13. Groundwater

Gateway Upgrade Project

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13. Groundwater

13.1 Introduction

TOR Requirements:
The EIS should review the quality, quantity and significance of groundwater in the Project area, together with groundwater use in neighbouring areas. The depth to groundwater should be identified, as should any Declared Groundwater Areas.

The groundwater assessment should take into account the findings of the acid sulphate soils assessments as per Section 4.3.

The environmental values of the groundwater should be described in terms of:

- values identified in the Environmental Protection (Water) Policy;
- sustainability, including both quality and quantity; and
- physical integrity, fluvial processes and morphology of groundwater resources.

A groundwater assessment has been undertaken for the GUP and neighbouring areas to provide information on the quality, quantity and significance of groundwater. The assessment includes the identification of potential impacts on groundwater associated with the development during construction and operation. Mitigation and management measures have been recommended where appropriate to minimise the identified potential impacts.

Regionally, the groundwater system will interact with surface water bodies and in this case the creeks and rivers which eventually drain to and support the coastal resources of the region. In this case, significant changes to groundwater outflow quality would be an impact of concern should dilution effects not be dominant. Changes to groundwater dynamics caused by the project are overall expected to be minimal.

Locally, variations to recharge, recharge quality and local groundwater levels may cause impacts on phreatophytic vegetation, or on water level impacts on flooding or seepage. In a local sense, these impacts may have significance particularly during the construction stage of the project. In the longer term, the groundwater environment of local areas would come to a new equilibrium and the receiving environment would adapt accordingly.

13.2 Methodology

Information relating to the groundwater hydrology of the study area varies along the GUP corridor, and in particular there is a paucity of data to the south of the Brisbane River. In view of this, there is a need for additional groundwater investigation works prior to the commencement of project construction.

Consequently, this description of the existing environment and conclusions drawn herein is based on the following sources:

- Geological mapping data from the Department of Natural Resources, Mines and Energy (DNRM&E 2002), the Geological Survey of Queensland (1980) and Willmott W and Stevens N (1992);
- Available groundwater data from DNRM&E Water Resources Section and BAC;
- Geotechnical drilling data and groundwater observations from studies by Golder Associates (GHD 2003),
- Land use and topographic maps information prepared by Connell Wagner specific to this project; and

- Discussions with staff from DNRM&E Water Resource Group.

Assessment of this information has allowed the specification of management measures to mitigate identified potential impacts.

13.3 Geological Background

The main geographical feature of the area is the Brisbane River, an estuarine channel comprising estuarine and alluvial soils deposited over bedrock. It is likely that the Brisbane River has been in existence since the late Triassic period and has had a significant impact on the surrounding landforms.

The bedrock of the area is characterised by sandstone, tuff, coal seams and shale from the Tingalpa Formation, and siltstone conglomerates and basalt from the Aspley Formation. Mudstone and some basalt intrusions that were encountered during the geotechnical studies to the south of the river are associated with the Petrie Formation.

To the north of the river, the upper stratum of the area is dominated by alluvium deposited during the Quaternary Period (<2million years ago). The Pleistocene alluvium comprises hard clays, medium to dense clayey sands and dense silty sands. Varying densities of alluvium deposited during the Holocene epoch generally overlay these deposits. During this period the Brisbane River deposited estuarine and deltaic sediments.

On the southern side of the river in the vicinity of Lytton Road, bedrock from the Tingalpa and Aspley formations are closer or at the surface. The bedrock of the area generally comprises siltstone and sandstones, however other rock types common to these formations may be encountered.

Geotechnical studies indicate that residual clays and colluvial soils and sediment, from undifferentiated coastal plains deposited in the Holocene epoch, overlie the bedrock.

The Devonian Neranleigh-Fernvale Beds form a basement for all rocks subsequently deposited in the region, and are present at ground surface from CH5700-5800 to CH6150-10200. The formation is comprised mainly of medium to fine grained hard meta-sedimentary rock, primarily argillite, greywacke, quartzite, jasper and greenstone

13.4 Hydrogeological Setting

13.4.1 General

The hydrogeological description for the project area has been based on limited available data. There is less information pertaining to the hydrogeologic conditions of the project area to the south of the Brisbane River, however to the north of the Brisbane River information is available, although this information is somewhat historic and limited in some cases.

The geological units discussed below are shown in Figure 9.1.

13.4.2 Mt Gravatt-Capalaba Road to Cleveland Branch Rail Line

Quaternary Coastal Plains Unit (Qhc)

Between CH13950 (north of Wynnum Road) to CH15100 (Cleveland Branch Rail Line) and closely associated with the Bulimba Creek tidal area system, Quaternary Coastal Plains deposits are indicated to be present at the surface (DNRM&E 2003). This unit consists of muds and unconsolidated sands and is likely to be overlain by a thin veneer of alluvial deposits (Qa) associated with Bulimba Creek. Within this unit, shallow groundwater is likely to be present within the granular/more permeable strata (sands) where sufficient thickness exists.

Groundwater flow within this Quaternary unit is likely to be dominated by the associated Bulimba Creek drainage line and may be tidally influenced to some degree within the estuarine zone. Groundwater is likely to be unconfined within this near surface unit.

Triassic Formations (Rip and Rin)

To the south towards the Mt Gravatt-Capalaba Road junction and north towards the Cleveland Branch Rail Line, the undifferentiated coastal deposits associated with Bulimba Creek (Qhc) pinch out and the underlying Triassic age Aspley (Rip) (sandstone, conglomerate and minor shale) and Tingalpa (Rin) (siltstone, shale and thin coal seams) formations are indicated to immediately underlie surface soils. These formations extend below the Quaternary coastal deposits to form the deeper groundwater system. The Tingalpa Formation is also present at surface in the extreme south of the project corridor, from Wecker Road (CH5630) to the Mt Gravatt-Capalaba Road junction (CH5160).

Away from the Bulimba Creek system, where the formations are exposed or near surface, shallow groundwater is likely to be present within the weathered profile of these units. The deeper groundwater system is likely to be present within both formations and groundwater flow regimes may become more complex at depth. Within the Tingalpa (Rin) formation, the presence of groundwater is likely to be restricted to more permeable coal seams and within fractures and fissures within the siltstone and shale units. Within the Aspley (Rip) formation, groundwater is likely to be present within both permeable units, such as sandstone and conglomerate and within fractures and fissures where impervious units are present.

Deeper groundwater flow within the Aspley and Tingalpa units is likely to be dominated by the distribution of fracture sets and permeable layers, however it is anticipated that overall groundwater movement is to the northeast and towards the Brisbane River and the coast. The deeper groundwater within these units may also be semi-confined or confined.

Devonian Neranleigh-Fernvale Beds (DCf)

Underlying the Triassic formations and indicated at or near surface between CH5700 and CH10200 is the Neranleigh-Fernvale Bed (DCf). This unit consists chiefly of metamorphosed and folded sedimentary rock including shale, arenite, jasper, quartzite, chert pillow lava and conglomerate. Groundwater within this unit is likely to be restricted to the near surface weathered profile and fractures or fissures at depth.

Shallow groundwater of the Neranleigh-Fernvale Beds within the weathered profile is anticipated to be controlled by weathered profile thickness and varying permeabilities, the structure of the less weathered or competent basement and the local topography (where shallow groundwater is present). Deeper groundwater flow within the Neranleigh-Fernvale Beds is likely to be controlled by the presence and density of fracture sets and complex structure, however overall groundwater movement is likely to be to the northeast, predominantly towards the coast. Groundwater within this unit is likely to be unconfined in the upper weathered profile to confined at depth.

13.4.3 Cleveland Branch Rail Line to Pinkenba Rail Line

Anthropogenic Deposits – Fill (Qhh)

Although indicated on local geological maps to stretch along the northern bank of the Brisbane River (between CH17350 and 17800) and to the northern extent of the GUP corridor, little information is available pertaining to the elevation and thickness of this unit. Within this area, information is restricted to a single geotechnical borehole, indicating a thickness of approximately 2m on the immediate northern bank of the Brisbane River. This unit is likely to be highly heterogeneous, dependent on fill type and distribution. Should groundwater be present within this unit, it is likely to exist at the base, perched above the underlying clayey Quaternary alluvial deposits (Qha and Qpa).

