Airport Link

Phase 2 – Detailed Feasibility Study

CHAPTER 7

HYDROGEOLOGY AND GROUNDWATER QUALITY

- October 2006

Contents

7 Hydrogeology and Groundwater Quality

This Chapter addresses Section 5.2 and that part of 5.3 relating to groundwater aquifer in the Terms of Reference. It describes the quantity, distribution, quality, use and importance of groundwater in the study corridor and, where relevant, in immediately adjacent areas. Environmental values of groundwater are described in terms of the Environmental Protection (Water) Policy, sustainability of water quality and quantity and physical integrity and fluvial processes of the groundwater resource.

An assessment is made of the potential for environmental impact to be caused by the Project to any affected groundwater resources. The extent of the potential area within which groundwater resources are likely to be affected by the Project, the significance of the Project to groundwater depletion and recharge and any groundwater dependent ecosystems are identified. Cumulative impacts associated with the construction of the Airport Link project and a part of the Northern Busway project, at the same time, are also addressed.

The potential for draw-down on known and potentially contaminated groundwater has been investigated. This assessment also takes into account Section 5.1.2 of the EIS with reference to acid sulphate soils.

Management options available to monitor and mitigate any potentially deleterious effects on groundwater resources are identified.

Australasian Groundwater & Environmental (AGE) Consultants Pty Ltd undertook the specialist hydrogeological study which forms the basis for this Chapter. The AGE report is provided in full in Technical Report No 2- Hydrogeology in Volume 3 of the EIS.

7.1 Existing Groundwater Regime

7.1.1 Drainage and Topography

The topography of the study corridor consisting of generally undulating terrain with minor surface catchments between hills. This was described in detail in Chapter 6.

The two main west to east flowing streams, Enoggera Creek in the south and Kedron Brook in the north, receive the drainage from the study corridor. Two secondary drainage catchments are of significance in the study corridor, namely:

- The area from Lutwyche Road west to Eildon Hill between Newmarket Road in the south and Maygar Street in the north; drainage from this area gathers to cross Lutwyche Road, in the centre of the study corridor at the Bowen Street intersection; and
- A secondary stream, the Eagle Junction tributary, joining Kedron Brook just east of Sandgate Road, receives drainage from Eagle Junction, Wooloowin from Melrose Park along the railway line and west to Kedron Park Road, much of Clayfield including north-western slopes east of the railway line, and Lutwyche as far south as Chalk Street.

7.1.2 Aquifers

The hydrogeological regime of the study corridor comprises two broad aquifer types:

- A fractured rock aquifer system in either of the Brisbane Tuff, Neranleigh-Fernvale Beds or Tingalpa or Aspley Formations; and
- Isolated Quaternary alluvial systems associated with the valleys of Enoggera Creek and Kedron Brook.

A number of geotechnical boreholes have been drilled along the study corridor and adjacent areas, either directly for this project or for other projects. These boreholes are supplemented, in the study corridor adjacent to Enoggera Creek, by 10 boreholes drilled as part of the NSBT investigation. In most of these boreholes, *in situ* permeability tests were undertaken, often at several levels, to provide an understanding of groundwater capacity within each rock unit.

A summary of the location of the geotechnical drilling mentioned above and the results of the hydrogeologically focused testing program undertaken therein are presented in Technical Report No 2 – Hydrogeology in Volume 3 of the EIS.

With the exception of the alluvium, the geological units of the study corridor may be regarded as typical fractured rock aquifers and contain essentially no primary porosity. Groundwater flow is through secondary features such as joints and fractures and along bedding planes. On a localised scale, the permeability depends on the number and aperture of fractures/joints and can vary over several orders of magnitude.

Each of the rock units along the study corridor is described below in terms of their hydrogeological characteristics. A map of the geological units is shown in **Figure 6-1**.

Neranleigh-Fernvale Beds

The Neranleigh-Fernvale Beds, underlying the entire study corridor, are hard folded and steeply inclined metasedimentary rocks of very low permeability. However, some isolated areas of higher permeability exist and it is considered likely these zones are associated with areas of localised fracturing rather than broad areas of high permeability. A summary of results of permeability tests on this unit from the study corridor is provided in Technical Report No 2 - Hydrogeology in Volume 3.

Brisbane Tuff

The rock unit is described as cream, pink, mauve or green, hard, very fine-grained rock. A brecciated zone is generally present at the base of the unit, resting on the unconformity with the Neranleigh-Fernvale Beds.

