

18 Groundwater

18.1 Overview

This chapter provides an assessment of the groundwater impacts associated with the construction and operation of Melbourne Metro. The chapter is based on the impact assessment presented in Technical Appendix O *Groundwater*. All relevant references are provided in Technical Appendix O.

Groundwater would be encountered across almost the entire Melbourne Metro alignment. A key requirement of the Melbourne Metro EES is that it assesses the potential risks and impacts of the project's development on groundwater dependent assets and identifies ways to protect groundwater quantity and quality in accordance with statutory requirements.

The principal potential impacts of Melbourne Metro on groundwater arise because most of the tunnels, stations and other sub-surface infrastructure are located below the watertable. Groundwater can seep into excavations that are below the watertable, which can result in groundwater drawdown around the structures during construction and operation. Groundwater drawdown is the primary pathway for potential impacts on groundwater dependent assets to occur. These assets include groundwater dependent surface water bodies such as the Yarra River and Moonee Ponds Creek, dependent vegetation, and existing bore users. Tanking methods (sealing structures to minimise groundwater inflow) would reduce groundwater inflow to negligible rates during both construction and operation, and prevent impacts to these assets.

The bored tunnels are proposed to be tanked as the TBMs progress, so inflows would be negligible during construction and operation. For the mined sections of tunnels and other excavations, the drawdown associated with construction would be short-term and groundwater levels would recover after tanking of the structures at the end of construction. As all structures associated with Melbourne Metro would be tanked for operation, drawdown would be insignificant post-construction. The removal, storage and transport of groundwater which flows into the excavations (especially in areas with known groundwater contamination) would require a high level of containment and best practice treatment, management and disposal measures.

The design and mitigation measures to be implemented would result in there being no significant adverse impacts to groundwater dependent assets from the construction or operation of Melbourne Metro. Temporary impacts to local groundwater dependent assets may occur during the construction of Melbourne Metro as a result of groundwater drawdown, but the use of standard design techniques and mitigation measures can minimise drawdown so that impacts are acceptable.

Drawdown from groundwater inflows prior to tanking of structures during construction is the primary pathway for impacts to occur on local groundwater dependent assets. The key drivers for groundwater management for the Melbourne Metro are the impacts of this groundwater drawdown on migration of existing groundwater contamination and on land settlement. While those issues are assessed in Chapter 20 *Contaminated Land and Spoil Management* and Chapter 19 *Ground Movement and Land Stability*, the groundwater impact assessment has identified mitigation measures in addition to the Concept Design that could be used to further reduce groundwater drawdown in order to manage contamination and settlement. It is expected that the detailed design would include mitigation measures such as grouting and temporary recharge bores at the western portal, Arden station and CBD South station to manage settlement. Mitigation measures would also potentially be required at CBD North station to manage existing groundwater contamination.

Some ground settlement due to groundwater drawdown could occur where the tunnels, stations, shafts and portals are close to palaeovalleys*, such as the Yarra River or Moonee Ponds Creek palaeovalleys. Asset condition surveys would be undertaken pre- and post-construction and groundwater levels would be monitored to manage this issue. Ground settlement is discussed in detail in Chapter 19 *Ground Movement and Land Stability*. Similarly, Chapter 20 *Contaminated Land and Spoil Management* discusses on-site contamination issues.

The potential impacts of the temporary lowering of groundwater levels on tree health has also been assessed and is considered to be a low risk in most precincts. Where temporary impacts to trees may occur, it is recommended that groundwater dependent trees are identified and irrigated over the period of drawdown.

The activation of potentially acid forming soils is another impact of groundwater drawdown that has been assessed. With application of mitigation measures, this risk is low in all precincts.

The contractor's CEMP would include well-established groundwater inflow prevention, minimisation and treatment practices along with control and disposal measures to manage and minimise groundwater risks. Specific controls would be included in the CEMP to minimise drawdown and impacts on local groundwater levels. These measures would include progressive tanking (sealing) during construction and fully tanked solutions during operation. They could also include grouting, recharge bores, tree watering, development of a detailed design model, groundwater monitoring and appropriate disposal of groundwater.

* Ancestral river valleys subsequently filled by sediment and other rock.

What is groundwater?

Groundwater is water located beneath the earth's surface. It is rainfall that has seeped through the ground and become stored in porous soils and rocks.

Groundwater can occur in tiny spaces between soil and rock particles or in narrow cracks and crevices in the rock itself.

Soils and rocks that transmit large quantities of groundwater are known as aquifers. The top of this saturated ground is known as the watertable. Soil and rock that restricts groundwater flow are called aquitards.

Groundwater comes from two main sources:

- Rain – when it rains, water seeps into the soil until it reaches the watertable of an aquifer
- Aquifers can also gain water from rivers and streams draining into the ground.

Groundwater is a finite resource. It is replenished only when rainfall and surface water seeps into aquifers. Groundwater quality varies from place to place. It can be naturally saline due to salt from rock and can also become contaminated, due to industrial discharges, agricultural practices, landfill and other processes.

Groundwater drawdown refers to the lowering of the groundwater level around an excavation or a bore.

In some areas, groundwater can be an important resource for drinking water supplies, irrigation, industrial development, and ecosystem and streamflow maintenance. Increasing demand for water and a trend towards a drier climate is placing pressure on some groundwater resources.

At the national and state levels, Australian governments have policies in place to manage groundwater. These plans aim to achieve a balance between water use and the water needs of the environment, as well as controlling groundwater pollution and overuse.

18.2 EES Objective

The EES Scoping Requirements set the following draft evaluation objective for the EES:

- *Hydrology, water quality and waste management – To protect waterways and waterway function and surface water and groundwater quality in accordance with statutory objectives, to identify and prevent potential adverse environmental effects resulting from the disturbance of contaminated or acid-forming material and to manage excavation spoil and other waste in accordance with relevant best practice principles.*

In accordance with this objective, a study was conducted to document existing groundwater conditions within the project boundary and provide a preliminary identification of the potential impacts and risks for groundwater dependent assets associated with the construction and operation of Melbourne Metro.

Using this information, Environmental Performance Requirements and proposed mitigation measures have been recommended to manage adverse groundwater impacts associated with the project.

18.3 Legislation and Policy

As discussed in Chapter 4 *EES Assessment Framework and Approach*, groundwater encountered by Melbourne Metro would be assessed and managed in accordance with Commonwealth and Victorian groundwater quality standards, objectives and management requirements. The main laws and policies relevant to Melbourne Metro are set out in the table below.

Table 18–1 Groundwater legislation and policy relevant to Melbourne Metro

Legislation	Policy/guideline	Comment
Commonwealth		
<i>National Environment Protection Council Act 1994</i>	National Environment Protection (Assessment of Site Contamination) Measure	<p>This Act and complementary State and Territory legislation enable the National Environment Protection Council to prepare National Environment Protection Measures. These measures assist in protecting or managing particular aspects of the environment. The NEPMs covering groundwater are the National Environment Protection (Assessment of Site Contamination) Measure and Amendment Measure 2013 (No. 1) Amendment of the National Environment Protection (Assessment of Site Contamination).</p> <p>The impact of groundwater interactions from the project would be assessed in accordance with the Assessment of Site Contamination NEPM, as adopted by the complementary Victorian State Environment Protection Policy: SEPP (Groundwaters of Victoria).</p>
	Australian Standard 2159-2009: Piling – Design and Installation	<p>This standard sets out minimum requirements for the design, construction and testing of piled footings for civil engineering and building structures on land or immediate inshore locations. The detailed design of any Melbourne Metro structures would need to take into account potential aggressive ground conditions in accordance with this standard.</p>
State		
<i>Water Act 1989</i>		<p>The <i>Water Act 1989</i> is the primary legislation for the management of water resources in Victoria. In the context of groundwater, this Act establishes the DELWP as the authority responsible for the sustainable, efficient, equitable management and allocation of groundwater. For groundwater in southern Victoria, the DELWP has delegated this responsibility to Southern Rural Water, whose responsibilities include licensing any extraction from and injection to the groundwater system.</p> <p>Groundwater dewatering and recharge through bores requires a licence from Southern Rural Water (for construction of bores and for pumping from/to bores).</p>
	Water Industry Regulations 2006	<p>These regulations set out the criteria for discharging trade waste to sewers.</p> <p>A Trade Waste Agreement would be required to enable discharges to sewer. Acceptance criteria define the contaminant load/concentration permitted.</p>

Legislation	Policy/guideline	Comment
<i>Environment Protection Act 1970</i>	SEPP (Groundwaters of Victoria) (GoV)	<p>The <i>Environment Protection Act 1970</i> was developed to protect and improve the environment in Victoria by regulating discharge and emissions of waste to land, air or water and setting environmental goals and programs. The Act provides for the development of SEPPs, which identify beneficial uses of the environment that require protection and specify environmental quality indicators and targets that protect these uses.</p> <p>SEPP (GoV) categorises the groundwater environment into segments based on background groundwater salinity. Beneficial uses of groundwater required to be protected, and quality objectives protective of each beneficial use are designated for each groundwater segment. Protected beneficial uses include Maintenance of Ecosystems; Potable Water Supply; Potable Mineral Water Supply; Agriculture, Parks and Gardens; Stock Watering; Industrial Use; Primary Contact Recreation; and Buildings and Structures.</p>
	SEPP (Waters of Victoria) (WoV)	SEPP (WoV) includes objectives for the protection of surface water beneficial uses and the maintenance of ecosystems, which includes the point of discharge/interaction of groundwater and surface water.
	EPA Victoria powers and guidelines	<p>The Act provides for Environmental Audits, which are an integral part of Victoria's land use planning and approvals process. The EPA publishes guidelines for managing groundwater, including:</p> <ul style="list-style-type: none"> • Groundwater Sampling Guidelines (Publication 669) • Guidelines for Hydrogeological (Groundwater Quality) Assessments (Publication 668) • Sampling and Analysis of Waters, Wastewaters, Soils and Wastes Publication, EPA Victoria Publication IWRG701 (June 2009) • The cleanup and management of polluted groundwater (Publication 840.1).
	Australian groundwater modelling guidelines – Waterlines Report Series No. 82, June 2012 (Sinclair Knight Merz and National Centre for Groundwater Research and Training)	The Australian groundwater modelling guidelines are intended as a reference document to ensure consistency for groundwater modellers, project proponents (and model reviewers), regulators, community stakeholders and model software developers who may be involved in the process of developing a model and/or modelling studies.