Quaternary Deposits (Qhe, Qhc and Qpa)

The geotechnical investigations (Golders Associates (2002) in GHD (2003)) studies have indicated significant thicknesses (up to 33m) of Holocene (estuarine and alluvial) sediments associated with the Brisbane River. Pleistocene alluvial sediments (Qpa) are indicated to underlie the Holocene estuarine and alluvial sediments under the Brisbane River channel. These sediments extend northwards from the southern bank of the Brisbane River, underlying the anthropogenic deposits and are indicated at or near surface on the local geological map from around Fison Avenue (CH18100) northwards. This is supported by information obtained from the geotechnical drilling investigation (Golders Associates 2002).

The Holocene sediments generally consist of sequences of soft clays and loose sands overlying Pleistocene sediments of firm-stiff clays, gravels and medium-dense sands. Shallow groundwater was encountered within these Quaternary deposits during the geotechnical drilling investigation. Groundwater within these alluvial units is likely to be restricted to more porous layers and lenses. Lateral and vertical hydraulic connectivity may become complex in areas where sand/gravel lenses are discontinuous or where clay properties may retard groundwater movement.

Limited drilling information suggests groundwater to the north of the Brisbane River is quite shallow with depths to water table of around 2.5m observed during geotechnical drilling. The limited drilling and topographical data suggests the water table is likely to be generally quite flat in this area, with shallow groundwater movement within the alluvial deposits likely to occur to the south towards the Brisbane River.

Triassic Formations (Rip and Rin)

Underlying the Quaternary system to the south of Pinkenba Rail Line are the Triassic Sedimentary Formations the Tingalpa (Rin), consisting of siltstone, shale and thin coal seams and Aspley (Rip), consisting of sandstone, conglomerate and minor shale). Geotechnical drilling information has confirmed the presence of the underlying Triassic Formations, with low-medium strength sandstone and mudstone (and coal seams nearing the Brisbane River) being observed to underlie the Quaternary alluvial sediments. From the southern bank of the Brisbane River to the Cleveland Branch Railway Line, the local geological map (DNR&M 2003) indicates the Tingalpa Formation at or near surface. This is supported by geotechnical drilling undertaken by Golders Associates (Golders Associates (2002) in GHD 2003), to the immediate south of the Brisbane River.

Deeper groundwater in these formations, in particular the Aspley Formation, is likely to be contained within permeable strata such as the sandstone and conglomerate units or near surface weathered zones. Groundwater within the impermeable layers such as shale and mudstones is likely to be restricted to fractures and fissures with fracture density a controlling factor for groundwater availability. Dependent on the distribution of strata and overall formation thickness, groundwater in the Triassic Formations is likely to be unconfined near surface and semi-confined or confined at depth. Overall deeper groundwater flow in this near vicinity of the Brisbane River is likely to be towards the river, with a component towards the coast.

13.4.4 Pinkenba Rail Line to Nudgee Road

Anthropogenic Deposits – Fill

Although not indicated on the local geological map, information from the geotechnical drilling investigation (Golders Associates (2002) in GHD 2003) has indicated varying thicknesses of fill (up to about 3m) along the Project Corridor. Drilling log information indicates the fill is quite heterogeneous, ranging from granular to clayey in nature. Should groundwater be present within this unit, it is likely to exist at the base, perched above the underlying clayey Quaternary alluvial deposits (Qpa).

Quaternary Deposits (Qhc and Qpa)

The geotechnical drilling investigation studies have indicated varying thicknesses (between about 16m to 30m) of Holocene and Pleistocene alluvial sediments along the northern section of the project corridor from Pinkenba Rail Line to south of the Kedron Brook Floodway crossing (CH22700). A generalised subsurface profile is presented in Section 9, Figure 9.2. Beyond the Kedron Brook Floodway crossing, drill logs indicate the Pleistocene deposits pinch out, leaving a thin veneer of Holocene alluvial sediments. These deposits were observed to generally consist of near-surface Holocene sequences of soft clays and loose sands overlying Pleistocene sediments of firm-stiff clays, gravels and medium-dense sands. Shallow groundwater was encountered within these Quaternary deposits during the drilling investigation. Groundwater within these alluvial units is likely to be restricted to more porous layers and lenses. Lateral and vertical hydraulic connectivity may become complex in areas where sand/gravel lenses are discontinuous or where clay properties may retard groundwater movement.

Limited drilling information indicates that groundwater to the north of the Pinkenba Rail Line is quite shallow with depths to water table of around 2.5m observed during geotechnical drilling. The limited drilling and topographical data also indicates the water table is likely to be generally quite flat to the north of the Brisbane River, with shallow groundwater movement towards local tributaries such as Kedron Brook Floodway as well as local drainage tributaries to the north and east of the GUP corridor.

Tertiary Formations (Tp)

Underlying the Quaternary deposits from CH21000 (Airport Drive area) and northwards to Nudgee Road are Tertiary mudstone, sandstone, siltstone, brown coal and limestone of the Petrie Formation (Tp). During the geotechnical drilling, weathered basalt, likely Tertiary in age, was also identified underlying the Quaternary sediments. The weathered basalt was observed at CH20000 and extending from CH20700 to CH21000. Data from DNRM&E borehole logs indicates the weathered basalt also extends northwards immediately beyond the northern extent of the GUP corridor.

Groundwater is likely to be present within the permeable strata within these units, including identified low strength sandstones or weathered zones of the Petrie Formation or basalt unit. Groundwater is likely to be unconfined (or possibly semi confined where sufficient thickness of an overlying aquitard layer exists), depending on structure, weathering and prevalence of porous units. Groundwater flow direction is likely to be overall towards local drainage lines, including towards Kedron Brook Floodway and wetland areas to the north and east, and the Brisbane River to the south closer to the Pinkenba Rail Line.

Triassic Formations (RJbw)

Underlying the Quaternary system and Tertiary systems to the north of Pinkenba Rail Line and to the north of Airport Drive are the Triassic sediments of the Woogaroo Subgroup (predominantly thick sandstone beds, with minor conglomerate, siltstone, shale and coal beds). Drilling information has confirmed the presence of the underlying Triassic Formation, with low-medium strength sandstone and mudstone (with coal seams nearing the Brisbane River) being observed to underlie the Quaternary alluvial sediments and although not recorded may also underlie the Tertiary formations where present.

Deeper groundwater in these formations is likely to be contained within permeable strata such as the sandstone and conglomerate units. Groundwater within the impermeable layers such as shale and mudstones is likely to be restricted to fractures and fissures with fracture density a controlling factor for groundwater availability.

Dependent on the distribution of strata and overall formation thickness, groundwater in the Triassic Formations is likely to be semi-confined or confined at depth. Overall groundwater flow within these deeper formations is likely to be to the east and towards the coast.

13.5 Groundwater Levels and Extent of Aquifers

Data was acquired from DNRM&E listing registered groundwater bores and available monitoring information for all listed private and DNRM&E monitoring bores. A total of 33 bores were listed, however these were primarily in the vicinity of the Brisbane Airport to the north of the Brisbane River (refer Figures 13.1a-c). A description of observed groundwater levels, aquifer thickness and type, and several estimated maximum well yields from pump tests from available DNRM&E data is detailed in Table 13.1.

Table 13.1 Summary of Static Water Level and Aquifer Data (Source: DNRM&E 2004)

DNRM&E Reg No.	Monitoring Date Range	Static Water Level (SWL) Metres above AHD		Aquifer depth Top – bottom (mbgl)	Aquifer Description	Estimated Yield (l/s)
		Maximum	Minimum			
Mt Gravatt-Capalaba Road to Cleveland Branch Rail Line						
79718	-	-	-	-	-	1.2
Cleveland Branch Rail Line to Pinkenba Rail Line						
7912	-	-	-	-	-	-
7189	-	-	-	-	-	-
Pinkenba Rail Line to Nudgee Road						
14220002	09/79-01/81	1.61	0.53	11.00-12.00	Tp(basalt)	-
14220003	09/79-09/83	1.15	0.28	3.00-4.00	Qh	-

FIGURE 13.1a
Historic Groundwater Monitoring Sites

Q:\graphics\graphics\jobs\579210NZ\Historic and Existing Groundwater Sites - A.cdr June 2004