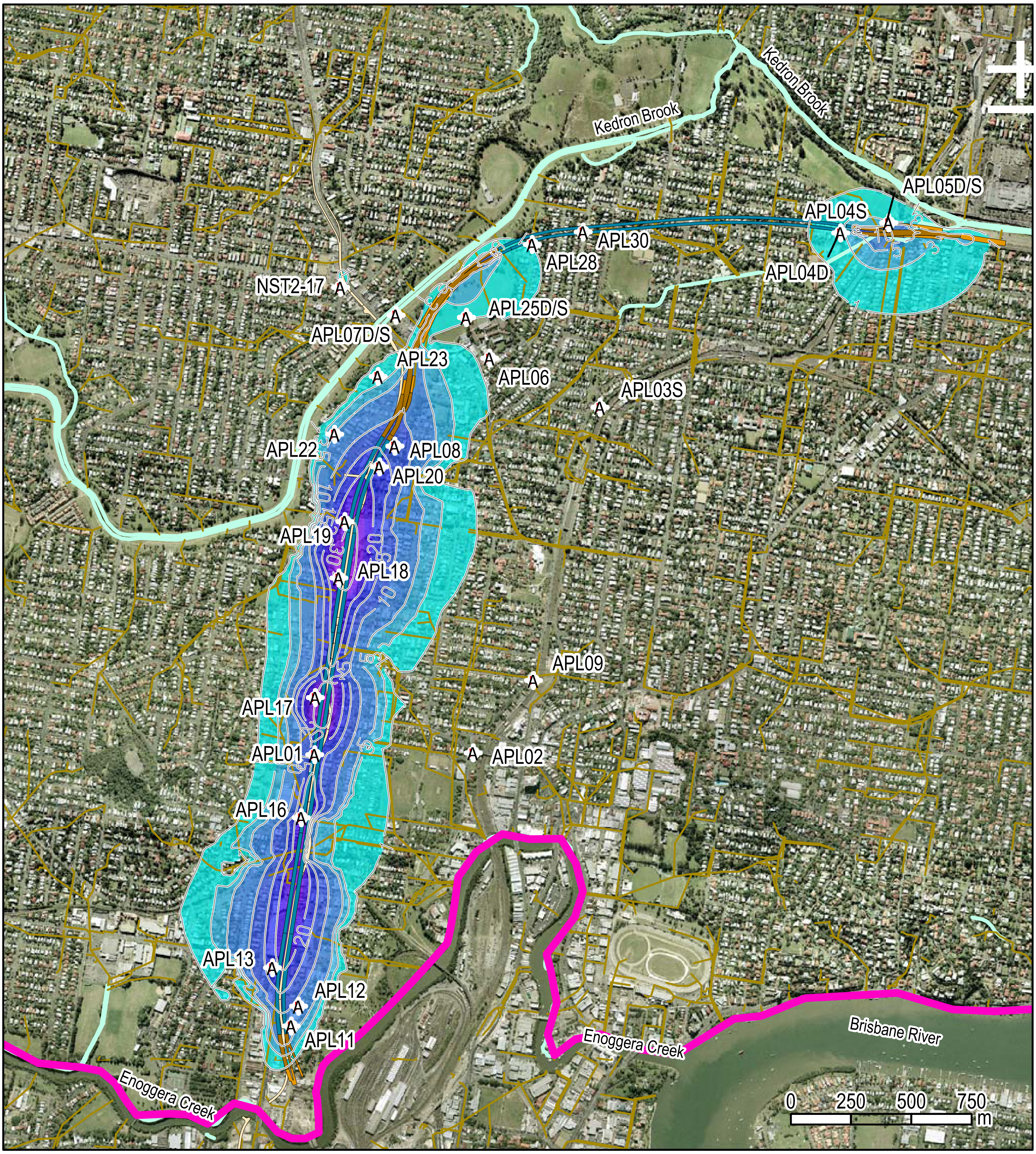
Permeability testing of Brisbane Tuff in boreholes drilled for the S1 Sewer tunnel (south of the study corridor), the NSBT Project (south of the study corridor) and this project indicates variable permeability, ranging from negligible or low permeability (39 tests) to some tests where water loss (i.e. permeability) was so great the test could not be completed. The latter circumstance was due to intersection of a joint fracture in at least one drill hole test and almost certainly is the case with the other extremely high permeability test results.

Permeability testing of the lower parts of the unit show it to be up to twice as permeable as the Neranleigh-Fernvale Beds. Although based on limited data the variable permeability apparent in these data suggests a high probability of intersecting a permeable joint/fracture in the tuff during tunnelling. However, volumes of groundwater stored within an intersected joint system are considered to be low and groundwater inflows from individual joints would be expected to diminish relatively quickly as the stored water is drained.

Aspley and Tingalpa Formations

The Aspley Formation has essentially zero primary porosity and its permeability will be governed by the number of fractures and the degree to which fracture zones are interconnected.

The Tingalpa Formation comprises variable siltstones, shales and thin coal seams and has variable permeability, based on the tests carried out to date.



LEGEND

Drawdown (m)

- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45

APL Alignment

- Cut and Cover Tunnel
- Driven Tunnel
- Transition Structure
- Northern Busway
- Waterway
- Stormwater Drainage
- APL09 A Modelled Monitoring Bore
- Drawdown Contour (m)
- Model Domain

AIRPORT LINK - Figure 7-1

Cumulative Impact Modelled Drawdown

Post APL Construction (1 year)

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Source: Australasian Groundwater & Environmental Consultants Pty Ltd 2006

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Quaternary Alluvium

The alluvium is expected to be quite thick in the centre of the main creek alignments, thinning rapidly as the ground surface rises away from the stream. Drilling on the northern side of Enoggera Creek intersected 21.5m of alluvium over Brisbane Tuff, indicating that the valley is deeply incised. Variation in the groundwater levels measured in this drill hole suggested that the alluvial groundwater in that area is in hydraulic connection with the tidal creek.

