and progressively updated during design and construction. The detailed geotechnical model would include: <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. 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. 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.	Where required
GW6	Ground movement and settlement	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.	Where required

Note 1: WMS: Westmead metro station; PMS: Parramatta metro station; CSMF: Clyde stabling and maintenance facility; SSF: Silverwater services facility; SOPMS: Sydney Olympic Park metro station; NSMS: North Strathfield metro station; BNS: Burwood North Station; FDS: Five Dock Station; TBS: The Bays Station; Metro rail tunnels: Metro rail tunnels not related to other sites (e.g. tunnel boring machine works); PSR: Power supply routes.

18.8.3 Interactions between mitigation measures

Mitigation measures in other chapters that are relevant to the management of potential groundwater and ground movement impacts include:

- Chapter 19 (Soils and surface water quality – Stage 1), specifically measures which address acid sulfate soils, interaction with contaminated land and requirements for treated water discharge
- Chapter 20 (Contamination – Stage 1) specifically measures which address the management of potential contamination
- Chapter 22 (Biodiversity – Stage 1), specifically measures which addresses potential drawdown effects on groundwater dependent ecosystems.

Together, these measures would minimise the potential impacts of Stage 1.

There are no mitigation measures identified in the assessment of other environmental aspects that are likely to affect the assessment of groundwater and ground movement impacts.