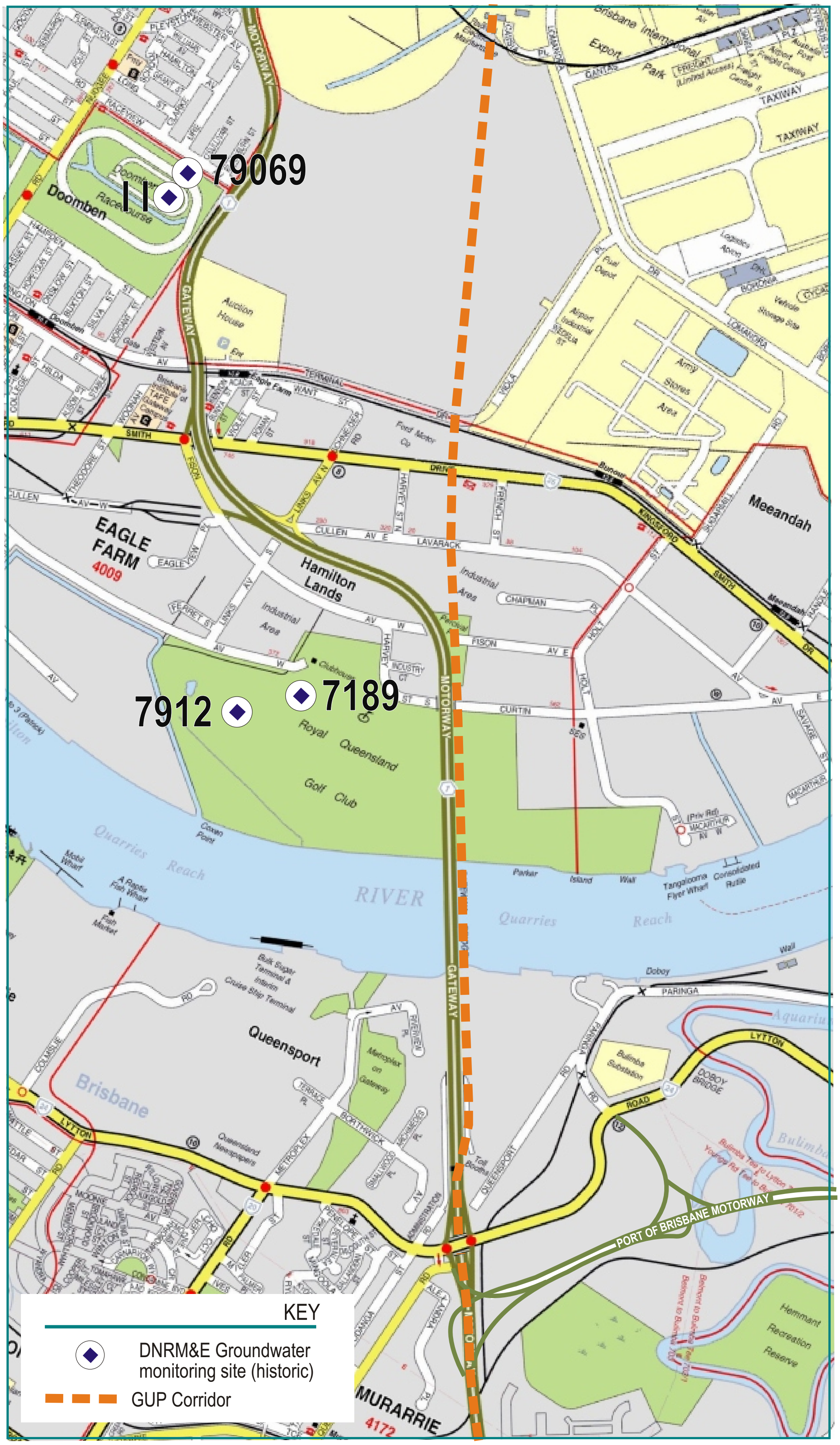

FIGURE 13.1b
Historic Groundwater Monitoring Sites

Q:\graphics\graphics\jobs\579210NZ\Historic and Existing Groundwater Sites - C.cdr June 2004

Queensland Government
Australian Government Department of Transport and Regional Services
Connell Wagner

FIGURE 13.1c
Existing and Historic Groundwater Monitoring Sites

DNRM&E Reg No.	Monitoring Date Range	Static Water Level (SWL) Metres above AHD		Aquifer depth Top – bottom (mbgl)	Aquifer Description	Estimated Yield (l/s)
		Maximum	Minimum			
14220004 (a)	09/79-03/87	1.03	0.1	5.00-11.00	Tp(basalt)	-
14220004 (b)	09/79-03/87	1.09	0.22	2.00-3.00	Qh	-
14220005 (a)	09/79-09/86	1.39	0.3	24.00-26.00	Tp(basalt)	-
14220005 (b)	09/79-09/86	0.94	0.29	3.00-6.00	Qh	-
14220006	09/79-03/87	1.08	-1.09	7.00-9.00	Qhc	-
14220007	09/79-12/79	1.64#	2.12#	5.00-6.00	Qhc	-
14220008	09/79-05/84	1.05	0.35	13.00-15.00	Tp(basalt)	-
14220009	09/79-05/84	4.01	2.33	9.00-10.00	Tp(basalt)	-
14220010	09/79-03/87	3.86	1.87	5.00-10.00	Tp(basalt)	-
14220011 (a)	09/79-03/87	3.04	1.3	24.00-26.00	Tp	1.13
14220011 (b)	09/79-03/87	2.1	1.49	3.00-6.00	Qhc/Qpa	-
14220012	09/79-03/87	1.11	0.29	5.00-10.00	Tp(basalt)	0.18
14220013 (a)	09/79-09/80	1.06	-0.72	17.00-22.00	Tp	-
14220013 (b)	09/79-09/80	.095	0.45	3.00-5.00	Qhc	
14220014 (a)	09/79-08/86	1.89	0.87	12.00-15.00	Tp	-
14220014 (b)	09/79-08/86	1.89	0.93	5.00-6.00	Qh/Qp	
14220015 (a)	09/79-10/79	1.05	1.03	16.00-18.00	Tp	-
14220015 (b)	09/79-10/79	0.99	0.96	5.00-6.00	Tp	
14220016	09/79-05/80	1.72	0.82	9.00-10.00	Tp	-
14220017	09/79	1.49	-	6.00-10.00	Qhc	-
14220018 (a)	09/79-05/84	2.97	1.33	17.00-20.00	Tp	-
14220018 (b)	09/79-05/84	2.89	1.65	5.00-6.00	Qhc	
14220019	09/79-05/84	1.39	0.71	10.00-12.00	Tp	-
14220020 (a)	09/79-05/84	1.57	0.98	27.00-28.00	Tp(basalt)	-
14220020 (b)	09/79-05/84	1.16	-0.04	0.00-6.00	Qhc	
14220021	09/79-03/87	4.92	2.21	6.00-8.00	Qh/Qp	-
14220023	09/79-05/80	1.44	-1.21	-	-	-
14220025	09/79-03/87	5.86	5.38	-	-	-
14220026	10/79-03/87	1.85	1.4	-	-	-
14220027	10/79-03/87	0.98	1.46	-	-	-
14220028	08/86	1.27#	1.30#	-	-	-

DNRM&E Reg No.	Monitoring Date Range	Static Water Level (SWL) Metres above AHD		Aquifer depth Top – bottom (mbgl)	Aquifer Description	Estimated Yield (l/s)
		Maximum	Minimum			
14220029	09/79-05/82	0.26	-1.38	-	-	-
14220030	09/79-12/79	1.83	1.39	-	-	-
11	02/87	-	-	Max depth 544.38	-	0.38
76069	-	-	-	Max depth 543.20	-	-

Table Notes:
no elevation data available to confirm water level as AHD, recorded as metres below top of casing.
mbgl metres below ground level

Confirmation of the accuracy of drilling, well installation and monitoring data cannot be confirmed by Connell Wagner and as such, the following information is limited by the accuracy of the data provided by DNRM&E.

13.5.1 Mt Gravatt-Capalaba Road to Cleveland Branch Rail Line

Aquifer information to the south of the Brisbane River is scarce with only one well reported on the DNRM&E database. The well in question (DNRM&E Reg. 79718) is located around CH10300 near the junction of Old Cleveland Road. Information indicates that this well was drilled into shales of the Devonian Neranleigh-Fernvale Beds (to a depth of 68m). Water level information indicates that the groundwater level at this location is at or near surface, which may indicate the deeper aquifer is semi-confined or confined, however it must be noted that this is representative of deeper groundwater levels at this location only.

Given the topography and geology, it is anticipated that shallow aquifer groundwater levels within the GUP corridor to the south of the Brisbane River are likely to be topographically dominated, with the water table likely to be near surface towards the base drainage lines and marsh areas As no data regarding shallow groundwater depths is currently available, water table depths to the south of the Brisbane River cannot be assessed. A bore yield of 1.2l/s is indicated from the single well in this part of the GUP corridor.