The study corridor includes alluvium along Kedron Brook in the Lutwyche/Gympie Road area and either side of Sandgate Road in the north-east. Just west of Sandgate Road the alluvium forks into the valleys of Kedron Brook and the Eagle Junction Creek. Several boreholes just east of the Lutwyche/Gympie Road bridge have variable thicknesses of alluvium generally more than 10 metres consisting of loose sands and gravels. Drillholes in the Sandgate Road area further downstream suggest that the alluvium is generally in excess of 10 metres thick and contains a higher percentage of generally stiff clays.

A drilling program undertaken in the early 1950s for the North Kedron Brook Sewer Tunnel, which passes through the Kedron Brook alluvium just north of the study corridor, provides useful information. Data presented in Technical Report 2 – Hydrogeology in Volume 3, show regular intersections of water bearing sands and gravels. These results, in relation to groundwater in the valley of Kedron Brook, show:

- The alluvium grades from clay at surface to gravel at depth;
- Test bore No. 24 in Kalinga Park intersected 15.7m (51’6”) of alluvium;
- An hydraulic connection was suggested between the groundwater in the sewer tunnel and Kedron Brook;
- At Shaft 43, situated in Kalinga Park, groundwater inflow was measured at $68m^3$/day (15,000gpd);
- The most difficult tunnelling was beneath Schulz Canal, Kedron Brook and Kalinga Park and eventually tunnelling in this area was abandoned in favour of open cut methods; and
- The behaviour of the alluvium during tunnelling was variable with clays below the water table acting as “squeezing ground” with the greatest difficulty experienced with water bearing sand and gravel horizons.

7.1.3 Groundwater levels

Groundwater levels in the study corridor are available from standpipe monitoring bores and vibrating wire piezometers (VWP) installed in geotechnical bores drilled for this project and in the northern parts of the NSBT project area. Locations and results of these facilities are presented in Technical Report No 2 – Hydrogeology in Volume 3 of the EIS. At sites located on the alluvial plain of Kalinga/Wooloowin, piezometric levels in the underlying formations are greater than those in the shallow alluvium, which indicates that upward groundwater flow is occurring. It is expected that the upward flow of groundwater is recharging the alluvial sediments and contributing to the baseflow in Kedron Brook.

7.1.4 Groundwater Quality

Groundwater quality data in the study corridor are obtained from samples collected as part of the geotechnical investigation for the project. Sixteen standpipe monitoring bores have been installed at thirteen sites to obtain groundwater samples from the Quaternary alluvium or underlying rock. These data are supplemented by standpipes constructed in the Enoggera Creek alluvium as part of the NSBT geotechnical investigation.

Groundwater samples were collected in uniform manner from each of the standpipe monitoring bores, which are shown on **Figure 7-1**. As the bores were completed in a variety of geological units, there is a marked difference in water quality within the study corridor. Electrical conductivity (EC), which is a measure of salinity, is probably the most appropriate and readily understood method of assessing the water quality variability within the area. Analyses of groundwater samples from the study corridor, collected as part of this project or as part of NSBT investigations in the Enoggera Creek area are presented in Technical Paper 2 – Hydrogeology in Volume 3 of the EIS.

In addition to the above data, an extensive program of groundwater sampling was undertaken for the NSBT project at monitoring bores in alluvium, Tingalpa Formation, Brisbane Tuff and Neranleigh-Fernvale Beds. Whilst not within the Airport Link corridor, these data provided further basis for defining groundwater quality that may be expected within the project area. Electrical conductivity is a readily useable method of assessing the various qualities and the ranges observed to date, within the NSBT project area are shown in **Table 7-1**.

- **Table 7-1 Observed ranges of electrical conductivity from NSBT data for different rock formations**

Alluvium	:	230µS/cm – 9700µS/cm	Typically ~3000µS/cm
Tingalpa Formation	:	3460µS/cm – 6000µS/cm	
Brisbane Tuff	:	320µS/cm – 10,700µS/cm	Typically ~3500µS/cm
Neranleigh Fernvale Beds	:	1300µS/cm – 44,660µS/cm	Typically ~5000µS/cm

Water quality within the study corridor is quite variable, with electrical conductivity values ranging from 490µS/cm (APL04D) to 9700µS/cm (NST57). In terms of water quality from specific geological units at present there is only a single monitoring bore constructed in the Tingalpa Formation and Neranleigh-Fernvale Beds and the single values of EC should not be taken as being representative of these units. Five standpipe monitoring bores have been constructed in the Brisbane Tuff and show a reasonably consistent EC in the range 1400µS/cm to 2500µS/cm. The EC observed in the alluvium monitoring bores adjacent to Kedron Brook show that the EC of the alluvium groundwater in the area is between 820µS/cm and 1500µS/cm. It is expected that this water quality results from mixing of recharge rainfall and upwelling groundwater from underlying aquifers. This supposition is supported by the fact that upward hydraulic gradients are present in the area of Kedron Brook.