Legislation	Policy/guideline	Comment
	EPA Environmental Guidelines for Major Construction Sites (Publication 480)	These guidelines would be incorporated within the Construction EMP for the project. This would include the development of a dewatering strategy and the implementation of groundwater control measures.

18.4 Methodology

18.4.1 Assessment Approach

Study Area

The study area for the groundwater impact assessment was based on the extent of the regional groundwater model, which covers an area of approximately 26 km². This original area was extended for the impact assessment to include previously identified groundwater values – namely, the irrigation bores located at Flemington Racecourse 1.7 km northwest of the start of the western portal decline structure. The western turnback in West Footscray was also included in the study area.

The vertical extent of the study area was based on the Melbourne Metro vertical alignment and extends up to 40 m below ground level.

Assessment Methodology

Using available baseline and background data (see Section 18.5), a groundwater impact assessment was conducted. This included:

- Obtaining and assessing groundwater data and meteorological information to establish existing conditions and characteristics within the study area
- Reviewing the construction and operation activities proposed for the Concept Design in each Melbourne Metro precinct, and identifying the activities that would result in potential impacts on groundwater
- Confirming the locations of key sensitive receptors that could be impacted during the construction and operation phases
- Identifying the main potential groundwater impacts and risks for each precinct
- Establishing measures to avoid or minimise adverse groundwater impacts during construction and operation of Melbourne Metro.

In addition, this assessment was independently peer reviewed.

18.5 Existing Conditions

Baseline groundwater conditions have been determined for each precinct through field investigations and from data from previous studies. These include the geology across the Melbourne Metro alignment, existing aquifers and their properties, depth to groundwater, groundwater quality, current groundwater users and the presence of surface water bodies and vegetation that are potentially dependent on groundwater. Key findings in relation to groundwater baseline conditions are summarised in the following sections.

18.5.1 Geology

The geology of Melbourne consists of Silurian bedrock overlain by Tertiary and Quaternary sediments and basalts. The Silurian bedrock in the area of the Melbourne Metro project is the Melbourne Formation, which consists of mudstone, sandstone and siltstone that has been folded, faulted and intruded with igneous rocks. These rocks have been weathered to varying depths, with fresh (unweathered) rock sometimes existing within the shallow profile, whereas in other areas weathered bedrock has been encountered at depths of 60 m.

The nearest granite intrusion in the project area is near the eastern portal, where some minor metamorphosis of the siltstone has also occurred. It is not expected that metamorphosed rocks would be encountered by the tunnels. Volcanic dykes and sills are expected to be encountered across the project alignment. These intrusions have been moderately to extremely weathered to clay and range in thickness from <1 m to 16 m.

The Melbourne Formation is overlain by Tertiary sediments and volcanics, including lake and swamp deposits (Werribee Formation), basalt flows and ash (Older Volcanics), marine sediments within eroded valleys and sandy material (Brighton Group). A series of sea level fluctuations in the Quaternary period then deposited gravels, sands, silts and clays in the Yarra Delta. These formations include Fishermans Bend Silt, Coode Island Silt, Moray Street Gravels and Quaternary Fluvial Sediments. These formations comprise the palaeovalley sediments around the Yarra River, Maribyrnong River and Moonee Ponds Creek, and variously underlie much of Port Melbourne and South Melbourne. Surface geological conditions are shown in Figure 18-1 and sub-surface conditions are shown in Figure 18-2.

18.5.2 Aquifers

Forming part of the groundwater system, aquifers are permeable rocks or soil that transmit groundwater. Aquifer types in the vicinity of Melbourne Metro are either fractured rock or porous aquifers. A fractured rock aquifer is one where groundwater is stored and transmitted through fractures or joints in the rock, such as in the Older Volcanics or Silurian mudstones. A porous aquifer is one where water is stored and transmitted in the pore spaces of unconsolidated or semi-consolidated materials, such as in the Moray Street Gravels.

Aquifers can either be confined or unconfined depending on whether the aquifer is closest to the surface and hosts the watertable (unconfined) or is buried beneath other units (confined). For most of the study area the Melbourne Formation is unconfined and forms the watertable aquifer. However, in the palaeovalleys where Tertiary and Quaternary sediments overlie it, the Melbourne Formation behaves as a confined aquifer.

The Fishermans Bend Silt and Coode Island Silt act as confining layers to the underlying sediments in the Yarra River palaeovalley. The confined units below the Fishermans Bend Silt (Moray Street Gravels, Quaternary Fluvial Sediments and Lower Newer Volcanics Flow) are likely to have some degree of hydraulic connectivity. There may also be hydraulic connectivity between these units and the overlying Holocene Alluvium in some locations.

Between the Maribyrnong River and Moonee Ponds Creek, the Werribee Formation and Older Volcanics are confined where they are overlain by the Coode Island Silt and unconfined or semi-confined elsewhere.

18.5.3 Groundwater Levels

The highest groundwater elevations along the alignment occur in the Parkville area at 25 m AHD (Australian Height Datum) and the lowest groundwater levels occur in the area of the CityLink tunnels under Kings Domain at around – 10 m AHD. Regionally, the highest groundwater levels are associated with higher topographic areas. The lowest groundwater elevations coincide with groundwater sinks such as the North and South Yarra Main Sewers, the City Loop tunnels and the CityLink tunnels as well as deep basements in Parkville, the CBD and Southbank.

Figure 18-1 Surface geology across the Melbourne Metro alignment

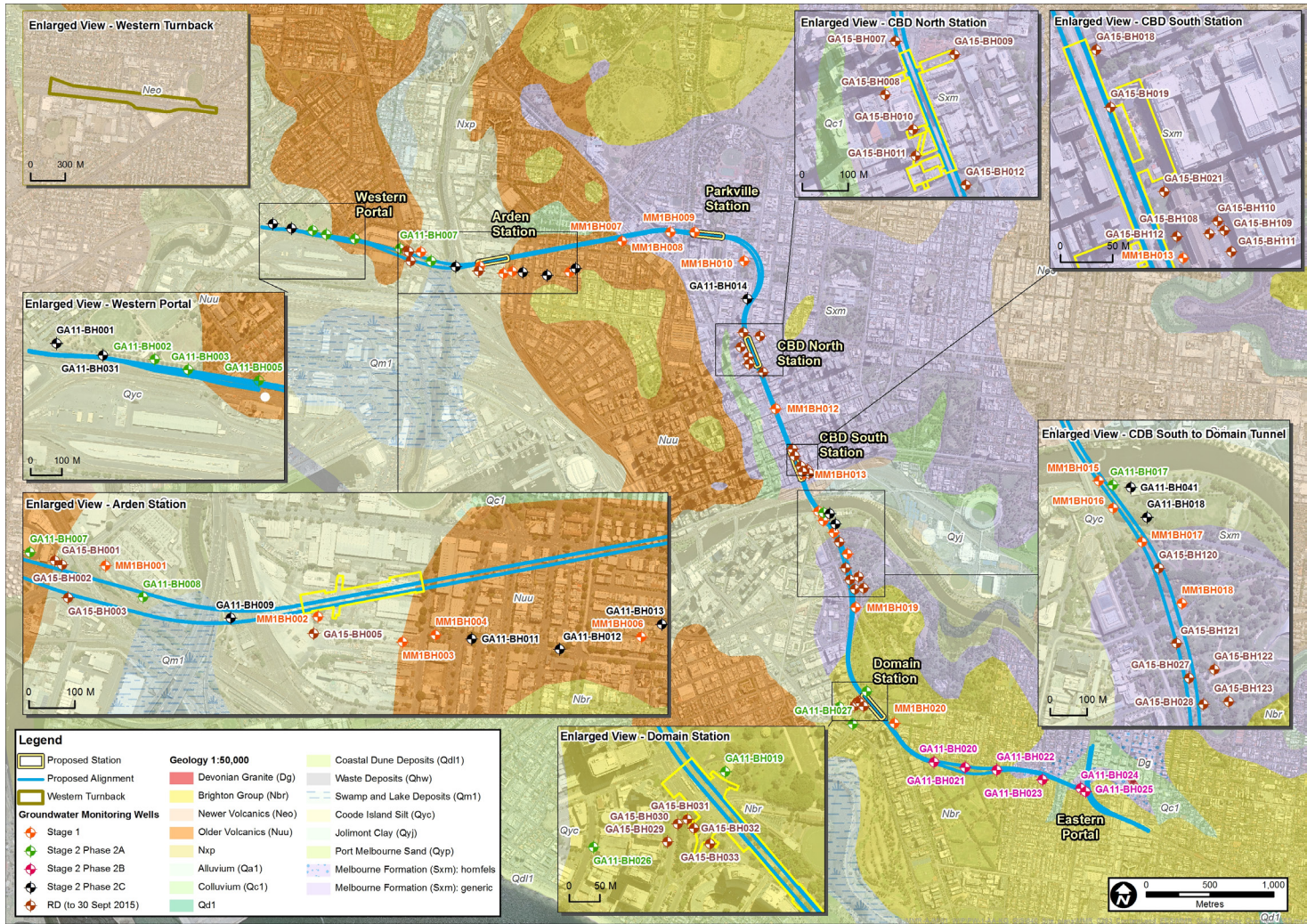
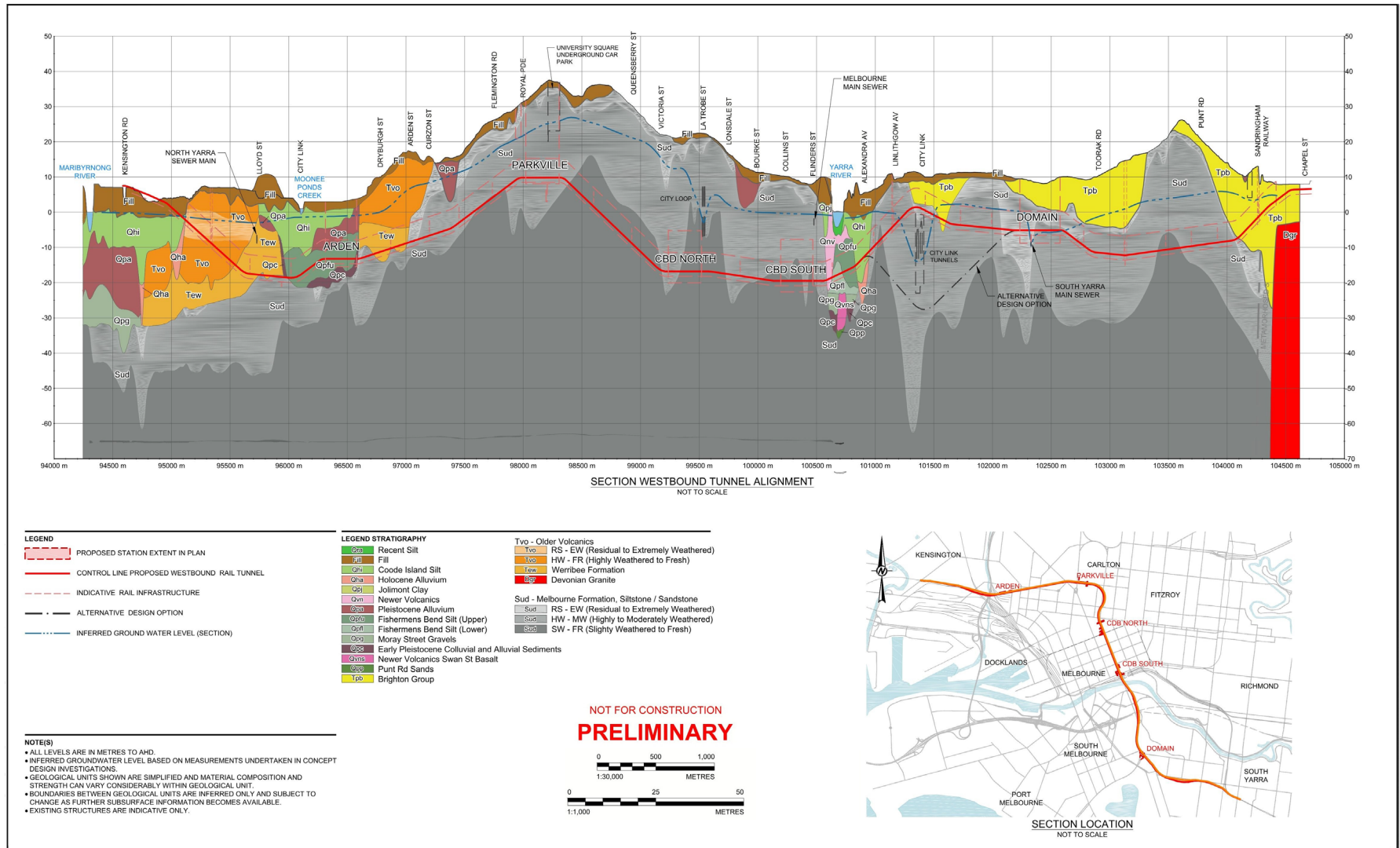