13.5.2 Cleveland Branch Rail Line to Pinkenba Rail Line

Although two wells are indicated on the DNRM&E databases (Reg. 7189 and 7912), information regarding groundwater levels and aquifers monitored is not available. However from the geotechnical drilling investigation, it was observed that to the north of the Brisbane River, groundwater levels are shallow (around 2.5m below ground level). Given the generally flat topography surrounding the Brisbane River, it is very likely that this is indicative of groundwater levels within this part of the GUP corridor.

Bore yield data was not available for this area, although it is likely that similar conditions to the northern area exist with low yields expected.

13.5.3 Pinkenba Rail Line to Nudgee Road

Observations of static groundwater levels from both DNRM&E data and data from the geotechnical drilling indicates very shallow depth to groundwater in the area to the north of the Brisbane River, with static water levels ranging between approximately ground surface (and to some extent artesian for the deeper wells) to 2.0m below ground level for both shallow and deeper aquifer wells.

Where multiple groundwater wells have been installed, time series water level data indicates varying hydraulic connectivity between the observed shallow and deeper aquifers. This is evident through the variations in differences between the deeper and shallow aquifer piezometric levels over time, examples of which are presented in Figures 13.2a-d, which include boreholes (DNRM&E Reg.) 14220004(a&b), 14220005(a&b), 142200011(a&b) and 142200018(a&b) and are generally located in the northern project area. Borehole log information (refer Table 13.3) from these locations indicates that the shallow wells (denoted by "b" and ranging between 3.2m and 6m below ground level (mbgl) in depth) are situated within the Quaternary Coastal deposits (primarily clays and silts). The deeper wells (denoted by an "a" and ranging between 11.3 and 20mbgl) are situated within the mainly Tertiary formations (Petrie Formation/Basalt) and within underlying Triassic formations (shale, sandstone and minor coal seams) at some locations. The data may indicate the following:

- The deeper aquifer ranges from unconfined to semi-confined at some locations. Possible semi confinement of the deeper aquifer at some locations is indicated by periodic poor correlation between deeper and shallow groundwater levels over time. This is supported by groundwater quality data, in particular electrical conductivity, may indicate systems separated by a confining or semi-confining layer. In addition, occasional slight artesian deeper groundwater levels were observed. In this case, it may be considered that the overlying clayey Quaternary sediments may be acting to confine the deeper aquifer.
- Deeper observed groundwater levels, which are generally higher than shallow groundwater levels in this area. This may be indicative of a trend of deeper groundwater discharge into the shallow groundwater system in this area.

It should be noted that the above is based on limited available data that is limited by its accuracy.