7.1.5 Groundwater Users

The Queensland Department of Natural Resources, Mines and Water groundwater database shows only one registered bore in the study corridor, Bore No. 73993 at 1 Nellie Street, Clayfield. A further 8 registered sites from the database lie within adjacent areas that could be affected by the tunnel. The study corridor and surrounding area is regarded as possessing a very limited groundwater resource. Prior to the *Water Act 2000* there was no reporting requirement for groundwater facilities in the study corridor. Despite the previous absence of a regulatory requirement for drilling contractors or landholders to submit details of bores to DNRM, the Department regularly provided extension services to people desiring to construct a bore on their property. A review of DNRM files showed that in the period since the late 1940s numerous requests have been made by residents of the inner northern suburbs regarding groundwater potential. In general the advice was negative, citing potentially low bore yields and elevated salinities and recommending that drilling not be attempted. With no requirement to report results of drilling, it is unknown if any proposed bores were constructed or used. The fourteen registered bores in the general vicinity of the Project are detailed in Technical Paper No 2 – Hydrogeology in Volume 3 of the EIS.

7.2 Groundwater Contamination

The study corridor encompasses the area of Lutwyche Road/Gympie Road which historically has been the main northern route within Brisbane. There have been a variety of land users in the area ranging from service stations/petroleum storage to quarrying of the Brisbane Tuff at two locations in Windsor. The industries with petroleum storage tanks are considered to have the greatest potential for possessing mobile contaminants and these are highlighted on **Figure 6-4** which also shows the other potentially contaminated sites in the area.

The drilling programs undertaken to date focused on providing geotechnical data with collection of groundwater and contamination related information an ancillary consideration. Analyses for potential contaminants have included trace metals (arsenic, aluminium, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc), nutrients (ammonia, nitrate, nitrite, ortho phosphorus), Volatile Organic Compounds (VOCs) and Semi-Volatile Organic Compounds (SVOCs).

Concentrations of the trace metals arsenic, cadmium, copper, chromium, nickel and lead were typically at or below the laboratory level of detection in all geological formations. Concentrations of nutrients ammonia and nitrate were highest in the alluvial aquifer at 4.8mg/L and 1.32mg/L, respectively. Maximum concentrations of these nutrients in the in the older geological formations are well below 0.5mg/L. Semi-Volatile Organic Compounds were detected in samples from 4 monitoring sites (as discussed in Technical Report No. 2 – Hydrogeology in Volume 3 of the EIS). VOCs and SVOCs were below the level of laboratory detection in all other monitoring bores.

7.3 Environmental Values

The *Environmental Protection (Water) Policy (1997)* serves to protect Queensland’s environment while allowing for ecologically sustainable development. This is achieved through the policy by providing a framework for:

- Identifying environmental values for Queensland waters;
- Deciding and stating water quality guidelines and objectives to enhance or protect the environmental values;
- Making consistent and equitable decisions about Queensland waters that promote efficient use of resources and best practice environmental management; and
- Involving the community through consultation and education, and promoting community responsibility.

In terms of the policy, the relevant qualities of the groundwater of the study corridor are discussed below.

Aquatic Ecosystems

Regardless of whether the groundwater is considered a pristine or non-pristine water, it is considered that any aquatic ecosystems dependent upon groundwater within the study corridor would be limited to those within Kedron Brook. Even along Kedron Brook the impervious clays of the stream alluvium almost certainly isolate the surface ecosystems of the Brook from the groundwater of the suballuvial rock formations suggesting that the stream ecology relies on surface water flow in the stream rather than local groundwater. Any ecosystems established at the edge of the Enoggera Creek would be dependent upon the tidal creek flows and the saline water quality rather than the relatively small groundwater fluxes discharging to the creek from the surrounding rocks.

Recreational Use

There are no recreational activities in the area that rely directly or indirectly on groundwater. Hence, recreational use as an environmental value is not relevant.

Drinking Water

The water quality data obtained from the standpipe monitoring bores installed as part of this project indicate that in general, the water is unsuitable for human consumption. This is due to elevated salinity which is difficult to treat. Issues of contamination and the ease of obtaining a mains water supply are also factors which preclude the use or potential for use of the groundwater as a drinking water source.

Agricultural Use

The permeability of the alluvium in the Wooloowin/Kalinga area suggests that viable bore yields may be readily obtained and it is possible that a number of residences have established bores to supply water for lawns and gardens. Water quality in the area ranges from 820µS/cm to 1500µS/cm and is possibly marginal for irrigation. Widespread extraction at high rates is considered unlikely.

In the remaining areas of the study corridor, land use and elevated salinity would preclude the use of the groundwater for irrigation purposes.

Industrial Use

There are no known industrial users of the groundwater within the study corridor. The potential for industrial usage of the water is considered to be greater than that for either agricultural or drinking water usage. Industrial users generally have the capital required to drill and equip bores and if necessary appropriately treat the water before use. On the negative side, industrial users tend to require large volumes of water which will be difficult to obtain from bores in the area. The reliability and ease of obtaining a mains supply of water is considered to be a dominating factor, and as such, the likelihood of any industrial water users within the area drilling, constructing and equipping a bore is low.

7.4 Potential Impacts and Mitigation Measures

7.4.1 Groundwater Modelling

A numerical groundwater flow model incorporating the hydrogeological characteristics of the study corridor and the tunnel alignments was formulated to assist in undertaking the impact assessment by simulating groundwater inflows to the tunnel, levels of groundwater drawdown and the extent of the area of influence upon groundwater levels. The objective of the modelling was to simulate the impact of the project on the hydrogeological regime of the area and in particular to undertake predictive modelling in order to assess:

- The extent and amount of water level drawdown in the surrounding area as a result of inflow to the tunnels and construction sites;
- The potential groundwater inflow volumes to the tunnels.