Figure 18-2 Cross section geology across the Melbourne Metro alignment



18.5.4 Groundwater Quality

Natural groundwater quality varies across the alignment and is controlled by water-rock interactions and interaction between groundwater and surface water sources. The salinity of the groundwater ranges from 1,300 mg/L to 38,000 mg/L total dissolved solids (TDS), with a regional trend of higher salinity in the west and lower salinity in the east of the alignment. Elevated salinities also occur in deeper confined aquifers where the alignment crosses the Maribyrnong River, Moonee Ponds Creek and Yarra River. These higher salinities are probably due to sea water intrusion from the estuarine reaches of the rivers.

The potential uses of groundwater are defined based on groundwater salinity. Over the Melbourne Metro alignment, three beneficial uses segments are applicable (SEPP GoV):

- Segment C from the western portal to CBD North station, which requires protection of groundwater quality for ecosystem maintenance, stock watering, industrial water use, and primary contact
- Segment B from CBD North station to the eastern portal, which requires protection of groundwater for the above uses as well as for mineral water supply and irrigation
- Segment A in some parts of the eastern portal precinct, which requires protection of all beneficial uses including drinking water.

Groundwater parameters

Salinity

Total dissolved solids (TDS) is a measure of groundwater salinity. TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water. Sulfate concentration is usually highly correlated with salinity.

Groundwater levels

Groundwater levels are a measurement of the depth or elevation above or below sea level where groundwater occurs and ground is saturated with water.

Hydraulic conductivity/transmissivity

Hydraulic conductivity describes the ease with which a fluid (usually water) can move through soil pores or rock fractures when submitted to a hydraulic gradient. Hydraulic conductivity is measured as the rate of flow through a cross-sectional area of aquifer. Transmissivity is measured as the rate of flow under a unit hydraulic gradient through a unit width of aquifer of unit thickness.

Soils with high hydraulic conductivity have a greater potential for groundwater contamination by a contaminating source. Higher hydraulic conductivity occurs in the aquifers (Moray Street Gravels and Holocene Alluvium) and lower hydraulic conductivity occurs in the aquitards (Fishermans Bend Silt and Jolimont Clay).

Human activities have also influenced groundwater quality, and areas of groundwater contamination from current or historical land uses exist in some areas along the alignment. This contamination could be mobilised by groundwater drawdown resulting from Melbourne Metro's construction activities and long-term operation. Contaminant migration could impact the beneficial uses of groundwater at sites adjoining the areas of existing contamination, and could also cause volatile contaminants to come into contact with underground structures, creating a risk of vapour intrusion to the underground structures. Both of these risks could impact groundwater users, the health and safety of construction workers, groundwater disposal options and, potentially, other drained structures in the areas (such as basements).

A number of Groundwater Quality Restricted Use Zones have been designated at sites in the vicinity of the Melbourne Metro alignment and have been identified for each precinct. The designation indicates that groundwater is contaminated to an extent that it is not suitable for certain uses.

A plume of contaminated groundwater is known to occur on the tunnel alignment between the Parkville and CBD North stations, associated with a former industrial site located at 539-553 Swanston Street, Carlton (the key contaminant is trichloroethylene –TCE) and a former service station on Swanston Street in Carlton (the key contaminants are dissolved petroleum hydrocarbons).

Groundwater samples have been collected for laboratory analysis from a total of 65 bores along the Melbourne Metro alignment.* Technical Appendix O *Groundwater* provides the full groundwater sampling results. The majority of bores sampled along the alignment did not detect significant contamination at tunnel depth. Concentrations of organic compounds were generally below laboratory detection levels, but a comparison of contaminant concentrations with Groundwater Investigation Levels showed that organic compounds exceeded some of the adopted Groundwater Investigation Levels in eight bores across the alignment. The bores with identified exceedances above Groundwater Investigation Levels are located at the western portal, CBD North, CBD South, the tunnels between Parkville and CBD North stations, and the tunnels between CBD South and Domain stations. In all cases, the concentrations of organic compounds were relatively close to the Groundwater Investigation Level values, and as such, may be indicative of low-level contamination of soil and groundwater from the intensive land use in the area, rather than specific contaminant plumes. Elevated levels of metals were detected, however these are expected to be predominantly the result of interactions between the groundwater and aquifer rocks and sediments, and as such are naturally occurring rather than contamination.

* The contaminated land and spoil management impact assessment conducted for the EES identifies potential sources of contamination based on available data: see Chapter 20 and Technical Appendix Q *Contaminated Land and Spoil Management*.

It should be noted that the bores along the alignment have generally been designed to monitor the groundwater at the depth of the tunnels. The bores have not been designed to monitor potential contamination. Whilst it is possible that there would be some organic contamination of the groundwater that has not been identified by the groundwater bore samples, they are only one of the lines of evidence used for assessing contamination. A combination of evidence, including groundwater bore samples, identification of Groundwater Quality Restricted Use Zones in the vicinity of the area and information on the current and historical land use, has been used to establish the level and type of contamination.

There is a possibility of activating potential acid sulfate soil (PASS) through lowering of the watertable in Coode Island Silt or in fresh to slightly weathered Melbourne Formation. Acid sulfate soil or acid sulfate rock can occur naturally and comprises soils, sediment or rocks that contain elevated concentrations of iron sulfides. These iron sulfides formed when the soil was waterlogged and rich in organic material. Under conditions where there is no air available and where soils are below the watertable, the sulfides in the soil remain stable and do not present any environmental concerns. However, if the watertable is lowered or soil is excavated and exposed to air, a chemical reaction between the sulfides and oxygen produces acid. This can cause groundwater acidification and lead to the release of heavy metals from the rock and soils. When the watertable rises, the acidic groundwater and heavy metals can mobilise, causing potential impacts on aquatic vegetation and deep rooted vegetation, as well as corrosion of underground concrete and steel structures, foundations or services.

The Coode Island Silt and unweathered Melbourne Formation are the units that contain the most sulfides and are therefore associated with a risk of potential acid sulfate soil activation. Impacts related to excavation of the potential acid sulfate soil and their management are addressed in Chapter 20 and Technical Appendix Q *Contaminated Land and Spoil Management*. Technical Appendix O *Groundwater* considers the potential impacts associated with dewatering that could occur during the construction and operation of structures below the watertable.