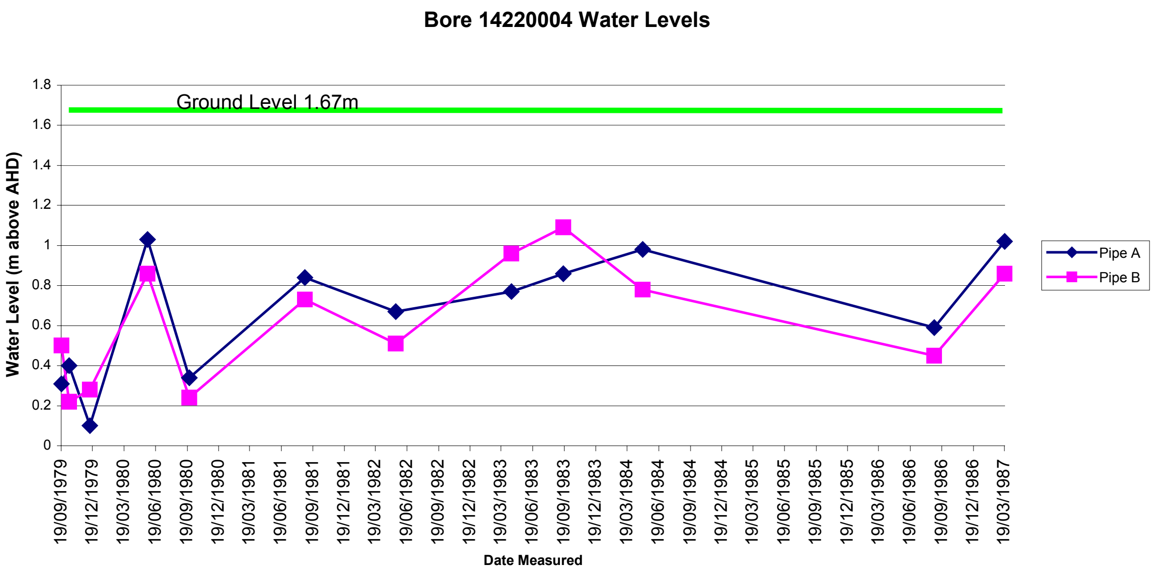

Figure 13.2a Borehole 14220004

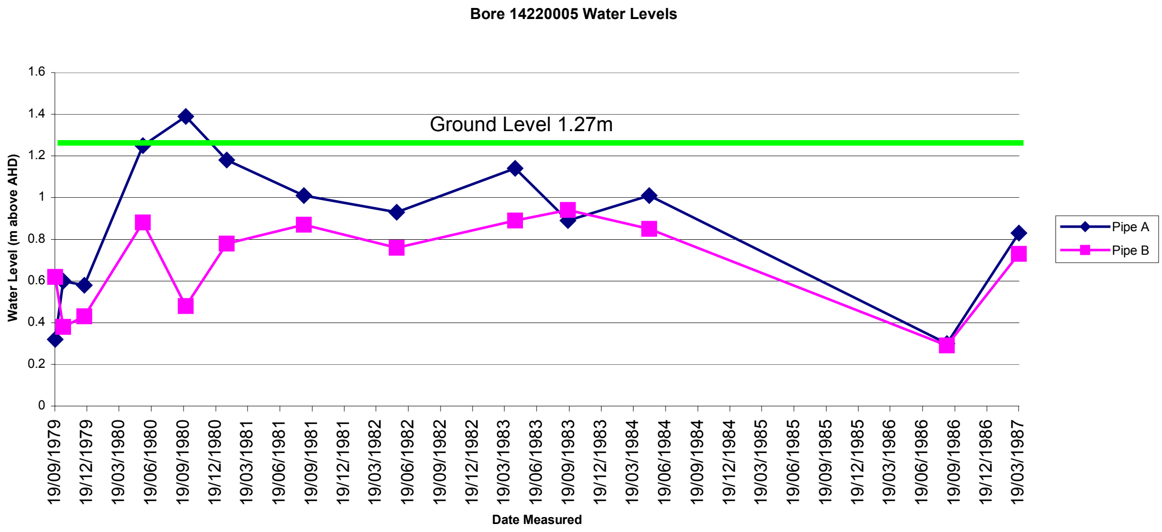

Figure 13.2b Borehole 14220005

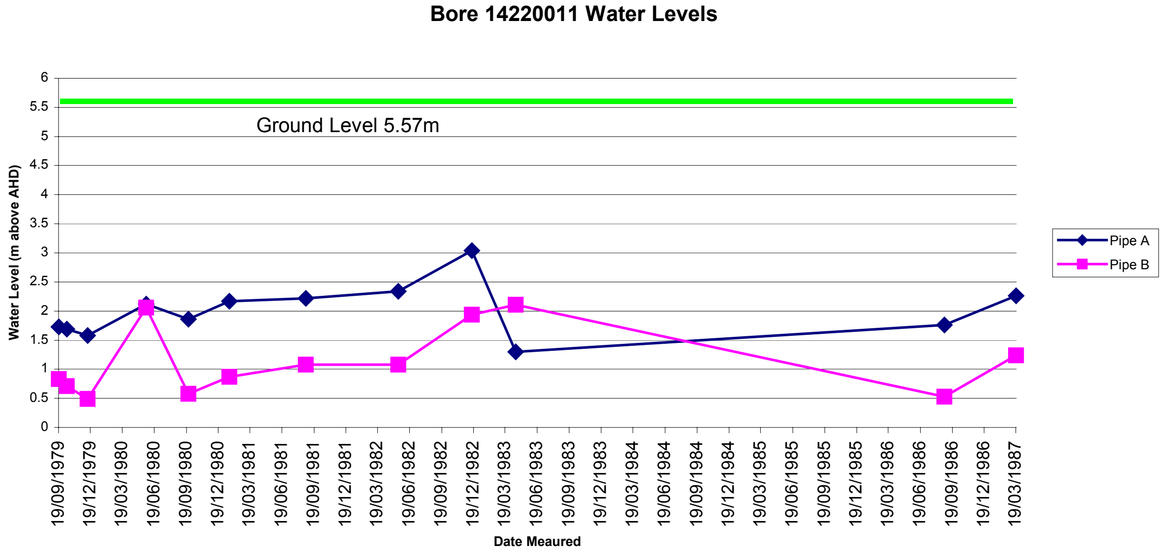

Figure 13.2c Borehole 14220011

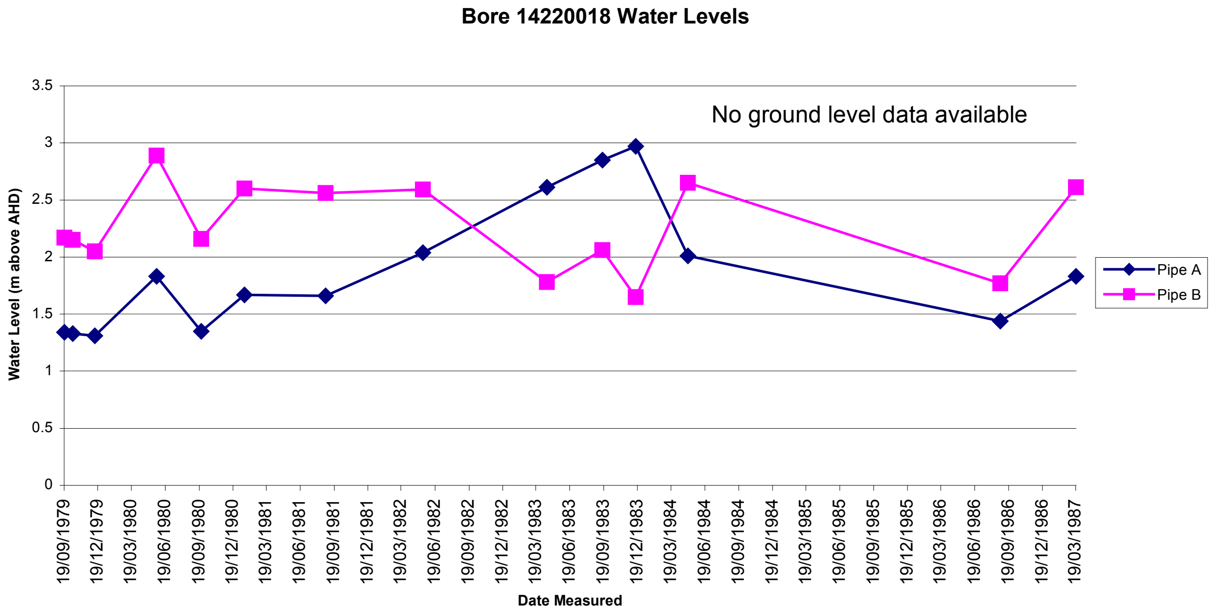

Figure 13.2d Borehole 14220018

The very limited available bore yield data indicates a range of maximum yields of between 0.18l/s and 1.13l/s. Recharge estimates were not available at this time. Additional anecdotal information from DNRM&E (Pers. Comm. Ellis; R, 27 May 2004) indicates generally low yielding aquifers in the area.

13.5.4 Groundwater Recharge and Discharge

Due to the generally flat, low lying area surrounding the GUP corridor, in particular to the north of the Brisbane River, it is likely that shallow groundwater recharge occurs primarily through the direct infiltration of rainfall, high tides or floodwaters.

Limited available DNRM&E data for several multiple well installations, regarding variations between shallow and deeper groundwater potentiometric levels, indicates possibly complex recharge patterns for the deeper aquifer and semi-confined aquifers in some areas. In some locations, correlation between shallow and deeper groundwater levels is reasonable, indicating some hydraulic connectivity and hence the potential for recharge from the upper aquifer. However in many areas, correlation between upper and deeper groundwater level response was quite poor, indicating poor vertical hydraulic connectivity, hence recharge through lateral groundwater movement to the deeper aquifer system may occur.

Shallow groundwater discharge is likely to occur along local drainage lines, such as Kedron Brook Floodway and Bulimba Creek. Shallow groundwater discharge is also likely to occur into low topographic areas, in particular the low lying wetlands in the northern project areas and the wetland system associated with Bulimba Creek to the south of the Brisbane River. Dependent on topography and structural constraints, groundwater discharge may also occur through springs and seeps in elevated areas.

Deeper groundwater discharge is likely to occur along major drainage lines such as the Brisbane River and towards the coastal areas where gradually more mixing with seawater will occur. Groundwater level data for nested monitoring well locations indicates an upward pressure gradient for groundwater in the northern area. This may be indicative of upward discharge from the deeper to the shallow aquifer systems at these locations in the northern area.

13.5.5 Tidal Influences

It is likely that groundwater levels in the immediate vicinity of the Brisbane River and other estuarine areas, such as Bulimba Creek or Kedron Brook Floodway may be affected to some degree by tidal fluctuations, in particular in permeable formations such as fill areas along the Brisbane River. However the diurnal nature of the tide in this area and the silty or clayey nature of the alluvial sediments should result in relatively minor extent of tidal influence on groundwater levels other than immediately adjacent the Brisbane River and other tidally affected watercourses.

13.6 Groundwater Quality

Limited data about groundwater quality is currently available. Sampling and quality data from DNRM&E has often undertaken at different times and with differing analytical suites and as stated previously, most of the data is available for the project area to the north of the Brisbane River, in the vicinity of the Brisbane Airport. Table 13.2 provides a summary of available groundwater quality data from 27 bores.

Groundwater quality data from DNRM&E is generally restricted to electrical conductivity (EC) and pH, major cations and anions, and some nutrient analyses (nitrates). Data analyses of dissolved metals concentrations is limited to one bore to the south of the Brisbane River near the Gateway Motorway/Old Cleveland Road Junction (DNRM&E Reg 79718), Table 13.4 provides a summary of this information.

Available groundwater data has been compared to relevant guideline levels based on probable receptors, including:

- ANZECC 2000 95% Protection of aquatic ecosystems for marine/estuarine environments; and
- ANZECC 2000 Irrigation Guideline Values (long term use – up to 100 years).

In general, groundwater quality along the GUP corridor is quite poor, mainly due to dissolved salts associated with the estuarine environment.

13.6.1 Mt Gravatt-Capalaba Road to Cleveland Branch Rail Line

Groundwater quality information is available for one well (DNRM&E Reg 79718), which is located near the Old Cleveland Road junction. Water quality information from this location indicates:

- pH value of 7.8, indicating neutral conditions;
- Electrical conductivity (EC) of 1,750 μS/cm, which may be considered marginal (800μS/cm – 2400μS/cm) and may be suitable for moderately sensitive crops (ANZECC 2000);

- Metals data available for this location indicates zinc exceeded the ANZECC (2000) Guideline value for freshwater and marine ecosystems (95% Protection) of 0.008mg/l and 0.015mg/l, respectively, however the value does not exceed ANZECC 2000 irrigation guideline value (2mg/l) (refer Table 13.4).

It must be noted that these results are representative of the deeper aquifer system at this location and should not be inferred beyond the immediate area. No data is available as to the characteristics of the shallow groundwater system to the south of the Brisbane River, nor the deeper system for the major extent.

13.6.2 Cleveland Branch Rail Line to Pinkenba Rail Line

Within this sector of the GUP, there is no information relating to groundwater quality. It is assumed however that water quality will be similar to available results from the northern area.

13.6.3 Pinkenba Rail Line to Nudgee Road

In the northern section of the GUP there are a number of groundwater boreholes with limited groundwater quality information (refer Table 13.2).