Modelling was undertaken in a number of stages, namely:

- Steady state conditions, that is, before commencement of tunnelling;
- Transient predictive modelling for two scenarios:
  - impact of construction of the tunnels from 2008 to 2012 and impact of operation of the Project for 100 years or until steady-state conditions are realised,
  - cumulative impact of the Northern Busway tunnels from 2008 to 2026 and impact of operation of both projects for 100 years or until steady-state conditions are realised.

The model is based upon the hydrologic catchments in which the Project is found and these are shown in Figure 11 of Technical Report 2 – Hyrdogeology and Groundwater in Volume 3 of the EIS. The northern boundary is Downfall Creek. Kedron Brook itself has not been chosen as a model border to allow for the possibility that groundwater drawdown caused by the project may extend beyond Kedron Brook.

The southern boundary follows Enoggera Creek and the Brisbane River. The model extends east almost to the Brisbane Airport, with some sections of this boundary defined by major stormwater drains. In the west, the model is confined by the hills of Ashgrove, Mitchelton and Enoggera.

The model represents the local geology in four layers, vertically:

- The top layer is the surface geology with alluvium and the rock formations of Brisbane Tuff, Neranleigh-Fernvale beds/ Bunya Phyllite and Tingalpa Formation;
- Layer two represents the subsurface geology as interpreted from bore logs;
- Layer three simulates areas of Brisbane Tuff underlying Tingalpa/Aspley Formation; and
- Lowest layer is the underlying Neranleigh-Fernvale Beds at –80mAHD, which is a sufficient thickness to assess the indirect groundwater influence of the deep tunnel sections.

The reasoning that defined the vertical and horizontal limits of the model area is provided in detail in Technical Report No 2 – Hydrogeology in Volume 3 of the EIS.

In addition to the Brisbane River, Enoggera Creek and alluvial drainage channels, the major features governing groundwater flow in the project corridor are man-made. Specifically, there are the numerous stormwater drains constructed in now in-filled creek beds. Where the observed water levels indicate a control of the groundwater surface by these structures, the stormwater drains have been implemented into the model as drainage boundary conditions.

The transient predictive simulation of the hydrogeological impact of the Project considered two scenarios. One analysis addressed the impact of construction and operation of the Project. The other analysis is of the cumulative impact of the Project and the Northern Busway Project.

Base Scenario - Airport Link Project only

The project alignment includes the tanked (lined) TBM-driven east-west tunnel beneath Wooloowin/Clayfield, the untanked (unlined) roadheader-excavated north-south driven tunnel, untanked cut and cover tunnels and untanked access ramps. The cut and cover and ramp sections are considered untanked because their floors will not be initially sealed despite their diaphragm walls that are assumed to fully penetrate the alluvial sediments being equivalent to a tanked structure. The untanked north-south driven tunnels will act as groundwater drains throughout construction and tunnel operation. The east-west driven tunnel is proposed to be fully tanked during construction and operation so is assumed to have no impact on the groundwater regime and is not explicitly represented in the model.

It was assumed in this study that the north-south driven tunnel would be excavated simultaneously from the northern and southern portals towards the centre. Thus, within the groundwater flow model, the tunnel has been divided into northern, central and southern sections. The northern and southern sections would be excavated first, followed by the central section. Similarly the cut and cover tunnel at the north-western connection has been divided into three sections within the groundwater flow model. The model simulates a consecutive excavation sequence from south to north.

During simulation, the different tunnel sections become active drains from their starting dates. Generally, the drainage level coincides with the tunnel floor elevation. If the construction site is within alluvium, the drainage level is lowered by one metre to provide for a dry floor within the excavation site. By draining immediately down to the final floor elevation, a high groundwater inflow derived from release of groundwater from aquifer storage will be generated. With time, the groundwater inflow rate is reduced to a steady-state level.

Cumulative Impact - Northern Busway Project

The completion of the Northern Busway Project is proposed in 2025/2026. During the interim stages works are proposed to be carried out simultaneously with the Airport Link construction (refer to Technical Report No. 2 – Hydrogeology in Volume 3 of the EIS). The Northern Busway interim stages would comprise a series of tunnel and transition structures directly above the north-south tunnels of the Airport Link Project. At the northwestern connection, the Northern Busway would deviate towards the north-west. All Northern Busway structures are untanked.

The Northern Busway tunnels would be shallower than the Airport Link tunnels. Within the model the driven tunnels are assigned as drainage boundary conditions on overlying layers. The near-surface structures such as cut and cover tunnels and transition structures are assigned on the top layer. Where the near-surface structures intersect, the deeper one, that is the Airport Link Project structure, is modelled.

Modelling Results

An appreciation of the appropriateness of the model formulation and calibration can be achieved by comparison of the predicted and observed water levels at each of the standpipe monitoring bores and vibrating wire piezometers. A summary of this data corresponding to the average water level in the period October 2005 to March 2006 (see Table 12 of Technical Report 2 – Hydrogeology in Volume 3 of the EIS) shows that, in general, there is a good correlation between simulated and observed groundwater levels.