18.5.5 Groundwater Users

There are 20 bores registered for 'stock and domestic' groundwater use in the vicinity of the alignment; however, investigations have indicated that these bores are not used and it is expected that most of them no longer exist. Discussions with Southern Rural Water indicate that most of these bores can be disregarded on the grounds that they are no longer active or do not exist. Seven bores have been identified as possibly existing and the potential impacts on these bores have been assessed.

18.5.6 Connection between Groundwater and Surface Water

It is unlikely that groundwater along the alignment contributes significantly to river and creek flow based on the groundwater levels and presence of low permeability sediments in the base of the watercourses. The Moonee Ponds Creek, Yarra River and Albert Park Lake are unlikely to be connected to groundwater. However, the ponds in the Royal Botanic Gardens were observed to respond to groundwater drawdown during CityLink construction and are therefore considered to be groundwater dependent.

18.5.7 Groundwater Dependent Vegetation

Potential groundwater dependent vegetation in the study area includes deep rooted vegetation in areas where groundwater levels are shallow, such as around watercourses, lakes and ponds. The arboriculture studies conducted for the EES (see Technical Appendices R and S *Arboriculture*) have concluded that there are no trees within the project boundary that are dependent upon groundwater, with the possible exception of one eucalypt at the eastern portal.

However, since drawdown may occur outside the project boundary, trees further from the alignment have also been considered. In the west of the study trees are more likely to rely on water sources such as soil water or leaking pipes than groundwater, since groundwater in the area is saline. In the east of the study area groundwater is fresher, and where it is shallow, is more likely to provide a water source for deep-rooted trees, particularly during dry periods. Shallow groundwater occurs around the Yarra River, Albert Park Lake, and the ponds in the Royal Botanic Garden. Therefore, deep-rooted trees in these areas are considered to be potentially groundwater dependent in this assessment.

18.6 Risk Assessment

An Environmental Risk Assessment has been completed for impacts of the Melbourne Metro in relation to groundwater. Further information about the risk assessment approach adopted for Melbourne Metro is included in Chapter 4 *EES Assessment Framework and Approach*.

An impact assessment must be informed by a risk assessment so that the level of mitigation action relates to the likelihood of an adverse impact occurring.

Potential hydrogeological hazards to environmental, economic and social assets from Melbourne Metro would be predominantly related to groundwater inflows and associated groundwater drawdown around Melbourne Metro’s infrastructure. Drawdown could occur during construction and operation of Melbourne Metro and could impact existing groundwater users, surface water bodies that rely on groundwater contributions or groundwater dependent vegetation. Drawdown could also cause groundwater quality impacts, including migration of existing contaminant plumes to areas previously unaffected by contamination, and activation of potential acid sulfate soil.

The risk of aquifer damming was also considered, whereby below ground infrastructure may restrict groundwater flow through an aquifer, causing changes to groundwater levels upstream and downstream of the structure.

These risks have been assessed for the EES. Other risks related to groundwater drawdown include ground settlement, which has been assessed Technical Appendix P *Ground Movement and Land Stability* and inflow of contaminated groundwater to Melbourne Metro structures, which has been assessed in Technical Appendix Q *Contaminated Land and Spoil Management*.

A number of groundwater risks were assessed as having high and medium initial risk ratings. As a result of the impact assessment, project-specific Environmental Performance Requirements – combined with proposed mitigation measures – have been recommended to reduce these risks. Achieving these requirements would be expected to reduce the residual risk ratings of all but one risk to low or very low.

As shown in Table 18–2, the only remaining risk assessed as having a medium residual risk rating level relates to the potential migration of known groundwater contaminant plumes as a result of dewatering during construction of CBD North station, and impacts to the uses of groundwater at neighbouring properties. A full list of groundwater risks, showing the initial and residual rating of each risk, is provided in Technical Appendix O *Groundwater* and in Technical Appendix B *Environmental Risk Assessment Report*.

The recommended Environmental Performance Requirements are listed in Section 18.18.

Table 18–2 Groundwater risks

Impact pathway		Project phase	Precinct	Residual risk rating
Category	Potential event			
Potential groundwater inflows to structures causing drawdown	Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures	Construction	5 - CBD North station	Medium

Activities with low groundwater related residual risk outcomes include diaphragm wall and secant pile wall construction, the operation of construction ventilation shafts and exhaust fans, boring and excavation works for the tunnels, restoration of surface areas and dewatering during the operation of the Melbourne Metro stations.

18.7 Impact Assessment

Potential groundwater impacts from Melbourne Metro would be primarily associated with construction activities. These potential impacts would be expected to occur at precinct or local levels only, and no significant adverse impacts to regional groundwater would be anticipated. Some minor impacts may occur during operation, but these potential impacts are low risk. Analysis has been undertaken to assess the anticipated volumes of groundwater that would flow into excavations (shafts, stations, portals, tunnels) during the construction and operational phases of the project.

The impact assessment involved data collection and analysis that allowed confirmation of whether the initial risk ratings were appropriate. In some cases, the initial risk ratings were changed based on the findings of the impact assessment, which revised either the likelihood of an impact occurring, or the consequence if the impact occurred.

For hazards that had an initial risk rating of medium or higher, the impact assessment enabled recommended Environmental Performance Requirements and mitigation measures to be identified. In all but one case, these measures reduced the risk to a residual risk rating of low or very low. There is only one hazard for which the residual risk rating remains medium: migration of the contaminant plume near CBD North station during construction impacting beneficial uses of groundwater at neighbouring properties. Further assessment of possible ways to mitigate this risk is currently underway.

Project-wide Environmental Performance Requirements have also been developed to ensure that impacts are within the predicted range and mitigation measures are sufficient to protect groundwater dependent values. These include adoption of detailed design features that minimise groundwater drawdown, further modelling of impacts in the detailed design phase and development of a Groundwater Management Plan detailing how potential impacts would be mitigated during construction.

An assessment has been undertaken to assess potential options for disposal of this groundwater. The impact assessment concludes that there are only two feasible options for disposal of groundwater inflows to excavations during construction and operation of Melbourne Metro: to sewer or stormwater (or a combination of both). Disposal to sewer is the preferred solution. Current inflow water quality constraints indicate that further assessment and discussion with regulators and Melbourne Water would be required. Disposal to stormwater is an option if sewer disposal is problematic. This option would require further evaluation and be subject to regulatory approval. The preparation of a Groundwater Disposal Strategy has been recommended.

Sections 18.8 to 18.16 describe the potential impacts predicted for each of the Melbourne Metro precincts, as well as the recommended Environmental Performance Requirements and recommended mitigation measures for each precinct.

18.7.1 Construction

Construction activities may cause drawdown around Melbourne Metro stations, tunnels, shafts and portals as a result of groundwater inflows to the structures. Groundwater dependent assets within the area of potential groundwater drawdown would be susceptible to impacts. The potential impacts are listed in Table 18–3, along with the proposed mitigation measures that would be applied to minimise impacts.

Table 18–3 Predicted main impacts of drawdown during construction

Groundwater dependent asset or risk	Unmitigated impact	Precinct	Proposed mitigation measures
Large trees that may access groundwater	Trees within the project boundary are not considered to be groundwater dependent (see Technical Appendices R and S). Trees outside the project boundary have not been assessed but trees in low lying areas such as near watercourses or waterbodies are considered potentially groundwater dependent	Construction <ul style="list-style-type: none"> Precinct 1 (<i>tunnels between CBD South and Domain stations</i>) – Linlithgow Avenue shaft construction Precinct 6 - CBD South station Precinct 8 - Eastern portal 	Deep-rooted tree species in areas of shallow groundwater should be identified and their dependence on groundwater should be assessed. If found to be groundwater dependent, the trees within the area of drawdown should be irrigated throughout the period of drawdown

Groundwater dependent asset or risk	Unmitigated impact	Precinct	Proposed mitigation measures
Beneficial uses of groundwater at third party properties degraded by migration of contaminant plumes	Moderate risk of impact on third party properties based on land use, presence of Groundwater Quality Restricted Use Zones and/or anthropogenic contaminants within predicted area of impact	Construction <ul style="list-style-type: none"> • Precinct 1 - Tunnels • CBD North station to CBD South station • Domain station to eastern portal (shaft in north-east corner of Fawkner Park) • Precinct 2 - Western portal • Precinct 3 - Arden station • Precinct 4 - Parkville station • Precinct 5 - CBD North station • Precinct 8 - Eastern portal 	Likely to involve further investigation and/or mitigation measures, for example: <ul style="list-style-type: none"> • Site specific risk assessment of contaminant location and concentrations • Use of temporary recharge or discharge bores to prevent contaminant migration • Minimisation of drawdown through construction techniques such as construction using a TBM or grouting of the tunnels
Beneficial uses of groundwater at third party properties degraded by groundwater acidification from potential acid sulfate soil activation	Moderate risk of impact on Beneficial Uses of groundwater within predicted area of impact	Construction <ul style="list-style-type: none"> • Precinct 1 - Tunnels • CBD North station to CBD South station • Precinct 3 - Arden station 	Testing of rock cores to assess site specific risk of potential acid sulfate soil. Prevent acidification of groundwater by minimizing drawdown in the area: <ul style="list-style-type: none"> • Use of injection or discharge bores to prevent drawdown and contaminant migration • Minimisation of drawdown through construction techniques such as construction using a TBM or grouting of the tunnels
Reduced groundwater levels at CityLink recharge bores	Some drawdown predicted at CityLink recharge bores	Construction <ul style="list-style-type: none"> • Precinct 1 - Tunnels • CBD South station to Domain station - Linlithgow shaft construction • Precinct 6 - CBD South station 	Mitigation measures would include grouting, and temporary injection bores located in the Yarra River palaeovalley

Drawdown has been assessed individually for each precinct and each tunnel section, but in practice, drawdown would occur at the same time for adjacent precincts as construction progresses. Where significant drawdown occurs, the drawdown cone from one precinct (or tunnel section) may intersect with the drawdown cone from a neighbouring precinct. The cumulative effect where drawdown cones overlap is a greater total drawdown, which may increase impacts on groundwater dependent values in the areas of overlap.