Assessment of the available groundwater quality information indicates:

- The available pH data in the vicinity of the Brisbane Airport ranges quite widely. In one area, low pH from both shallow and deeper systems, ranged from 4.4 (Reg. 14220018(b)) to 5.6 (Reg. 14220018(a)), located to the north of the existing Toombul Road intersection. Another low pH of 3.6 was observed in boreholes 1400021, located immediately north of the northern extremity of the GUP. These low pH values may be indicative of acid generation from acid sulphate soils within the area at the time of sampling (1982);
- A further total of seven DNRM&E wells indicated slightly acidic conditions (pH 6.3 – pH 6.9). The ANZECC 2000 Guideline range for the protection of aquatic ecosystems (in estuarine waters) is 7.0-8.5;
- At other locations pH values were within ANZECC 2000 guideline levels;
- Electrical conductivity to the north of the Brisbane River ranges widely, from 680µS/cm (fresh) near Doomben Racecourse to generally saline groundwater (greater than 15,000µS/cm (saline)) in most other locations. In many areas, the relevant ANZECC 2000 guidelines values for irrigation were exceeded;
- Very high electrical conductivities were detected beyond the northern tip of the project area (DNRM&E reg. nos, 14220002, 14220003, 14220004 and 14220023) with a number of results observed to be greater than seawater (> ~50,000µS/cm). In this area, groundwater movement may be very restricted due to lack of significant hydraulic gradient and geological constraints, and coupled with evapotranspiration, leading to a concentrating effect of salts in this area;
- Electrical conductivities from shallow and deeper aquifer systems is presented in Table 13.3, and from this information it was observed that in some cases, the lower aquifer was more saline than the shallow aquifer systems but not in all cases;
- Nitrates exceed the ANZECC 2000 Guideline values (95% protection) for freshwaters (southeastern Australia) of 0.7mg/l at a number of locations (with concentrations generally ranging from 0.2mg/l near Doomben Racecourse to 1.5mg/l to the north of the Nudgee Road intersection; and

- One area of highly elevated nitrate concentrations was observed to the immediate south east of the Nudgee Road intersection where values of between 8.5mg/l and up to 70mg/l were observed within the shallow aquifer system.

Table 13.2 Summary of Groundwater Quality Data from Available Data Sources (DNRM&E)

DNRM&E Reg No.	Date Measured	Electrical Conductivity (µS/cm)	pH	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	CO_3 (mg/l)	Cl (mg/l)	F (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)
ANZECC Guideline Values		NA	7 – 8.5**	NA	NA	NA	NA	NA	NA	NA	NA	0.7*	NA
ANZECC Irrigation Guidelines		950 - 1900	6 – 8.5***	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14220002	4/9/1979	59000	-	-	-	-	-	-	-	-	-	-	-
14220003	7/1/1982	49500	**6.9**	10500	300	520	1400	274	0	18500	0.5	**1**	3300
14220004 (b)	7/1/1982	88000	7.4	22000	360	800	2800	396	0	38000	0.4	**1.5**	6400
14220004 (a)	4/9/1982	72000 (f)	-	-	-	-	-	-	-	-	-	-	-
14220005 (b)	1/1/1981	38000	7.6	7550	240	220	1200	939	0	14600	0.3	**14**	50
14220005 (a)	4/9/1979	30000 (f)	-	-	-	-	-	-	-	-	-	-	-
14220006	7/1/1982	47000	7.5	9800	230	180	1320	98	0	18000	0.2	**70**	1120
14220008	7/1/1982	34500	7.4	6800	120	800	1200	1020	0	11200	0.5	**30**	4300
14220010	7/1/1982	800	7.3	150	0.6	2	6	136	0.2	160	0.1	**8.5**	6
14220011 (b)	4/9/1979	4800 (f)											
14220011 (a)	7/1/1982	21500	**6.8**	1730	25	1210	1110	180	0	8100	0.1	0.5	38
14220012	7/1/1982	37000	7.5	8000	100	640	860	823	0	13000	0.3	0	2750

Table Notes:
* 95% Protection for aquatic ecosystems (freshwater)
** Stressor Indicator for estuarine Rivers in southeastern Australia
*** Corrosion based only
- Not analysed
(f) field tested
(b) Shallow aquifer (generally 0-10m below ground level)
(a) Deeper aquifer (generally >10m below ground level)
NA No guideline values available
BOLD indicates exceedence of guideline values

DNRM&E Reg No	Date Measured	Electrical Conductivity (µS/cm)	pH	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	CO_3 (mg/l)	Cl (mg/l)	F (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)
ANZECC Guideline Values		NA	7 – 8.5**	NA	NA	NA	NA	NA	NA	NA	NA	0.7*	NA
ANZECC Irrigation Guidelines		950 - 1900	6 – 8.5***	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14220013 (b)	4/9/1979	17000 (f)	-	-	-	-	-	-	-	-	-	-	-
14220013 (a)	4/9/1979	19000 (f)	-	-	-	-	-	-	-	-	-	-	-
14220014 (b)	4/9/1979	8300 (f)	-	-	-	-	-	-	-	-	-	-	-
14220014 (a)	4/9/1979	23000 (f)	-	-	-	-	-	-	-	-	-	-	-
14220015 (b)	4/9/1979	11000 (f)	-	-	-	-	-	-	-	-	-	-	-
14220015 (a)	4/9/1979	8500 (f)	-	-	-	-	-	-	-	-	-	-	-
14220016	4/9/1979	2700(f)	-	-	-	-	-	-	-	-	-	-	-
14220017	4/9/1979	2700(f)	-	-	-	-	-	-	-	-	-	-	-
14220018 (b)	7/2/1982	1300	**4.4**	198	23	4	15	0	0	305	0.1	0	100
14220018 (a)	7/1/1982	1280	**5.6**	198	23	6	15	6.1	0	305	0.1	0	102
14220019	7/1/1982	6450	**4.8**	930	27	185	210	2.4	0	1430	0.2	0	1200
14220020 (b)	7/1/1982	17000	**6.4**	3050	50	250	470	83	0	5240	0.1	**4**	1450
14220020 (a)	7/1/1982	265	**6.9**	23	6.4	13	4.8	50	0	32	0.1	**3**	20

Table Notes:
* 95% Protection for aquatic ecosystems (freshwater)
** Stressor Indicator for estuarine Rivers in southeastern Australia
*** Corrosion based only
\- Not analysed
(f) field tested
(b) Shallow aquifer (generally 0-10m below ground level)
(a) Deeper aquifer (generally >10m below ground level)
NA No guideline values available
BOLD indicates exceedence of guideline values

DNRM&E Reg No	Date Measured	Electrical Conductivity (µS/cm)	pH	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	CO_3 (mg/l)	Cl (mg/l)	F (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)
ANZECC 2000 Guideline Values		NA	7 – 8.5**	NA	NA	NA	NA	NA	NA	NA	NA	0.7*	NA
ANZECC Irrigation Guidelines		950 - 1900	6 – 8.5***	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14220021	7/1/1982	3700	**3.6**	630	1	8	64	0	0	1100	0.1	0	77
14220023	4/9/1979	54000 (f)	-	-	-	-	-	-	-	-	-	-	-
14220025	7/1/1982	285	7.6	37	0.4	6.4	6.4	50	0.1	54	0	0	5
14220026	7/1/1982	42500	7	9200	300	320	1000	122	0	15500	0.7	**1**	2140
14220027	7/1/1982	20000	7	3850	125	140	430	156	0	6640	0.6	**1**	890
14220028	7/1/1982	1520	**6.3**	223	2	25	29	134	0	390	0.1	0	11
14220029	7/1/1982	350	**6.9**	45	1.8	7.2	7.5	48	0	68	0.1	0.5	9
11	22/02/1987	880	8.1	76	0.6	64	34	390	3.6	85	0.3	0.7	35
79069	21/11/1997	680	**6.9**	82	2.9	38	16.1	0.17	98	0.14	0.2	0.2	7.9
79718	28/05/1996	1750	7.8	306.2	6.6	52.3	22.2	439.7	1.9	339.6	1.8	0.3	36.6

Table Notes:
* 95% Protection for aquatic ecosystems (freshwater)
** Stressor Indicator for estuarine Rivers in southeastern Australia
*** Corrosion based only
- Not analysed
(f) field tested
(b) Shallow aquifer (generally 0-10m below ground level)
(a) Deeper aquifer (generally >10m below ground level)
NA No guideline values available
BOLD indicates exceedence of guideline values

Table 13.3 Nested Well Data Summary

Well	Pipe	Date Tested	Conductivity (µS/cm)	Well Base Depth (m)	Strata at Base of Well
14220004	a	4/9/79	72000	11.3	Tp(basalt)
14220004	b	4/9/79	88000	3.2	Qh/Qp
14220005	a	4/9/79	30000	26	Basalt
14220005	b	4/9/79	38000	6	Qh/Qp
14220011	a	7/1/82	21500	26.6	RJbw
14220011	b	4/9/79	4800	6	Qh/Qp)
14220013	a	4/9/79	19000	22	Tp(basalt)
14220013	b	4/9/79	17000	5	Qh/Qp
14220014	a	4/9/79	23000	15.1	Tp(basalt)
14220014	b	4/9/79	8300	6	Qh/Qp
14220015	a	4/9/79	8500	18	RJbw
14220015	b	4/9/79	11000	6	RJbw
14220018	a	4/9/79	22000	20	Tp
14220018	b	4/9/79	1400	6	Qh/Qp
14220020	a	4/9/79	21000	28	Tp(basalt)
14220020	b	4/9/79	14000	6	Qh/Qp

Table 13.4 Summary of Available Dissolved Heavy Metals Data (mg/L)

DNRM&E Reg No	Date Measured	Al	B	Cu	Zn
ANZECC 2000 (95% Protection)*		ID	ID	0.0013	0.015
ANZECC 2000 (Irrigation)**		5	0.5	0.2	2
79718	28/05/1996	0	0.1	0	**0.06**

Table Notes:
* ANZECC 2000 Guideline values for the 95% Protection of aquatic ecosystems – marine environments.
** ANZECC 2000 Guideline value based on long-term use (up to 100 years)
ID insufficient data to develop guideline value
BOLD indicates exceedence of guideline values

13.6.4 Potential Existing Groundwater Contamination

There is a potential for groundwater contamination within the vicinity of the GUP due to the presence of light and heavy industry and urbanisation in the surrounding areas as previous land filling. A number of land parcels within the GUP corridor have been identified as places where a Notifiable Activity is currently undertaken by industry (as listed on the Environmental Management Register). These activities include:

- Drum reconditioning;
- Oil and petroleum storage facilities;
- Chemical storage facilities;
- Metal treatment works;
- Tannery and hide curing; and
- Landfills.