The results of the modelling are shown in **Figure 7-1** and in Technical Report No. 2 – Hydrogeology in Volume 3 of the EIS. The results show the maximum extent of the drawdown is almost reached one year after construction for those sections to be constructed within alluvium. For the north-south driven tunnels, the drawdown continues to extend towards the west over the following decades. West of the north-south driven tunnels, where almost impermeable hardrock occurs, correspondingly low groundwater recharge occurs and no active drains have been identified. Thus, the relevant area of influence of the deep draining tunnel is quite large and needs some time to reach its final extent.

The model was used to predict groundwater inflows to various segments of the tunnels for steady state conditions. The predicted inflows are presented in Technical Report No 2 – Hydrogeology in Volume 3 of the EIS. The modelled long-term inflow rate for the tunnel is approximately 8L/s.

Cumulative Impact with Northern Busway

The Northern Busway runs almost along the same alignment as the project from Enoggera Creek to Stafford Road. At the north-western connection, the Northern Busway crosses Kedron Brook to the north-west. Generally the tunnel structures of the Northern Busway are overlaying the project tunnels, requiring less dewatering depth than the Airport Link structures. Hence, an additional significant impact on the regional groundwater drawdown does not take place.

Additional groundwater drawdown is only expected north-west of Kedron Brook, where the model predicts a local drawdown of less than 3m as the result of the construction of a cut and cover tunnel. The drawdown reaches a quasi-steady state condition rapidly and does not extend significantly in the long-term. This additional draw-down may have an impact on the transport of contaminants within the groundwater body as explained below. The inflow rate at the Gympie Road cut and cover tunnel is around 0.5L/s in the long-term. Thus the cumulative total inflow to the tunnels of the Project and Northern Busway is approximately 8.5L/s.

Sensitivity Analysis

A sensitivity analysis was undertaken based on the cumulative impact scenario to assess the significance that variations in hydraulic conductivity (permeability) and specific yield have on the area of water level drawdown and predicted groundwater inflows. The sensitivity analysis for specific yield shows very little variation from the cumulative impact scenario. This similarity indicates that in this environment, quasi-steady state conditions are reached very rapidly for most parts of the project. An exception is the area west of the north-south driven tunnel, where the drawdown extends more rapidly than for the base scenario.

7.4.2 Impacts on Groundwater

Extent of Area Impacted

Simulation of the cumulative impact scenario has not shown significant changes in respect to the base scenario, which only analysed the Airport Link Project. Therefore the base scenario is discussed by default, with any differences shown by the cumulative impact analysis noted. The key outcomes of the modelling in relation to the area of impact are as follows:

- Water level drawdown occurs predominantly at the untanked (unlined) north-south road header driven tunnels, cut and cover tunnels and deeper transition structures of the project;
- Water level draw-down as a result of the Project is horizontally aligned about the project axis and vertically aligned with the depth of the tunnels; greatest predicted draw down is at the deepest part of the north-south driven tunnels, where a drawdown of up to 45m is predicted as possible in the long term (after 50 years). In this area the existing watertable, as measured in project boreholes, is in solid rock some 2-10m below ground level and thus below the root zone of surface flora so that a lowering of 45m will have no effect on surface vegetation;
- The transient predictive modelling, including that of the sensitivity analysis, shows that a quasi-steady-state drawdown condition is achieved within about 20 years of construction. Generally, within the alluvial aquifers, steady-state conditions are reached faster than in the hardrock aquifers;
- The cumulative impact assessment indicates only additional local drawdown of around 2m at the north-western connection cut and cover tunnel of the Northern Busway, north-west of the Airport Link Project.

Groundwater Depletion or Recharge

The simulation of the cumulative impact scenario has not shown significant changes in respect to the Airport Link Project base scenario. As for the above discussion on the area of impact, the base scenario is discussed by default. The results of the simulation indicate the following regarding groundwater depletion and recharge:

- Total long-term groundwater inflow to the tunnel was modelled as approximately 8L/s for the base scenario and 8.5L/s for the cumulative impact scenario;
- The modelling also indicated that quasi-steady state conditions are reached after a period of 20 years post construction;
- Surface water inflow from Kedron Brook at the north-western and north-eastern connections may occur as a result of the groundwater table drawdown during construction and operation of the cut and cover tunnels. The simulation of the project works computed long-term inflow rates of around 0.9L/s at the north-western connection and 1.4L/s at the north-eastern connection;

- No inflow is derived from the Brisbane River or Enoggera Creek. Thus the long-term groundwater inflow to the tunnel is met mainly by infiltration of rainfall over the remainder of the area;
- The only area, where a deeper untanked tunnel section of the project crosses the alluvium is between Newmarket Road and Granton Street. The groundwater modelling results indicate that the alluvial aquifer directly above the tunnel will be locally depleted. However, experience with similar projects suggests that the alluvial aquifer will not dry out totally. A more likely scenario will be the development of a perched shallow aquifer. Thus the direct hydraulic connection between the alluvial aquifer and the deeper fractured rock aquifers will be interrupted.

Impacts of Land Disturbance

Land disturbance as a result of the project construction will be limited to the open trough structures and cut and cover tunnels. Rainfall events (i.e. any occasion when rainfall is sufficient to cause surface runoff and pooling) that coincide with the presence of open cut and cover areas or open troughs may temporarily flood workings and lead to a short period of localised increase in recharge. In the event that this does occur, the impacts are considered minor, localised and of short duration. No impact on any groundwater regime is anticipated.