In the areas of the alignment where cumulative impacts would be most significant (such as the mined tunnels and CBD North and CBD South stations), mitigation measures, such as those described in Table 18–3, would be employed to manage drawdown. This mitigated drawdown – even allowing for cumulative impacts – is expected to be significantly less than the unmitigated drawdown (not allowing for cumulative impacts) on which this assessment is based. Prediction of cumulative drawdown is therefore not critical for identifying risks in this assessment, but would be analysed further as part of the detailed design phase of the project.

18.7.2 Operation

Groundwater dependent assets would not be susceptible to impacts during operation due to the sealing of tunnels and sub-surface structures that would result in negligible groundwater seepage into tunnels or structures.

18.8 Precinct 1: Tunnels

18.8.1 Construction

Most of the tunnels would be constructed using a TBM. During construction, the TBM would maintain a pressure at its face to counter groundwater pressure. The tunnels would then be tanked almost immediately by installation of segmented lining as the TBM progresses. These methods largely prevent groundwater inflows during construction.

The mined sections of the tunnels between CBD North and CBD South stations would not be tanked as quickly as the bored tunnels due to the excavation technique. The mined tunnels construction method allows groundwater to seep into the excavation and these sections of the tunnels would be drained during construction. In cases where unacceptable inflow and drawdown impacts are predicted, additional mitigation measures such as grouting of the tunnels and the use of temporary injection bores would be applied to reduce impacts.

Cross passages and shafts could also act as drained structures during construction where they are under the watertable. However, for constructability reasons (depending on the geological material at the cross passage), techniques that prevent groundwater inflow may be required (such as grouting or ground freezing).

Tunnels Sector: Western Portal to CBD North Station

These sections of tunnels would be bored by TBMs, which largely prevent groundwater inflows during construction. Therefore, no impacts associated with groundwater drawdown are predicted.

Tunnels Sector: CBD North Station to CBD South Station

If no mitigation measures are implemented to prevent inflows, the drawdown from excavation and construction of the mined tunnels would be predicted to extend several hundred metres to the east and west of the tunnels by the end of construction.

As a result of the predicted unmitigated drawdown, potential impacts may include:

- Migration of existing contaminants to third party properties. There are three Groundwater Quality Restricted Use Zones within the area of drawdown, although these would be primarily influenced by drawdown from CBD North station as discussed in Section 18.12
- Groundwater acidification due to exposure of potentially acid forming Melbourne Formation.

Construction techniques to limit inflows to the tunnels and consequent drawdown of the groundwater levels would be employed, principally forward grouting at the tunnel face. With appropriate mitigation measures, the drawdown around the tunnels would be minor and groundwater drawdown would be minimised. Groundwater dependent values in the area would therefore not be impacted.

There are no active groundwater users within the predicted area of drawdown around this section of the Tunnels precinct. Similarly, the surface water bodies and vegetation within the area of drawdown are not expected to be dependent on groundwater (see Section 5 of Technical Appendix O). Therefore, drawdown would not impact these values.

Anthropogenic (human caused) Contamination has been detected in some samples along the tunnel alignment between CBD North station and CBD South station. Given the intensive development in the area, this could reflect diffuse contamination of the aquifer or may be indicative of particular contaminant plumes. The extent of the predicted drawdown would intersect this area of potential contamination and could cause migration of contaminants towards the tunnels. Due to the uncertainty about whether contaminant plumes exist, there is considered to be a medium risk of migration of contaminants and associated vapour migration in the area of drawdown. Mitigation measures and complimentary monitoring would be implemented during construction to reduce this risk to low. The predicted level of drawdown would be significantly reduced provided mitigation strategies such as pre/post-excavation grouting are effectively employed during construction to limit inflows and drawdown.

The risk of groundwater acidification due to activation of potential acid sulfate soil is considered to be low, as groundwater levels in this area are controlled by the City Loop tunnels and therefore have already been drawn down. The risk of any significant offsite impacts from potential acid sulfate soil at the southern end of this section is also considered low as mitigation measures including grouting and injection bores would limit drawdown in this area.

Tunnels Sector: CBD South Station to Domain Station

This section of tunnels would be bored by TBMs, which largely prevent groundwater inflows during construction. As such, the tunnel construction would not be expected to result in any impacts to groundwater dependent assets. The Linlithgow Avenue emergency access shaft would be above the watertable, and would therefore not cause groundwater drawdown and impacts.

A potential alternative design option for this tunnels sector is a deeper tunnel alignment, which would result in a deeper emergency access shaft being required. The deeper shaft would intersect the watertable and groundwater inflows could potentially occur during construction.

If a drained approach was taken during construction, the predicted drawdown extends several hundred metres from the shaft by the end of construction. Unmitigated drawdown at the emergency access shaft could impact on the following:

- A possible groundwater bore (WRK972626) 450 m east of the Linlithgow Avenue emergency access shaft (below CityLink) alternative design operation
- Large trees that may use groundwater near the Yarra River
- Migration of existing contaminants to third party properties. There is one Groundwater Quality Restricted Use Zone within the area of drawdown, and anthropogenic contamination has been detected at depth
- CityLink recharge wells to the east and west of the shaft.

It is expected that groundwater does not contribute to the Yarra River and therefore, drawdown impacts would be unlikely and have not been assessed. The justification for this assessment is provided in Appendix O *Groundwater*. Albert Park Lake and the lake in the Royal Botanic Gardens are outside the predicted area of drawdown associated with construction of the Linlithgow Avenue emergency access shaft (below CityLink) alternative design option.

A decline in groundwater levels that reduces the available drawdown in a bore by more than 10 per cent would be considered to have a significant impact on existing groundwater users. A reduction of available drawdown of up approximately 7 per cent has been predicted for the possible groundwater bore in this precinct. This predicted impact is within acceptable limits.

Vegetation in areas of shallow watertables within the area of predicted drawdown may be impacted during construction. Deep-rooted tree species should be identified and their dependence on groundwater should be assessed. If found to be groundwater dependent, the trees within the area of drawdown should be irrigated through the period of drawdown. This measure is expected to fully mitigate any potential impacts on trees that may be caused by groundwater drawdown.

The extent of the predicted drawdown cone would intersect one Groundwater Quality Restricted Use Zone located 500 m to the south-west of the emergency access shaft. The drawdown could cause migration of contaminants to previously uncontaminated areas, which could impact the beneficial uses of groundwater at third party properties. However, drawdown at the Groundwater Quality Restricted Use Zone is predicted to be minor (1 m or less); therefore, significant migration of the contaminants would not be likely during the short timeframes of construction. The risk of these contaminants precluding beneficial uses at third party properties is considered to be low.

Drawdown at the CityLink bores is predicted to be minor, but may still result in some depressurisation of the Coode Island Silt, which may require an increase in injection volumes or cause ground settlement. The ground movement impact assessment (Technical Appendix P *Ground Movement and Land Stability*) reviews the potential impacts of this level of drawdown in detail. Acceptable impact levels are to be agreed during the detailed design phase. Mitigation measures such as grouting of the shaft and establishing a temporary injection borefield in the Yarra River palaeovalley would reduce the predicted extent of drawdown so that the CityLink bores are unlikely to be affected.

Tunnels Sector: Domain Station to Eastern Portal

In an unmitigated scenario, drawdown would be predicted at the proposed Fawkner Park TBM launch shaft and the emergency access shaft in this tunnels sector. By the end of construction, groundwater drawdown could potentially extend several hundred metres from the shafts if no mitigation measures were applied.

Potential impacts on groundwater dependent values from this level of drawdown include:

- Third parties with properties close to possible contaminant plumes. Although there are no Groundwater Quality Restricted Use Zones within the area of predicted drawdown, there may be other contaminant plumes given the historical industrial land use of the area
- Groundwater acidification due to exposure of potentially acid forming Melbourne Formation.

There are no active groundwater users within 1 km of the tunnels and the area of impact does not intersect Albert Park Lake or the lake in the Royal Botanic Gardens. Therefore, impacts to these values are not expected. Likewise, it is expected that groundwater is not contributing to the Yarra River (see Section 5 of Technical Appendix O) and drawdown would not impact the river.

There are no Groundwater Quality Restricted Use Zones within the predicted area of drawdown, but there may be other areas with contaminated groundwater given the industrial land uses in the past. If contamination migrates to previously uncontaminated areas, beneficial uses of groundwater at third party properties could be precluded. Because there is uncertainty around the presence of contaminated groundwater within the predicted area of impact, there is conservatively considered to be a moderate risk of contaminant and associated vapour migration impacting beneficial uses of groundwater at neighbouring properties. Mitigation such as grouting of the shaft may be implemented to reduce this risk to low. The predicted level of drawdown would be significantly reduced provided mitigation strategies are implemented.

The shafts are mainly excavated through highly weathered to moderately weathered Melbourne Formation, and are predominantly above the 24 m used as an indicator of lower potential acid sulfate soil risk for the Melbourne Formation. Hence, the risk of potential acid sulfate soil oxidising and causing groundwater acidification is considered low.

18.8.2 Operation

During operation, it is an assumption of the Concept Design that all tunnels would be tanked to a water tightness classification of Haack 3.* This would result in negligible groundwater seepage into tunnels.

Tunnels Sector: Western portal to Arden station

Minimal drawdown is expected post-construction along most of the tunnels sector between the western portal and Arden station as inflows would be largely prevented by constructing the tunnels to a Haack 3 tightness classification. Therefore, no impact on groundwater dependent values is predicted.

* The Haack tightness classes are based on hydrogeological and other criteria (including aesthetic, health and other considerations) and provide a rate of inflow based on surface area of a tunnel. Refer to Section 4 of Technical Appendix O *Groundwater* for further information on the Haack tightness criteria assumed in the Concept Design.

