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Transport Infrastructure Development Corporation

North West Rail Link Environmental Assessment

Geology, Geotechnical & Groundwater Assessment

October 2006

GHD GEOTECHNICS

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1. Introduction

This report has been prepared as part of the environmental assessment of the proposed North West Rail Link (the proposal). The Transport Infrastructure Development Corporation is the proponent of the proposal, and the environmental assessment is being prepared by GHD, in accordance with the requirements of Part 3A of the *Environmental Planning and Assessment Act 1979*.

This report assesses the potential impacts of the proposal on geotechnical conditions and groundwater within the vicinity of the rail link. It includes a description the general geology along the North West Rail Link route and some commentary is provided on general geotechnical conditions likely to be encountered. It has been prepared to meet the Department of Planning Director General's Requirements for the environmental assessment.

The current preferred alignment for the North West Rail Line would commence on the Main North Rail Line between Beecroft and Cheltenham and terminate at Rouse Hill Town Centre, some 19 kilometres to the west. The eastern section (16 kilometres) would be in tunnel, and the western section (7.4 kilometres) would be on the surface. The NWRL would be a dual-track heavy rail system with six railway stations.

A preliminary assessment of the impact of the construction and operation of the rail line was carried out in 2003. The preliminary assessment identified potential environmental issues and suggested how identified potential impacts could be reduced or eliminated.

The purpose of this report is to look more closely at potential impacts and to identify the information that needs to be gathered to better assess the impacts.

1.1 Project outline

The proposed North West Rail Link would be the principal trunk public transport line in Sydney's North West. It would connect with the Northern Line between Beecroft and Cheltenham Stations and terminate at Rouse Hill Town Centre. The rail link would be twin track, approximately 23 kilometres in length and would include:

- A 2.5 km surface quadruplication of the Northern Line between north of Epping Station and Beecroft Station (including works at Cheltenham Station);
- A 16 km section in tunnel from the Northern Line to north of Norwest Business Park, including four underground stations (Franklin Road Station, Castle Hill Station, Hills Centre Station and Norwest Station);
- A 4 km surface section from north of Norwest Business Park to Rouse Hill, including two underground stations (Burns Road Station and Rouse Hill Station)
- An interim train stabling facility at Rouse Hill;
- Ancillary tunnel support facilities such as tunnel ventilation, transformers and a water treatment plant(s); and
- Construction work sites, including a large site within the Balmoral Road Release Area.

2. Methodology

Our approach and scope for undertaking this assessment is as follows:

2.1 2.1 Review Background Information

A desktop study of available geotechnical information relating to the NWRL has been undertaken. This study includes a review of previous investigations conducted for the project, in combination with information from our in-house database and publicly available resources such as soil landscape maps, topographic maps and geological plans. The study has been utilised for the initial identification of geotechnical and hydrogeological domains and potential constraints to the proposed development.

The review encompasses:

- The project design (rail alignment, station and interchange design, associated modifications to the transport network);
- Geologic conditions likely to be encountered during construction;
- Hydrogeologic issues likely to be encountered during construction and operation; and
- Groundwater quality issues and treatment options.

2.2 Site Inspection

A site inspection was conducted along the project corridor, focusing on the location of construction depots, future rail stations, and the geomorphology in the vicinity of the future rail line.

2.3 Analysis of construction and operational issues

This report details the findings of a desktop study of available geotechnical and hydrogeological information relating to the NWRL. The desktop study has included a review of previous investigations conducted for the project, in combination with information from our in-house database and publicly available resources such as soil landscape maps, topographic maps and geological plans.

2.4 Assumptions

No new investigative work has been undertaken in this analysis with information gathered from relevant site specific reporting previously undertaken for this project.

3. Regional Geology

The NWRL corridor is located north west of Sydney, in the Sydney Basin, which is characterised by a flat lying stratigraphic sequence. A review of the 1:100,000 series geological maps for Sydney (sheet 9131) and Penrith (sheet 9130) reveal that the North West Rail Link is contained within geological formations that predominantly include the Ashfield Shale, the Mittagong Formation and underlying Hawkesbury Sandstone.