The possibility exists for stress relief fracturing of rock to occur during excavation of the project. Any stress relief fracturing will likely be limited to the immediate area of any excavation and may temporarily increase inflows during construction. The inflows are expected to dissipate quickly and should create no additional impact on the groundwater system.

Within the alluvial aquifers, the groundwater drawdown caused during project construction and operation may lead to compaction of the dewatered soil column and to land subsidence in the immediate surroundings of the project construction site.

Groundwater Dependent Ecosystems

Groundwater dependent ecosystems exist in the following areas (Technical Report No. 7 – Flora and Fauna in Volume 3 of the EIS):

- Kalinga Park;
- Melrose Park, Wooloowin;
- Kedron Brook, adjacent to Gympie Road;
- Downey Park, Enoggera Creek and Northey Street plantings.

Modelling the base scenario (with the same conditions as mentioned above in respect of the cumulative scenario) indicates that:

- The cut and cover tunnel at the north-eastern connection lies within Kalinga Park and the groundwater modelling predicts a long-term drawdown of more than 3m in the alluvium in the vicinity of the construction site, with a maximum drawdown of 7m directly at the deepest section of the excavation site. This model is based on the cut and cover tunnel construction not being tanked despite the proposed diaphragm lined walls because the floor of the cut is not proposed to be tanked at least for much of the construction period;
- Melrose Park is situated south of the tanked TBM driven tunnel. No significant long-term drawdown in this area is predicted;
- The modelling indicates that the vegetated areas adjacent to Kedron Brook at the north-western connection should experience a long-term drawdown of less than 1m for most areas. Around the construction site for

the cut and cover tunnel parallel to Kedron Brook, a drawdown of more than 3m is predicted in the area of the alluvium. The effects of this are discussed in Chapter 11 – Flora and Fauna;

- Along Downey Park, Enoggera Creek and Northey Street areas of planting, a drawdown of less than 1m is predicted; and
- Recharge of the groundwater resources will be induced by surface water infiltration from Kedron Brook, as discussed above. Field observations suggest that the alluvial aquifer is already now recharged by surface water temporarily during flood events, thus the groundwater quality is already influenced by the surface water. To assess the scale of the impact of the infiltration on the groundwater dependant environment along the sections of Kedron Brook, more in-depth analysis of the hydrogeological properties of the alluvial aquifer and flow rates and water level changes over time within the Kedron Brook would be required. However, data analysis of surface water sampled at the north-eastern connection, near the shallow groundwater monitoring bore, indicates that groundwater quality may improve by additional recharge from Kedron Brook. In relation to salinity, a surface water measurement carried out on May 23rd 2006 at Kedron Brook showed brackish water quality with 5500µS/cm. This level of salinity is likely to be a result of the tidal nature of Kedron Brook in this vicinity. The potential thus exists for the fresh to slightly brackish aquifer to be adversely impacted at this location during construction. This section of the excavations is to be tanked when the floor is sealed against the pile walls and thus draw-down of the water table due to the project will cease. This potential impact during construction is addressed in Chapter 11–Fauna and Flora.

7.4.3 Management Options

The major environmental impacts associated with groundwater are:

- Drawdown and depletion of groundwater within the alluvial aquifer systems;
- Change of groundwater quality caused by induced recharge from Kedron Brook.

Monitoring of the water level drawdown of groundwater within the alluvial systems can be undertaken through the use of standpipe monitoring bores or vibrating wire piezometers. A suitable network of alluvial monitoring bores has been established through the geotechnical drilling program. Regular water level monitoring is being carried out to date by BCC City Design. The water level monitoring will be continued until construction commences to provide baseline water level data from the alluvial systems. Insufficient data are available at present to discern any seasonal trends or relationships between water levels and rainfall.

Once construction commences, water level monitoring will be continued and if necessary the frequency of monitoring increased. Deviations from seasonal baseline water levels will be assessed and if necessary mitigation options formulated. It is envisaged that mitigation of any impacts will be dependent upon the location of the increased draw-down. Strategies may range from “do nothing”, to an assessment of the extent of the impact and the establishment of surface irrigation networks to maintain root zone moisture content levels.

For the areas where the simulation results indicate a significant degree of depletion of the alluvial aquifer (north-western and north-eastern connections) the tanking of the respective tunnel segment may be an option. However, during construction, the cut and cover tunnels may not be tanked in any case. Mitigation measures during construction to manage larger groundwater draw-downs, especially in areas of potential Acid Sulphate Soil, hazard or groundwater dependent ecosystems may consist of wetting of the soil by sprinklers or re-infiltration of the discharged groundwater using infiltration galleries. These actions would reduce the groundwater table drawdown and with it the induced low-quality water infiltration from nearby creeks.

During operation, the tanking of the cut and cover tunnels within the alluvial aquifers would create hydraulic barriers, inhibiting the natural groundwater flow towards groundwater discharge zones. Without mitigation, water levels would rise upstream of the tunnels and would be lowered directly downstream. A mitigation option to be considered would be the installation of cross-drains, consisting of pipes which channel the natural groundwater flow from the upstream wall of the tunnel to the downstream side.