The potential for aquifer damming to occur was assessed for this tunnels sector where it crosses through the Moonee Ponds Creek palaeovalley. The risk of aquifer damming is low since the tunnels would not obstruct flow through the whole high conductivity layer of the Fishermans Bend Silt. Groundwater flow could be maintained through the unobstructed part of the aquifer with a minor increase in hydraulic conductivity. It is expected that groundwater pressures would be affected for a small area (tens of metres at most) around the tunnels, and no impacts to groundwater dependent values are anticipated from this change in groundwater pressure.

High groundwater salinity indicates a risk of corrosivity of the groundwater on project infrastructure. Design of any structures would need to take into account potential aggressive ground conditions in accordance with *Australian Standard 2159-2009: Piling – Design and Installation* (see Table 18–1). A durability assessment that considers the corrosivity of groundwater and associated design requirements is included in Chapter 20 *Contaminated Land and Spoil Management*.

Tunnels Sectors: Arden Station to Eastern Portal

Minimal drawdown would be expected post-construction along the tunnels sectors between Arden station and the eastern portal since inflows would be largely prevented by constructing the tunnel to a Haack 3 tightness classification. Therefore, no impact on groundwater dependent values is predicted.

The potential for aquifer damming to occur was assessed for the tunnels sector between CDB South and Domain stations, where the tunnels cross through the Yarra River palaeovalley. The risk of aquifer damming is low since the tunnels would not obstruct flow through the whole Holocene Alluvium aquifer. Groundwater flow could be maintained in the unobstructed part of the aquifer with a minor increase in hydraulic conductivity. It is expected that groundwater pressures would be affected for a small area (tens of metres at most) around the tunnels. No impacts to groundwater dependent values are anticipated from this change in groundwater pressure.

18.8.3 Alternative Design Options

The potential alternative design options and associated construction impacts would be:

- Between CBD South station and Domain station:
 - A potential alternative design option would be for the alignment to go below the CityLink tunnels (with a deeper emergency access shaft requirement). The deeper emergency access shaft would result in greater groundwater impacts in this precinct, as described above (see Tunnels sector: CBD South station to Domain station in Section 18.8.1)

- A potential alternative design option for the emergency access shaft to be located 150 m south of the Concept Design location (Tom’s Block). This alternative design option would not result in groundwater impacts because the shaft would be above the watertable.
- Between Domain station and the eastern portal:
 - Potential alternative design option would be for the emergency access shaft to be located in the north-west corner of Fawkner Park (at the potential TBM launch/retrieval shaft site). No additional groundwater impact would be predicted for this option because a TBM launch/retrieval shaft is already included in the assessment (see discussion of impacts in Section 18.8.1).

18.9 Precinct 2: Western Portal (Kensington)

18.9.1 Construction

The main construction activities that could influence groundwater in Precinct 2 would be excavation of the decline structure and the cut and cover tunnelling works required for the western portal. Construction methods include the use of a secant pile retaining wall with toe grouting, which would prevent groundwater inflows from the excavation walls during construction, but may still allow some inflows to occur through the base of the excavation.

If no mitigation measures were applied, drawdown is predicted to occur within several hundred metres of the western portal. Potential impacts to groundwater dependent values as a result of this level of drawdown include:

- Groundwater acidification due to exposure of potentially acid forming sediments
- Third parties with properties close to possible contaminant plumes. There are no Groundwater Quality Restricted Use Zones in the predicted area of drawdown, however the industrial land use of the area suggests that contaminant plumes may be present which may migrate if drawdown occurs.

Mitigation measures would be planned to limit inflows during construction and minimise groundwater drawdown. These measures include the use of a temporary injection borefield to inject water and maintain groundwater levels in the Older Volcanics aquifer, if required. Operation of these wells would be expected to reduce the risk of potential acid sulfate soil activation and migration of groundwater contaminants to a low residual risk rating.

There are no active groundwater users within the predicted area of drawdown around the western portal precinct. The predicted extent of the drawdown cone would not reach the groundwater bores used for irrigation at Flemington Racecourse, which are approximately 1.7 km to the northwest. Therefore, no impacts would be expected on existing groundwater users. Similarly, the surface water bodies and vegetation within the area of drawdown are not expected to be dependent on groundwater, so drawdown would not impact those values.

18.9.2 Operation

Minimal drawdown would be expected post-construction at the western portal precinct as groundwater inflows during operation would be largely prevented by constructing the portal to a Haack 3 tightness classification. Therefore, no impact on groundwater dependent values is predicted.

18.10 Precinct 3: Arden Station

18.10.1 Construction

Construction of Arden station would be expected to include the use of a diaphragm wall retaining structure with toe grouting beneath the wall. This method would prevent groundwater inflows through the excavation walls during construction, but may still allow some inflow through the base of the excavation.

Without the implementation of any additional mitigation measures, drawdown is predicted to propagate out from the excavation for several hundred metres. The shape of the drawdown cone is likely to be irregular, as it is controlled by the variable geology of the Moonee Ponds Creek palaeovalley around the station. Drawdown extends furthest towards the south-west and is restricted towards the east where it encounters the Melbourne Formation siltstone.

Groundwater dependent assets within this area of drawdown would be susceptible to impacts. As a result of the predicted level of drawdown at Arden station, potential impacts to groundwater dependent values include:

- Groundwater acidification due to exposure of potentially acid forming sediments
- Third parties with properties close to possible contaminant plumes. There are no Groundwater Quality Restricted Use Zones in the predicted area of drawdown, although the industrial land use of the area suggests that contaminant plumes may be present which may migrate if drawdown occurs.

However, with appropriate mitigation measures (such as recharge bores), it is considered that drawdown around the station would be minor and groundwater dependent values in the area would not be impacted. A series of temporary groundwater recharge wells would be installed. These wells would be used to inject water to maintain groundwater levels in the Early Pleistocene aquifer, if required. Operation of these wells would be expected to reduce the risk of groundwater acidification and contaminant migration to low.

There are no active groundwater users within the predicted area of drawdown around this station precinct. Moonee Ponds Creek is not expected to be strongly connected to groundwater and would be unlikely to be impacted if drawdown occurred at Arden station precinct (see Section 5 of Technical Appendix O *Groundwater*). Similarly, vegetation is not expected to be dependent on groundwater, so would not be impacted (see Section 5 of Technical Appendix O).

18.10.2 Operation

Minimal groundwater drawdown would be expected at the Arden station precinct during operation since inflows would be largely prevented by constructing the station to a Haack 2 tightness classification. Therefore, no impact on groundwater dependent values is predicted during operation.

The potential for aquifer damming to occur at Arden station was assessed since the station is located within the Moonee Ponds Creek palaeovalley and partially obstructs some of the Quaternary units that behave as aquifers. Groundwater flow is at a right angle to the station and is expected that flow would divert around the station without a significant increase in aquifer pressures on the upstream side, or decrease in groundwater pressures on the downstream side of the station. No impacts to groundwater dependent values are anticipated from this change in groundwater pressure.

18.11 Precinct 4: Parkville Station

18.11.1 Construction

Parkville station would be drained during construction and therefore groundwater inflows would occur where the excavation is below the watertable, resulting in drawdown around the station. At the end of construction, the drawdown cone at Parkville station would be expected to propagate several hundred metres out from the station if no mitigation measures are implemented to prevent inflows. Groundwater dependent assets within the area of drawdown would be susceptible to impacts.

As a result of the predicted level of groundwater drawdown at Parkville station, there would be the potential for existing contaminants to migrate to third party properties, potentially precluding the beneficial uses of groundwater at those properties. There is one Groundwater Quality Restricted Use Zone in the predicted area of drawdown. Vapour intrusion to underground structures is also a risk associated with migration of this contamination. However, because of the high groundwater salinity, low yields in the Melbourne Formation, and urban land uses, few beneficial uses of groundwater apply in this precinct. Therefore, the risk of precluding beneficial uses is considered to be low.

To further minimise the risks associated with contaminant migration, appropriate mitigation measures such as cut off barriers, grouting at the station box and hydraulic barriers to prevent groundwater inflows would be considered.

There are no active groundwater users within the predicted area of drawdown around this station precinct. There are no surface water bodies within 2 km of the Parkville station precinct, and vegetation is not expected to be dependent on groundwater. Therefore, impacts on groundwater dependent ecosystems would not be expected. The station would be excavated into Melbourne Formation that has already been moderately to highly weathered, and there is therefore a low risk of acid formation.

18.11.2 Operation

Minimal drawdown would be expected at the Parkville station precinct during operation since inflows would be largely prevented by constructing the station to a Haack 3 tightness classification. A shallow drawdown cone would extend out from the station due to inflows to the station over the long term. This drawdown could potentially cause impacts to third parties with properties close to possible contaminant plumes. There are six Groundwater Quality Restricted Use Zones in the predicted area of drawdown for this long term case.

As discussed in Section 18.11.1, there are few beneficial uses that apply to groundwater in this area due to high groundwater salinity, low yields, and urban land use. There are not expected to be any impacts on beneficial uses if this contamination did migrate during operation. In addition to this, the extent of migration would be minor. All six Groundwater Quality Restricted Use Zones would experience less than 1 m drawdown over the long term and migration would therefore be limited.

There are no active groundwater users within the predicted area of drawdown around this station precinct. Similarly, there are no surface water bodies in the drawdown cone, and vegetation within the area of drawdown is not expected to be dependent on groundwater. Therefore, impacts on these values are not expected.

18.12 Precinct 5: CBD North Station

18.12.1 Construction

Construction activities that may influence groundwater impacts in Precinct 5 are associated with the mined cavern construction of CBD North station, including connections to Melbourne Central Station. The proposed construction methods mean that the structure would be drained during construction and groundwater inflows would occur.