The Wianamatta Group is the uppermost unit of the Permo – Triasic sediments occupying the central position within the Sydney Basin (Jones Clark 1987) with the Ashfield Shale comprising dark grey to black sideritic claystone and siltstone which grades upward to fine sandstones and siltstone laminate. Ashfield Shale occupies ridgelines and erosional slopes of higher ground along the route. A wide variety of weathering profiles exist, from relatively fresh to highly weathered.

The Mittagong Formation is a transitional sequence between the overlying Ashfield Shale and underlying Hawkesbury Sandstone. The Mittagong Formation consists of alternating dark grey-brown shale and sandstone. Within the corridor, intersections of between 0 and 6 m are likely to be encountered.

The Hawkesbury Sandstone is an orange – yellow –brown medium to coarse grained sandstone with inter bedded shale and siltstone laminate. The unit is estimated to be on the order of 200 m thick within the vicinity of the rail corridor.

The north-western extent of the rail corridor includes surface rail sections where the rail link is expected to cross and incise relatively shallow deposits of unconsolidated Quaternary alluvial sediments which form narrow flood plains for the north-west trending tributaries of Cattai and Caddies Creeks. These sediments generally comprise silty sands of varying nature.

Although there are no major dykes indicated on the geology maps which directly cross the proposed rail lineament, it is possible that either fresh or weathered dyke materials may be encountered. Dykes would be expected to be sub-vertical in orientation.

4. Geological and Geotechnical Description of the Route

4.1 Epping to Beecroft (CH25.760 to CH26.220 km)

Cheltenham Dive Structure (CH25.760 to CH26.220 km); The cutting adjacent to the dive structure varies in height from 6m(CH25.920 km) to over 17.5m (adjacent to the tunnel portal to the north). BH1 (CH26.600 km) indicates that distinctly to slightly weathered Class III to Class II sandstone should be encountered in most of the cutting with only a thin layer (<2m) of superficial soil encountered near the crest.

4.2 Beecroft to Hills Centre Station (CH26.220 to CH35.210 km)

Tunnel portal (CH26.220 km); The tunnel portal is anticipated to be up to 17.5m high and extends from approximately 122.40m RL down to track level at 105.547m RL. BH1 (approximately 400m away) indicates that a thin layer of shale (<1m thick) may be encountered at approximate track level, otherwise the portal excavation should be within cross-bedded (<30 degrees) Class III sandstone with closely to medium spaced subhorizontal bedding (<10 degrees).

Ground water is anticipated at approximately RL121m (approximately near the crest of the portal)

Devlins Creek (CH27.550 km) is located approximately 24m above the proposed rail track level. BH2 (CH27.600 km), indicates that 3m of soil (or weathered rock) above distinctly to slightly weathered, Class III to Class II sandstone may be encountered within the vicinity of the creek. Interbedded weathered shale 100mm-200mm thick was also encountered at approximately 104.87m RL, which could intercept the tunnel excavation, as the proposed track level is at approximately 100m RL.

Tunnel alignment (CH27.600 to CH30.120) increases in elevation from 98.73 m RL at 27.840 km to 152m RL at CH30.100 km, adjacent to Franklin Road Station. However, the existing ground level increases from 124.60m RL (CH27.580 km) to 182.81m RL adjacent to Franklin Road Station (CH30.100 km). Based upon the information from BH2 and BH3 (CH30.225 km), distinctly weathered, Class III to II sandstone is anticipated to be encountered within the tunnel up to CH28.480 km (beneath Castle Hill Road). From CH28.480 to CH28.680 km the shallow dipping boundary (approximately 20-30 degrees) with the overlying Ashfield Shale is likely to be encountered in the tunnel. From CH28.680 to CH30.120 km the tunnel is anticipated to be excavated in distinctly weathered Class III to II Ashfield Shale with thin, shallow dipping (<5 degrees) laminations.

Franklin Road Station (CH30.120 to CH30.330km) is proposed to be founded at approximately 152m RL or between 15m and 20m below existing ground level (167m RL-172m RL). BH3 (at approximately CH30.225 km) indicates that extremely weathered (Class IV to V) Ashfield Shale could be encountered up to 7m below existing ground level. Below this Class III/II shale with thin laminations and subhorizontal bedding (0-5 degrees) is likely to be encountered. At approximately 138-140m RL it is noted that highly fractured zones were encountered in BH3 and these could indicate larger scale defects in the shale. However, this level is below the tentative station level (at 152m RL).