Before these remediation strategies are planned in detail, field tests would be carried out to verify the estimated hydrogeological properties of the alluvium.

Groundwater Contamination

An area of environmental impact or risk relates to the potential for mobilisation of contaminated groundwater towards the Project. The untanked portions of any construction below the water table will always act as a groundwater sink and will draw in water within the groundwater capture zone.

Contaminated Sites

A survey for sites with potentially contaminated land revealed that 135 properties within 1km of the tunnel alignment are listed on the Environmental Management Register (EMR). A further 10 properties have been identified within the study corridor from historical aerial photographs, where a potential exists for a notifiable activity. It is unlikely that the identified sites comprise all the contaminated or potentially contaminated sites within the study corridor. A number of the sites are petroleum storage areas or service stations (existing or past) which have the greatest probability of possessing mobile contaminants. An inspection produced a further 58 properties of interest within the project corridor that may be contaminated.

Groundwater contamination has been detected at two boreholes and other groundwater contamination is suspected in some locations.

Impact of the Project

Identified potentially contaminated sites are shown in relation to the area of steady-state drawdown caused by the cumulative impact of the project and Northern Busway construction and operation are shown in **Figure 6-5**. All mobile groundwater contaminants within this capture zone may be expected to report ultimately to the tunnel. Contaminant travel times will depend upon the contaminant itself, distance from the tunnels and the magnitude of the hydraulic gradient towards the tunnels. As groundwater inflows are expected to be low, contaminant fluxes will be correspondingly low.

The migration of contaminated groundwater towards or through adjacent, previously uncontaminated sites warrants further discussion. Contaminated groundwater, migrates under the influence of a hydraulic gradient. All things being equal, the steeper the hydraulic gradient, the greater the rate of groundwater flow and hence contaminant movement. Contamination of groundwater occurs when uncontaminated water comes in contact with a source of contamination. If the contaminant is soluble, a percentage dissolves and a contaminated groundwater plume is created as the groundwater moves naturally away from the source. Processes such as dispersion and diffusion, which are aquifer and contaminant dependent, serve to reduce the concentration of contaminant around the margins of the plume and the effect becomes greater the further the plume travels from the source. Migration of the contaminant continues until the groundwater discharges, either in the river or as baseflow in an alluvial stream.

Any contaminant plume within the fractured rock aquifers and in the “capture zone” of untanked tunnel sections will alter direction in response to the reversal or modification of the natural hydraulic gradient. Contaminant plumes in the alluvium would probably be impacted at the north-western connection, where contamination has been detected at monitoring bores and at the north-eastern connection. Untanked, shallow cut and cover tunnels would act as groundwater sinks and deviate the natural groundwater flow direction, from the natural watercourse towards the project alignment. In the alluvial area between Newmarket Road and Granton Street, a perched water table may be formed by the impact of the north-south driven tunnel. Contamination contained within the alluvium may seep from the perched aquifer towards the driven tunnel or flow to the shallow excavations of Northern Busway for the Windsor busway station and the approaches of the Roblane Street tunnel. In terms of the cumulative impact with the Northern Busway, contaminant plumes within the alluvium will probably be impacted by the Northern Busway Project at the north-western connection cut and cover tunnel.

The modification in groundwater flow direction and, by inference, the movement of any contaminated groundwater would result in contamination moving under properties that otherwise would not be on the contaminant plume flow path. It has been established that the possibility of industry or domestic residents attempting to secure a groundwater supply is remote. Groundwater in the non-alluvial areas of the tunnel alignment is generally well below root zone level and will become deeper as the tunnel is constructed. On this basis the environmental impact of such an event is considered negligible. Within the alluvium, the environmental impact may be significant, if a contaminant plume migrates towards a formerly non-contaminated zone and groundwater consumption by domestic residents or by groundwater dependent ecosystems occurs.

Contaminant management strategies for the alluvium may be considered if additional investigations at the potentially impacted sites indicate mobile contaminants within the groundwater system. In the areas where contamination has been detected, further investigations would need to be carried out to assess its scale. If remedial activities are deemed necessary, they would need to consider the impact of the tanking of the cut and cover tunnels as a mitigation measure against the groundwater drawdown.

Untanked tunnels and excavations below the water table would be permanent groundwater sinks and capture contaminated groundwater within the area of influence. The chemistry of the groundwater inflow to the tunnels would be dominated by the natural groundwater but may also contain contamination. It is intended that this water will be treated prior to disposal and therefore contaminated groundwater that would otherwise discharge to the creeks and alluvial channels would be intercepted and treated. Thus the capturing of contaminated groundwater would have a positive impact on the groundwater system.

Management of Acid Sulphate Soils

According to the Acid Sulphate Soils (ASS) map provided by the BCC, ASS with different levels of hazard risk are present within the alluvial aquifers. The predicted long-term drawdown of the groundwater table caused by construction and operation in the vicinity of the tunnel section in most areas is up to 3 metres. In the immediate vicinity of the cut and cover tunnel at the Sandgate Road connection, the drawdown as computed by the groundwater model can reach more than 7m if the cut and cover tunnel is not tanked.

It is intended that management plans would be put in place to contain and neutralise any acid sulphate soils encountered and disturbed during excavations. These management strategies would serve to minimise the potential impacts on the alluvial groundwaters of Enoggera Creek and Kedron Brook.