At the end of construction, the drawdown cone at CBD North station for the unmitigated scenario would be expected to propagate out from the excavation for several hundred metres if no mitigation measures were applied. As a result of the predicted unmitigated level of drawdown at CBD North station, potential impacts to groundwater dependent values include:

- Groundwater acidification due to exposure of potentially acid forming sediments
- Third parties with properties close to possible contaminant plumes. There are three Groundwater Quality Restricted Use Zones in the predicted area of drawdown and some low-level contamination in one Melbourne Metro bore.

Mitigation measures such as grouting of the cavern during construction would be implemented to limit inflows and drawdown in the surrounding aquifer. In addition to this, temporary injection or discharge bores may be used to control the hydraulic gradient and prevent the off-site migration of contaminants.

In addition to the three Groundwater Quality Restricted Use Zones, anthropogenic contamination has been identified in project sampling, and it would be possible, given the intensive development in this area and historical industrial land use, that there are other areas with contaminated groundwater. The extent of the predicted drawdown cone could cause migration of these contaminants towards the station. If the contamination migrates to previously uncontaminated areas, beneficial uses of groundwater at third party properties could be precluded.

The former industrial site at 539-553 Swanston Street (CARMS 64057) presents the highest risk of contaminant migration to neighbouring properties because drawdown at this Groundwater Quality Restricted Use Zone is predicted to be several metres. Over a construction period of two and half years, this level of drawdown would draw the containment plume towards the south. The presence of volatile components in this contaminant plume also raises the risk of vapour intrusion into existing underground structures in the area. Appropriate mitigation measures such as extraction of contaminated groundwater or the use of recharge bores to reverse hydraulic gradients away from the station are being assessed in order to minimise impacts from contaminant migration in this area.

The other two Groundwater Quality Restricted Use Zones (CARMS 55787 and 48717) are further from the station precinct, in locations where less drawdown is predicted. These lower levels of drawdown would not cause contaminants to migrate far from their current location. They are therefore considered to constitute a low risk in terms of migration to neighbouring properties. Once mitigation measures are applied for the CBD North station the drawdown cone would be smaller and these Groundwater Quality Restricted Use Zones would most likely be outside the predicted drawdown extents. Design phase groundwater modelling that assesses the effectiveness of mitigation measures is required to confirm this prediction.

There are no active groundwater users in the predicted area of drawdown around this station precinct. It is expected that groundwater is not contributing to flow in the Yarra River. Similarly, vegetation is not expected to be dependent on groundwater, so impacts are not expected.

18.12.2 Operation

Minimal drawdown would be expected at CBD North station during operation as inflows would be largely prevented by constructing the station to a Haack 2 tightness classification. Therefore, no impact on groundwater dependent values is predicted during operation.

18.13 Precinct 6: CBD South Station

18.13.1 Construction

Construction activities that could influence groundwater impacts in Precinct 6 would be associated with the mined cavern construction of CBD South station, including connections to Flinders Street Station and Federation Square. The proposed construction methods mean that the structure would be drained during construction and groundwater inflows would occur.

At the end of construction, the unmitigated drawdown around CBD South station would be expected to propagate out from the excavated station in an irregular shape controlled by the variable geology surrounding the station. To the north, the drawdown cone would be within uniform geology (the Melbourne Formation) and roughly circular in shape, extending several hundred metres out from the station cavern. To the south, the drawdown cone would be influenced by the Yarra River palaeovalley, with most drawdown confined to the northern side of the palaeovalley. Minor drawdown would extend across the palaeovalley and into the Melbourne Formation further south. Groundwater dependent assets within the area of drawdown would be susceptible to impacts. As a result of the predicted level of drawdown at CBD South station, potential impacts and receptors include:

- One possible stock and domestic groundwater bore (WRK972626)

- Large trees that may be using groundwater near the Yarra River
- Third parties with properties close to possible contaminant plumes. There are two Groundwater Quality Restricted Use Zones within the predicted area of drawdown
- Groundwater acidification due to exposure of potentially acid forming sediments
- Existing CityLink recharge wells.

In order to limit inflows and minimise groundwater drawdown, two mitigation measures are planned. Grouting of the tunnel and station caverns would reduce groundwater inflows to the excavations. A series of temporary groundwater injection wells would also be installed, which would inject water to the Moray Street Gravels in order to maintain aquifer pressures in the overlying Coode Island Silt. A conceptual approach to grouting and establishing a temporary injection borefield is described in Technical Appendix O. Based on the hydrogeology, academic studies and previous projects that use the same technology (for example CityLink), there is high confidence that these measures can readily control groundwater drawdown and prevent impacts to groundwater dependent values. Modelling of the effectiveness of these mitigation measures is likely to result in predictions of minor or negligible impacts on most of the groundwater dependent values identified above.

Without mitigation measures, the predicted impact on the stock and domestic bore is expected to be acceptable as it would be less than 10 per cent of available drawdown. Mitigation measures are expected to reduce this impact to a negligible level of drawdown.

Deep-rooted trees in areas where groundwater is expected to be shallow, such as along the Yarra River and near the lake in the Royal Botanic Gardens, may be dependent on groundwater. Many of these trees are within the area of predicted drawdown. Deep-rooted tree species should be identified and their dependence on groundwater should be assessed. If found to be groundwater dependent, the trees within the area of drawdown should be irrigated through the period of drawdown. This proposed measure would be expected to fully mitigate any potential impacts on trees caused by groundwater drawdown.

Several areas of groundwater contamination have been identified in the vicinity of CBD South station. In addition to the two Groundwater Quality Restricted Use Zones, project sampling of groundwater has identified anthropogenic contaminants that could be indicative of other contaminant plumes south of the Yarra River. The extent of the predicted unmitigated drawdown would intersect these Groundwater Quality Restricted Use Zones and contaminant locations, and could cause migration of contaminants towards the station. However, the predicted drawdown at these locations would be minor (approximately 0.2 m) and therefore little migration of this contaminated groundwater would be likely during construction. The additional mitigation measures that would be implemented during station construction would limit inflows and reduce the extent of drawdown. In this mitigated scenario, the Groundwater Quality Restricted Use Zones would be expected to be outside the predicted drawdown cone and therefore contaminant migration is considered to be a low risk.

There is some occurrence of potential acid sulfate soil at CBD South station, where the cavern would be excavated through slightly weathered or fresh Melbourne Formation. However, the risk of any significant offsite impacts from potential acid sulfate soil is considered low as mitigation measures (grouting and injection bores) would limit drawdown.

Two of the five existing recharge wells between the CBD South and Domain station precincts would be within the predicted unmitigated drawdown radius associated with construction activities at CBD South station. These wells inject water into the Moray Street Gravels to maintain groundwater pressures in the overlying Coode Island Silt and prevent ground settlement. Predicted unmitigated drawdown at the existing recharge wells could potentially lead to the watertable being lowered to an extent that could partially depressurise the Coode Island Silt, which would increase the risk of ground settlement. The ground movement and land stability impact assessment conducted for the EES reviews the potential impacts associated with this level of drawdown and concludes that, with implementation of the proposed mitigation measures, ground water impacts would be within acceptable limits (see Chapter 19 and Technical Appendix P *Ground Movement and Land Stability*).

Impacts on the Yarra River are not expected as there is little connection between groundwater and the river, based on the knowledge gained from the construction of CityLink, which did not significantly impact the river. The lake in the Royal Botanic Gardens could be groundwater dependent, but is outside the predicted area of drawdown so would not be impacted.

18.13.2 Operation

Minimal drawdown would be expected at the CBD South station precinct during operation since inflows would be largely prevented by constructing the station to a Haack 2 tightness classification. Therefore, no impact on groundwater dependent values is expected during operation.

18.14 Precinct 7: Domain Station

18.14.1 Construction

Due to the geological conditions at this location, it is assumed that diaphragm walls would be used as the retaining structures for this station. This method would be likely to result in very little groundwater inflow, which would be largely restricted to the base of the excavation. Other construction works in this precinct that could change the groundwater environment include the relocation of the South Yarra Main Sewer.

At the end of construction, the drawdown cone in the unmitigated modelled case is predicted to be roughly elliptical with the long axis along the length of the station (north-west to south-east) and extending several hundred metres from the station. There are no groundwater dependent assets within this area of drawdown, and therefore no impacts would be expected to occur.

If there is any change in construction technique that could cause greater inflows, potential drawdown impacts should be assessed for Albert Park Lake and potential groundwater dependent vegetation in Albert Park and the parkland adjacent to the station.

18.14.2 Operation

Minimal drawdown would be expected at the Domain station precinct during operation since inflows would be largely prevented by constructing the station to a Haack 2 tightness classification. Therefore, no impact on groundwater dependent values is expected during operation.

18.15 Precinct 8: Eastern Portal (South Yarra)

18.15.1 Construction

During construction of the decline structure, open cut methods would be used. Once the decline structure is more than 6 m deep, a cut and cover tunnel would be constructed to the TBM retrieval box. Earth retaining structures such as piles could be used where geological conditions or space constraints dictate. Where underground components of the eastern portal are below the watertable, it is assumed that these components would be drained during construction. This means that below the watertable, groundwater would seep into the excavation and would need to be pumped out from a slump in the excavation.

At the end of construction, the unmitigated drawdown cone at the eastern portal would be likely to propagate out from the TBM shaft in a circular shape for several hundred metres. As a result of this predicted level of drawdown at the eastern portal, there would be the potential for:

- Health impacts to one mature tree (*Eucalyptus cladocalyx*) in the South Yarra Siding Reserve that may be groundwater dependent
- Migration of existing contaminants to third party properties. There are no Groundwater Quality Restricted Use Zones within the predicted area of drawdown. However, the past industrial land use of part of the area suggests that contaminant plumes could be present and could migrate, if drawdown occurs.

The tree should be irrigated through the period of drawdown. This measure is expected to fully mitigate any potential impacts on trees caused by groundwater drawdown.