Groundwater was encountered between 6m (172mRL) and 7m (173mRL) below existing ground levels suggesting the possibility of up to 14m water head in excavation.

Tunnel alignment beneath Castle Hill Road (CH30.330 to CH32.650 km). The rail track elevation decreases along this section from 152m RL to 105.95 m RL. However, the depth of track, below existing ground level, is anticipated to vary from 30m to 60m. Based upon the existing borehole information (from BH3 and BH4 (CH32.660 km)) it is anticipated that this section of the tunnel will be constructed entirely within distinctly weathered Class III to II Ashfield Shale, similar to that encountered at Franklin Road Station, as the boundary within the underlying sandstone is only encountered at 115m RL (BH4), which is over 30m below most of the rail track level.

Castle Hill Station (CH32.650 to 32.860 km) is proposed to be founded at approximately104m to106mRL or between 34m and 36m below existing ground level. BH4 (CH32.660 km) indicates that soil overlying Ashfield Shale will be encountered down to approximately 115mRL. The top 6m (from 139m RL to 133m RL) of shale is anticipated to be extremely to distinctly weathered Class V to IV, with a further 6m of Class III to II shale below this. Below the shale, from 115mRL, distinctly weathered Class III Hawkesbury Sandstone is anticipated with occasional interbedded layers (<500mm thick) of shale at the top of the sandstone. The interbedded sandstone and shales are noted to be positioned above the founding level of the station but could be intercepted in the station excavation.

Groundwater levels were encountered in BH4 at levels of between 5m and 6m below existing ground level or 135m RL to 137mRL (within the Class V shale).

Tunnel alignment from Castle Hill Station beneath Showground Road to Hills Centre Station (CH32.860 to CH35.000 km). The track level decreases from 105m RL at Castle Hill to 98m RL at Hills Centre. However, tunnel levels are maintained at between 25m and 30m below the existing ground level. Boreholes BH4 and BH5 indicate that this tunnel section should be constructed within Class III/II sandstone as the boundary with the overlying shales is expected to increase from approximately 5m to 26m above the crown of the tunnel as you move northbound along the track.

Perched groundwater levels are anticipated to be formed in the overlying shale.

Hills Centre Station (CH35.000 to 35.210 km) is located approximately 9m to 24m below the existing ground level (approximately 67m RL). BH5 (CH 35.070 km) indicates that up to 20m of distinctly weathered Class IV to Class III weathered sandstone is likely to be encountered to approximately 72m RL (5m above rail level). Areas of core loss (up to 300mm thick) were encountered from 86m RL to 72m RL in BH5, which may indicate the presence of major defects in the sandstone, and occasional thin (<200mm thick) shale layers were also encountered at approximately 80.85mRL. From 72mRL to below the founding levels for the station (67mRL) it is anticipated that distinctly weathered Class III sandstone will be encountered.

Groundwater levels were noted in BH15 to be between 11m and 12m below existing ground levels i.e. approximately 83mRL (17m above the station founding levels).

4.3 Hills Centre Station to Burns Road Station (CH35.210 to CH40.350 km)

Tunnel alignment (CH35.210 to 37.240 km) along Salisbury Road/Norwest Boulevard between Hills Centre Station and Norwest Boulevard generally decreases in level from approximately 67m RL to 57 mRL at Hills Centre Station. However, the depth of the tunnel will be maintained at between 25m and 35m below the existing ground level. Boreholes BH5 and BH6 indicate that this tunnel section should be constructed in distinctly weathered Class III/II sandstone. The boundary with the overlying shales is also anticipated to increase from 8m to 20m above the crown of the tunnel as you move northwards towards Hills Centre Station. Perched groundwater levels are anticipated to be formed in the overlying shale.