Additional details of the above activities are provided in Section 10.

Light and heavy industries have also historically utilised the area encompassed by the GUP.

13.7 Declared Groundwater Zones and Groundwater Users

Advice from the DNRM&E has not indicated any Declared Groundwater Zones within the vicinity of the GUP (Larson, R; Pers Comm. 25 March 2004).

13.8 Significance of Groundwater Resource

No data is currently available as to groundwater users in the vicinity of the GUP corridor.

Due to the limited groundwater yields and quality characteristics, it is unlikely that industrial use or significant extraction of groundwater within the wide vicinity of the project corridor area is currently undertaken. Until recently there has been no requirement for the registration or notification of the drilling of private bores, limiting available information regarding possible groundwater use. There may be some localised use of groundwater for domestic or commercial gardens or for minor irrigation or water body (artificial ponds) upkeep at golf and racecourses within the wider project area.

Natural groundwater receptors include the Brisbane River and associated tributary watercourses as well as wetlands which are prevalent in the area. Man made lagoons may also be receptors to local shallow groundwater flow. Although limited in coverage, other natural groundwater receptors include vegetation, some of which may become stressed should degradation of groundwater quality occur.

Section 11 (Hydrology/Hydraulics) and Section 12 (Surface Water Quality) contains further details on surface water aspects.

13.9 Potential Impacts

TOR Requirements:
The EIS should include an assessment of the potential environmental harm caused by the project to local groundwater resources.

The impact assessment should define the extent of the area within which groundwater resources are likely to be affected by the project and the significance of the project to groundwater depletion or recharge. The assessment should take into account the potential impact of the project on the local groundwater regime caused by the altered porosity and permeability of any land disturbance. Management options available to monitor and mitigate these effects should be provided.

13.9.1 Potential Construction Impacts

Potential impacts to groundwater have been identified for the construction stage of the GUP, relevant to the specific activities proposed.

With respect to groundwater, the construction phase of the project represents the time of maximum disturbance to the groundwater system, both in terms of resource potential and water quality. This is due to changes to the existing environment from the emplacement of structures, disturbance of soils through cut and fill operations, and the potential for contamination with regards to the use of construction equipment and machinery.

The shallow groundwater system is particularly susceptible to changes in water quality, and this in turn has a direct effect on discharge quality to local waterways and hence possible effects on downstream aquatic ecosystems. The deeper groundwater system, will not be as readily affected by surface construction. Shallow groundwater quality is somewhat protected by the presence of the clayey sediments which form a major constituent of the overlying Quaternary deposits, in particular to the north of the Brisbane River.

To the south of the Brisbane River, the underlying rock units are exposed, which leaves a direct pathway for potential contamination into these deeper units. However, the more elevated and undulating landforms in the south may mean that inflow is less than for the northern section. The emplacement of structures into the substrata may also have an impact on the both flow and groundwater pathways within the immediate subsurface.

Particular potential impacts during the construction phase are detailed below.

Potential Disturbance of Acid Sulphate Soils

A potential impact during construction on groundwater is the disturbance of Acid Sulphate Soils (ASS) and consequent acid production. Areas of high ASS risk are summarised in Figure 10.5. These areas are associated with the following geomorphological features:

- Bulimba Creek and Brisbane River Floodplains, stretching from CH11100 (Meadowlands Road) to CH14900 (near Ingham Circuit), and from the southern bank of the Brisbane River; and
- Kedron Brook Floodway and marshlands of the Brisbane River floodplain stretching from the northern bank of the Brisbane River to Nudgee Golf Course.

Direct impacts on ASS and hence acidic water entering the shallow groundwater system are detailed in Section 10 (Soils), however potential impacts can be summarised as:

- Downward pressure on clays and unconsolidated sediments through heavy loading, siting of footings, piers and emplacement of foundations, resulting in chemically stable ASS (situated below the water table) becoming oxidised and acid production ensuing;
- Exposure of ASS through excavation and quarrying activities or exposure through excavation prior to the emplacement footings and piers; and
- Lowering of water table levels, leading to the oxidation of potential ASS and subsequent acid production.

Acidic leachate caused by the activities detailed above, may migrate through the shallow groundwater system down hydraulic gradient towards local receptors. These receptors include down hydraulic gradient surface watercourses, wetlands and lagoons, where acidic discharge may result in impacts on flora and fauna.

Domestic wells may also become affected should they be present. In addition to these effects, the lowering of groundwater pH may cause the dissolution and mobilisation of soil bound metals. These metals may in turn migrate down hydraulic gradient towards surface water and aforementioned domestic wells.

In addition to environmental factors, acidic groundwater may act to degrade susceptible foundations and infrastructure.

Dewatering of Aquifers

Dewatering of aquifers may be required as part for the construction program, in particular for the emplacement of foundations, footings and piers which will be used as part of bridge and structure building works.

Impacts resulting from dewatering activities associated with bridge structures and the placement of pile caps for each pier structure are likely to be localised and temporary in nature resulting in a cone of depression within the immediate subsurface area surrounding the placement excavations. This will be achieved through the installation of dewatering spears surrounding the proposed pile cap location and extracting groundwater for use during construction or disposal to the site surface drainage system. The quantity of groundwater to be removed at each pile cap location will vary depending on aquifer recharge capacity and standing groundwater levels. This will be determined prior to the commencement of dewatering activities.

It is proposed that the frequency of the dewatering activities associated with bridge construction over Bulimba Creek and Kedron Brook Floodway and the northern abutment of the Gateway Bridge duplication will be for a single fixed period throughout the duration of pile cap construction. Once construction at each location is complete groundwater extraction will cease and standing water levels will be allowed to return to equilibrium.

The potential for the presence of acid sulphate soils within the area of influence of the proposed dewatering activities will be assessed prior to the commencement of site disturbance and suitable management and treatment strategies for extracted groundwater and insitu soils will be incorporated into the Acid Sulphate Soil Management Plan to be developed by the Construction Contractor.

Significant dewatering of the shallow and deeper aquifers may cause the following potential impacts:

- Temporary lowering of water levels in the nearby surface water features, including ponds and lagoons;
- Temporary decrease in groundwater levels within any domestic wells; and
- The intrusion of salt water into previously brackish or fresh water aquifers from the Brisbane River and other tidal areas watercourses. Also, salt water intrusion from other aquifer systems may occur, should a notable water level drop occur which may enhance recharge. This has the potential to effect unregistered wells and degrade the existing groundwater quality.

Any impacts due to short term dewatering activities are likely to influence groundwater primarily within the immediate vicinity of the dewatering area, and estimates of the probable radius of influence cannot be made without additional aquifer information. Physical effects of dewatering are likely to be temporary, with groundwater levels returning to pre-works status some time after completion. Changes in water chemistry such as electrical conductivity may take some time before ingressed salt water is flushed through the system.

Contamination of the Shallow Groundwater System

Contamination of the shallow, and in some areas, the deeper groundwater system may occur primarily through incidents and inappropriate handling of contaminants during the construction process.