If contamination migrates to previously uncontaminated areas, beneficial uses of groundwater at third party properties could be precluded. Due to the uncertainty around the presence of contaminated groundwater within the predicted area of impact, there is considered to be a moderate risk of migration of contaminants and associated vapour migration in the area of drawdown. Mitigation and monitoring would be implemented to reduce this risk to low.

There are no registered groundwater users within the predicted area of drawdown around this portal precinct. Similarly, the surface water bodies and vegetation within the area of drawdown would not be expected to be dependent on groundwater, so impacts are not expected.

As discussed in Section 18.12.1, it is expected that groundwater is not contributing to flow in the Yarra River and therefore impacts would be unlikely.

18.15.2 Operation

Minimal drawdown would be expected at the eastern portal precinct during operation since inflows would be largely prevented by constructing the tunnels to a Haack 3 tightness classification. Therefore, no impact on groundwater dependent values is expected during operation.

18.16 Precinct 9: Western Turnback (West Footscray)

18.16.1 Construction

All construction works are above ground and there would be no interaction with groundwater. No impact on groundwater dependent values is expected.

18.16.2 Operation

The operational running of the western turnback would not interact with groundwater. No impact on groundwater dependent values is expected.

18.17 Early Works

Significant early works on Melbourne Metro which would have groundwater effects include the reconstruction of South Yarra Main Sewer at Domain station, the Franklin Street east shaft and A'Beckett Street shaft at CBD North station and the demolition of the City Square Car Park at CBD South station. South Yarra Main Sewer would be replaced in the area of the proposed Domain station and the construction process may locally impact groundwater levels.

The Franklin Street East and A'Beckett shafts are part of the CBD North precinct, and impacts of drawdown associated with construction of these shafts is considered as part of the overall drawdown for CBD North station in Section 18.12. The inclusion of these works in the early works package does not change the modelled drawdown and predicted impacts associated with excavation of the shafts. It is important to note that the shafts at CBD North would be excavated to below the watertable during the early works program and, as such, there may be groundwater inflows that require disposal. Therefore, the Groundwater Disposal Strategy must be in place for the early works program.

The demolition of the City Square car park in the CBD South station precinct would only reach just below the existing water table and is unlikely to have a significant impact on groundwater levels. The impacts are considered together with the construction of CBD South station in Section 18.13. Analysis of the impacts is in Technical Appendix O.

18.18 Environmental Performance Requirements

As noted in Section 18.7, mitigation measures are available to avoid or minimise the groundwater impacts from construction activities. The following table shows the recommended Environmental Performance Requirements for Melbourne Metro and proposed mitigation measures in relation to managing groundwater impacts.

The risk numbers listed in the final column align with the list of groundwater risks provided in Technical Appendix B *Environmental Risk Assessment Report*.

Table 18–4 Environmental Performance Requirements for Groundwater

Draft EES evaluation objective	Environmental Performance Requirements	Proposed mitigation measures	Precinct	Timing	Risk No.
<p>Hydrology, water quality and waste management</p> <p>– To protect waterways and waterway function and surface water and groundwater quality in accordance with statutory objectives, to identify and prevent potential adverse environmental effects resulting from the disturbance of contaminated or acid-forming material and to manage excavation spoil and other waste in accordance with relevant best practice principles</p>	<p>Design the tunnel and underground structures so that they minimise groundwater drawdown during construction and operation to minimise impacts on groundwater dependent values, ground movement and contamination plume migration.</p>	<p>Adopt design features such as proposed in the Concept Design to minimise groundwater inflows. This should include:</p> <ul style="list-style-type: none"> • TBM tunnel construction • Diaphragm wall station construction at Domain and Arden stations • Secant pile wall construction at the western portal • Tanking to Haack criteria 2 or 3. 	All	Design	GW001 to GW059
	<p>Develop a groundwater model for the detailed design phase to predict impacts associated with any changes to construction techniques or operational design features proposed during detailed design, and reconfirm that the Environmental Performance Requirements and mitigation measures are sufficient to mitigate impacts from changes in groundwater levels, flow and quality.</p> <p>Undertake monitoring during construction to ensure that predictions are accurate and mitigation measures are appropriate.</p>	<p>Groundwater model should:</p> <ul style="list-style-type: none"> • Incorporate all new data • Predict impacts associated with detailed design and proposed construction timing • Assess cumulative impacts for construction and operation • Model uncertainty • Enable detailed design of mitigation measures (grouting approaches, injection borefield configuration and operation) to mitigate predicted impacts. 	All	Design	

Draft EES evaluation objective	Environmental Performance Requirements	Proposed mitigation measures	Precinct	Timing	Risk No.
	<p>Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction.</p> <p>The GMP must be based on the detailed design phase groundwater model, and should include the following details:</p> <ul style="list-style-type: none"> • Approach to collection, treatment and disposal of groundwater collected during construction in accordance with the MMRA Groundwater Disposal Strategy • Identifying and if necessary, specifying mitigation measures to protect groundwater dependent vegetation during periods of drawdown • An approach identified in consultation with the EPA so that contaminant migration causes no significant impacts on beneficial uses and vapour intrusion into underground structures, and establish appropriate monitoring networks to confirm effectiveness of approach • Methods for minimising drawdown in areas of known PASS and establishing appropriate monitoring networks to confirm effectiveness of approach • Methods for minimising drawdown at any existing recharge bores, and establishing appropriate monitoring networks to confirm effectiveness of mitigation • Groundwater drawdown trigger levels for groundwater dependant values at which additional mitigation measures must be adopted • Design, operation and management of groundwater injection borefields • Contingency measures if impacts occur at existing active groundwater bores and surface water bodies. <p>The GMP must satisfy the EPA and relevant water authorities that groundwater dependent values will be protected.</p> <p>The groundwater management plan should also address MMRA's sustainability requirements where appropriate.</p>	<p>The Groundwater Management Plan would set out in detail how potential impacts would be mitigated.</p> <p>Possible mitigation measures include:</p> <ul style="list-style-type: none"> • Site specific risk assessment of contaminant location and concentrations • Use of injection or discharge bores to prevent contaminant migration • Minimisation of drawdown through construction techniques such as grouting of structures • Temporary injection bores located in the palaeovalleys • Identification of groundwater dependent vegetation and throughout the period of drawdown • Testing of rock cores to assess site specific risk of PASS. 	All	Construction	

Draft EES evaluation objective	Environmental Performance Requirements	Proposed mitigation measures	Precinct	Timing	Risk No.
	Use the Groundwater Disposal Strategy and GMP to obtain a Trade Waste Agreement with the relevant Water Retailers for groundwater disposal.	Develop a groundwater disposal strategy that confirms disposal option, contingency measures and emergency response plan if unexpected groundwater contamination is encountered and requires disposal.	All	Construction / Operation	GW055 GW056
	<p>Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential:</p> <ul style="list-style-type: none"> • Contaminant migration on the beneficial uses of groundwater at third party properties caused by drawdown and vapour intrusion to underground structures • Activation of PASS and groundwater acidification • Reduction in access to water for bore owners in the area around the project • Reduction in access to groundwater for trees– particularly in the Tunnels precinct between CBD South and Domain stations, and the CBD South station and eastern portal precincts • Change in groundwater levels in any existing recharge bores that may be present in the area around the project. 	Groundwater monitoring strategy would set out monitoring required to ensure no significant impacts to groundwater dependent values, and contingency measures for if impacts exceed acceptable levels.	All	Construction / Operation	GW001 to GW059

Refer also to the recommended Environmental Performance Requirements in relation to contaminated land and spoil management impacts. These requirements and proposed mitigation measures are provided in Chapter 20.

18.19 Conclusion

Melbourne Metro would generally be constructed below the groundwater table and consequently, groundwater inflows would occur during construction. This may cause groundwater drawdown around structures, which could impact groundwater dependent values in the area. For the operation of Melbourne Metro, all the structures would be tanked (made water tight) and consequently, the groundwater inflows and associated drawdown would be minimal.

A range of possible groundwater impacts associated with construction of Melbourne Metro have been identified. Groundwater drawdown is the primary pathway for potential impact, and without mitigation, may result in a reduction in groundwater levels at existing private bores and existing recharge bores, impacts to the health of groundwater dependent vegetation, and groundwater acidification due to exposure of PASS. Other impacts include the risk of groundwater drawdown changing hydraulic gradients and causing existing contaminant plumes to migrate to neighbouring properties, precluding the potential uses of groundwater as well as causing vapour migration into existing underground structures at those properties.

The potential for impacts to connected surface water features and for changes in groundwater levels due to 'damming' of aquifers by Melbourne Metro structures has been assessed and found to be low for all precincts. Groundwater disposal options are also discussed.

Well established underground construction measures have been routinely applied throughout the world to manage groundwater inflows and hence prevent unacceptable groundwater related impacts. These routine mitigation measures include applying the most appropriate design and construction methods, grouting around structures and the use of injection bores to counter any groundwater drawdown. Throughout the project different mitigation measures have been considered depending on the local geology and hydrogeology.

The numerical and analytical modelling for the Concept Design has identified that:

- Impacts to groundwater users, groundwater dependent vegetation and surface water receptors would be acceptable;
- The potential impacts of groundwater drawdown on ground settlement and migration of existing contamination are more sensitive.

The groundwater impact assessment has identified mitigation measures such as temporary injection bores and grouting which would further mitigate groundwater inflows to reduce groundwater drawdown, consequently reducing settlement and contaminant migration.

A risk assessment has ranked all but one of the mitigated groundwater impacts as low risk. The sole risk ranked as medium was the possible migration of contaminant plumes under third party properties during the construction of CBD North station. Several matters are still being discussed with the relevant authorities, specifically how to deal with contaminated sites and how to appropriately dispose of groundwater.

The recommended Environmental Performance Requirements have been formulated to ensure that any groundwater impacts are minimal. These requirements must be complied with during the construction and operation of Melbourne Metro. A key recommended Environment Performance Requirement is the development of a comprehensive monitoring programme to ensure that any groundwater drawdowns and associated impacts are within acceptable levels.