Norwest Station (CH37.240 to CH37.450 km) is proposed to be constructed at approximately 57m RL, or roughly 25m to 37m below existing ground level. BH6 (CH 37.300 km) indicates that up to 15m of distinctly weathered Class III weathered shale is likely to be encountered in the excavation down to approximately 72m RL (15m above the proposed rail level). From 72m RL to below the founding levels for the station it is anticipated that Class III/II distinctly to slightly weathered sandstone will be encountered. Groundwater levels were encountered in BH6 at levels of between 2m and 3m below existing ground level or 135m RL to 137mRL (within the Class V shale).

Tunnel alignment beneath Norwest Station and Celebration Drive (CH37.450 to CH39.950 km) is generally subhorizontal (57m RL to 58m RL) and is approximately 25m to 35m below the existing ground level. However, cover decreases to less than 15m to the north of Celebration Drive. Borehole records from BH6 and BH7(CH40.400 Km) indicate that this tunnel section should be constructed within Class III/II sandstone up to approximately CH37.840 where the boundary between the sandstone and overlying shale (approx 5 -10 degree dip) may be intercepted. From CH37.840 to 38.320 km it is anticipated that interbedded shales and sandstone will be encountered and from CH38.320 km to the portal at CH39.950 km it is anticipated that the tunnel will be constructed entirely within Class III/II shale. Borehole logs indicate that the shale has subhorizontal (0-10 degrees) bedding and occasional moderately spaced, inclined (50-80 degrees) shear zones/joints.

Perched groundwater levels are anticipated to be formed in the overlying shale.

Groundwater is anticipated to follow the boundary between the sandstone and shales and may therefore be encountered within the tunnel excavation especially at the boundary with the underlying sandstone, from CH37.840 to 38.320 km.

The tunnel portal to the north of Celebration Drive (CH39.950km) is anticipated to be 14.3m high. BH7 (CH40.400 km) indicates that up to 4m of soil may be encountered at the crest of the portal. In addition, a further 4m of extremely weathered, Class IV shale may be encountered below the soil layer. It is therefore anticipated that less than half of the portal face may be constructed in Class III or better rock.

Groundwater levels are expected to be high, as water was encountered at less than 2m below the existing ground level in BH7.

The cut and cover tunnel from Balmoral Road to Burns Road Station (CH39.950 to CH40.350 km is proposed to be open excavated down to 54.5m RL, approximately 14m below the existing ground level. Based upon the information from BH7 (CH40.400 km) it is considered that a similar geological profile to the tunnel portal adjacent to Celebration Drive will be encountered in the open excavation. It is therefore anticipated that soil and extremely weathered shale will be encountered down to approximately 61m RL.

Groundwater pressures are anticipated to be high with the possibility of a 12m head when this area is intersected, as water was encountered at less than 2m below the existing ground level in BH7.

Burns Road Station (CH40.350 to CH40.560 km) is proposed to be founded at approximately 54.50m RL within a deep cutting, between 8.4m and 13.4m deep. BH7 indicates that up to 4m of soil and 4m of extremely weathered shale (Class IV) may be encountered at the top of the cutting for the station, with distinctly to slightly weathered Class III/II shale encountered below this, down to the founding levels for the station. It is also anticipated that defects such as subhorizontal (0-10 degrees) bedding and occasional moderately spaced, inclined (50-80 degrees) shear zones/joints may be encountered in the Class III/II shale. Groundwater levels are expected to be high, as records indicate a possible water table at less than 2m below the existing ground level (BH7).

4.4 Burns Road Station to Rouse Hill Stabling Facility (CH40.560 to 45.660 km)

The cut and cover tunnel (CH40.560 to 40.760 km) to the north of Burns Road is proposed to be excavated down to approximately 6m below the existing ground level (between 54m and 55m RL). A similar geological profile as the adjacent Burns Road Station is anticipated in the cut and cover tunnel to the north of Burns Road based upon the records from BH7. The portal excavation at CH40.760 km is anticipated to be up to 5.1m high, and it is envisaged that this will be mainly constructed in soil and extremely weathered Class IV/V shale.

An open cutting, approximately 5.1m to less than 1m high, is proposed from 40.760 to 40.960 km. Based upon the findings of BH7 it is considered that this excavation will be mainly in soil and extremely weathered Class IV/V shale.