Potential impacts from contamination can occur through:

- Spillage of fuels, lubricants and chemicals onto open ground or into ponded surface waters. This would allow seepage through the sub surface and towards the shallow water table. This is of particular importance in areas where surface soils are porous or where recent excavation has created preferential pathways or increased the infiltration potential through the local soils;
- Uncontrolled stormwater runoff entering the groundwater system from controlled areas, including refuelling areas, chemical storage and raw material stockpiles, potential contaminants could range from petroleum hydrocarbons, oils and grease, polynuclear aromatic hydrocarbons (from bitumen products) and heavy metals;
- Spillage of chemicals from designated storage areas;
- Disturbance of ASS affected material; and
- Disturbance of insitu soil contamination.

Any contamination of the site has the potential to impact on the water quality of the shallow aquifer. Once within the shallow groundwater system, and dependent on subsurface conditions, there is a potential for migration of contaminants down hydraulic gradient towards surface water receptors, including watercourses, lagoons or wetlands. Domestic wells may also be impacted should they be located down hydraulic gradient. In addition, contamination may migrate vertically towards the deeper aquifer system causing degradation of groundwater quality. This is of particular prevalence to the south of Lytton Road, where the Triassic units are near the surface.

13.9.2 Potential Operational Impacts

The operational phase of the GUP represents a period of minor disturbance to the groundwater in the local environment. Potential impacts to groundwater systems have been identified for the operational stage, and would be similar potential impacts as for the existing Gateway Motorway.

Contaminants that may potentially migrate into local aquifers would mainly originate from motor vehicles. Contaminants could include metals common in motor vehicles such as Cd, Cr, Cu, Pb, Ni and Fe, and also petroleum hydrocarbons. The concentrations of these potential contaminants being produced during the operational phase of the GUP is expected to be quite low, with the major potential contaminant being small amounts of hydrocarbons from vehicles utilising the Motorway. The release of petroleum hydrocarbons into the local environment and infiltration into the water table may also occur during motor vehicle accidents.

Further discussion on potential surface water quality impacts which may influence potential groundwater impacts is contained in Section 12.

13.10 Mitigation Measures

13.10.1 Construction Phase

Identification of all Sensitive Receptors

Further assessment will need to be undertaken during detail design to determine both human and natural receptors that may be influenced by the works. This is needed to confirm users or environments that may be influenced by the activities. The assessment will need to include:

- Conducting a census for potential unregistered groundwater wells located in the area surrounding (up to 250 metres) locations where any dewatering activities may be undertaken; and
- Identifying any sensitive surface water receptors to site groundwater movement.

Installation of Monitoring Network

Based on the available information, there is currently a lack of data in relation to the existing groundwater conditions. It is recommended that a detailed groundwater monitoring program be developed prior to construction. On this basis, the following outline of works is proposed:

- Installation of groundwater wells at key locations along the GUP where potential impacts may occur, (such as storage and stockpile areas of construction materials, or where major earthworks are being undertaken) or where local topography and geological conditions dictate. The wells would be sited within the shallow aquifer system as this represents the initial sensitive groundwater receptor. It is anticipated the wells would be between 5 and 10 metres in depth, dependent on terrain and depth to water table;
- Installation of groundwater wells may also be required in areas adjacent to the GUP, in particularly sensitive areas in order to determine local shallow groundwater flow direction. These wells should be surveyed in the appropriate height datum (mAHD);
- Should significant dewatering works be undertaken, install up to two nested groundwater monitoring wells, sited to monitor changes to groundwater levels and quality in the upper and lower aquifer systems. It is anticipated that the shallow groundwater monitoring well should be between 5m and 10m in depth and the deeper well between 10m and 20m in depth; and

- monitoring of groundwater adjacent to GUP during construction to identify whether any impact has occurred.

Water Quality Monitoring Parameters and Frequency

Baseline monitoring should be undertaken for physical parameters and water quality at all installed monitoring well locations prior to the commencement of works. Groundwater samples should be taken and monitored for the insitu parameters outlined in the table below.

Table 13.5 In situ Monitoring Parameters

Parameter	Compliance Requirement
Water level (mbRL)	NA
pH	6.5 to 9.0
Electrical Conductivity	No significant change
Oils	No visible films or odours

Table Notes:
mbRL Metres below Reference Level

As part of the baseline monitoring, the table below provides the laboratory analyses that should also be undertaken.

Table 13.6 Laboratory Analysis Parameters

Parameter	Compliance Requirement
Total Petroleum Hydrocarbons	<10 mg/l*
Oil and Grease	<20 mg/L (in line with surface water quality)
Polynuclear Aromatic Hydrocarbons (PAHs)	<0.003mg/l**
Nitrogen	No significant increase above baseline levels.
Phosphorus	No significant increase above baseline levels.
Heavy Metals (As, Cd, Cr, Cu, Pb, Ni, Zn)	<relevant ANZECC 2000 water quality guidelines (marine ecosystem, 95% protection)

Table Notes:
* New South Wales EPA (2002) - Experienced based guideline for Service Stations
** NEPC (1999) Groundwater Investigation Guidelines – Marine ecosystems

Monitoring should be undertaken on a regular basis throughout the project, with a frequency of once a month considered appropriate. More frequent monitoring may be required should an environmental incident occur, such as a chemical or oil spill, or after a significant rainfall or flooding.

Groundwater Monitoring Parameters and Frequency during Dewatering Activities

Throughout the proposed duration of dewatering activities to be undertaken for pile cap construction, daily groundwater monitoring for *in situ* parameters (refer Table 13.5) should be undertaken in all installed shallow and deeper system groundwater wells in the vicinity where dewatering activities are undertaken. With permission, groundwater monitoring should also be undertaken in any identified private wells.

Dewatering of Aquifers

Potential dewatering activities should be carefully managed during the construction works. This may be required in areas where deep excavation is being undertaken. Any dewatering activities should include the following management strategies where significant dewatering is required:

- Ensuring sufficient groundwater monitoring wells are installed prior to the commencement of works and baseline data is acquired;
- Minimal dewatering as necessary to be undertaken;
- Daily monitoring for in situ parameters should be undertaken in installed groundwater monitoring wells. Weekly monitoring of private wells should be undertaken, as permission dictates;
- Receptors to groundwater level changes, including private wells and natural receptors (lagoons or wetlands) are identified;
- Dependent on nearby receptors, an estimation of radius of effect may be required to be undertaken, based on anticipated pumping rates and dewatering requirements;
- Only the minimum required groundwater quantity should be extracted;
- Poor quality discharge water should be contained and treated on site and water quality guidelines achieved prior to discharge;
- Significant degradation in groundwater quality or levels should be noted, in particular should it be determined whether the downstream waterways are being influenced;
- Should water quality degrade significantly (ie due to salt water intrusion), corrective action may be required and a longer term monitoring program should be implemented until groundwater quality returns to an acceptable level; and
- ASS monitoring and management should be implemented as detailed in Section 10.

Contamination of the Groundwater System

To minimise the potential for contamination of the groundwater system the mitigation measures contained in Section 10 (Soils) and Section 12 (Surface Water Quality) should be implemented.

13.10.2 Operational Phase

The overall potential impact to groundwater from the operational phase is considered minor. The ongoing management strategies would remain similar to the existing Gateway Motorway management system including:

- Management and upkeep of stormwater and road runoff;
- Management of incidents such as fuel spills through appropriate clean up mechanisms; and
- Upkeep of general services along the Motorway.

13.11 Conclusions

It is concluded that, given appropriate management, the GUP has a relatively minor to moderate potential to impact on groundwater as a resource and in terms of downstream water quality. This is due to the nature and type of works being undertaken and the overall hydrogeological setting.

The GUP corridor does not form part of a declared groundwater zone. From the limited existing information, it can be inferred that in general, groundwater resource potential in the area is low, given the low to moderate bore yields and generally poor groundwater quality. This is observed to be the case to the north of the Brisbane River, however assessment to the south is more limited due to lack of data.

The underlying groundwater system is not considered to be highly vulnerable, due to the properties of the near surface aquifer over the northern part of the GUP, providing some degree of protection in this area where ground disturbance will be at a maximum.

The unique coastal environment, downstream environmental values and the large scale of some of the works has highlighted some key potential impacts including:

- Acid sulphate soils and impacts on groundwater from disturbance and dewatering;
- Dewatering of the underlying aquifer system, leading to short term falling water levels in groundwater in natural systems and currently unknown and unregistered private wells;
- Dewatering leading to the potential degradation of groundwater quality through ASS disturbance and salt water intrusion; and
- General potential for contamination of the underlying groundwater system from stockpiling, fuel and chemical handling and spill management.

The implementation of mitigation measures, including a groundwater monitoring program and emergency response plan will ensure that potential groundwater impacts are minimised and the groundwater resource and downstream environmental values are protected.