The embankment to Samantha Riley Drive up to 12m high is proposed from CH40.960 to 41.820 km. Based upon the findings of BH7 it is considered that this embankment will be mainly founded on soil and extremely weathered Class IV/V shale.

A viaduct over Caddies Creek Tributary 5 and Windsor Road is proposed to be constructed from CH41.820 to 42.760 km and a further embankment/viaduct is proposed to be constructed over Caddies Creek Tributary. 4 from CH42.750 to CH43.240 km. BH8 (CH44.030 km) indicates that the subsurface conditions in the area of the proposed viaducts may comprise up to 3m of soil, overlying 7m of extremely weathered (Class V to Class IV) shale. Distinctly weathered Class III sandstone is anticipated at approximately 11m below the existing ground level, or approximately 40 m RL.

A cut and cover tunnel is proposed to be excavated along the alignment of Windsor Road from CH43.240 to CH44000 km. The cut and cover tunnel is proposed to be excavated down to a level of 39.50 m RL or between 10m and 15m below the existing ground level. A tunnel portal approximately 4.5m high is anticipated to be constructed at CH43.400 km BH8 (approximately 300-400 m away) indicates that the tunnel will probably be founded in distinctly weathered sandstone. However, most of the excavation will be formed in soil and extremely weathered (Class V and Class IV) shale. It is also anticipated that numerous defects including very closely to extremely closely spaced shallow dipping bedding (<20 degrees), and occasional closely spaced joints may be encountered in the weathered shale bedrock. The tunnel portal is anticipated to be constructed in soil, and extremely weathered (Class V to Class IV) shale. Groundwater levels are anticipated at approximately 13m below the existing ground level (approximately 41m to 42m RL), or just above the founding level for the excavation.

Rouse Hill Station (CH44.000 to CH44.210 km) is proposed to be constructed at 12 and 14m below the existing ground level (39.50m RL). Geological conditions are anticipated to be the same as for the cut and cover tunnel to the south of the station, with the station being founded on sandstone, but with most of the excavation in extremely weathered shale (Class V/IV) and soil.

The cut and Cover tunnel under Windsor Road to the stabling facility (CH44.210 to CH44.850 km) is proposed to be excavated to approximately 39m RL to 42m RL, between 10m and 20m below the existing ground level. Based upon the records from BH8, geological conditions are anticipated to be the same as for the cut and cover tunnel to the south of Rouse Hill Station. However, at CH44.850 km it is anticipated that a 15m high portal slope will need to be constructed and founded in soil, and extremely weathered (Class V/IV) and possibly distinctly weathered (Class III/II) shale exists adjacent to the open cutting for the Stabling Facility. No sandstone is anticipated to be encountered in the portal excavation based upon the existing geological data.

4.5 Rouse Hill Train Stabling Facility (CH44.850 to 45.660 km)

The proposed Rouse Hill Train Stabling Facility from CH44.850 to 45.660 km is proposed to be constructed in an open cutting to the west of Windsor Road. A small (40m long) cut and cover tunnel is also proposed to be constructed beneath Rouse Road from CH45.280 to CH45.320 km. The cutting and tunnel section are proposed to be excavated to a level of between 42m RL and 47m RL and will probably be excavated partly in extremely weathered shale (Class V/IV) and partly in distinctly weathered shale (Class III), with a thin layer of soil at the crest.

5. Hydrogeology

5.1 Introduction

The proposed route of the NWRL is situated within the centre of the Sydney Basin in the northwest of the Sydney metropolitan area. The running tunnels of the NWRL are to be excavated within a variety of rock and soil types including Class I, II & III Hawkesbury Sandstone, Class II, III, IV & V Ashfield Shale of the Wianamatta Group and the transitional Mittagong Formation of varying thickness between the two. The following sections are a review of outcomes from previous groundwater assessments.

The hydrogeology of the route has previously been interpreted by SKM 2002 to contain four broad hydrogeological units which in brief summary are:

- Shallow alluvial sediments;
- Igneous dykes;
- Ashfield Shale (weathered and unweathered); and
- Hawkesbury Sandstone.

5.2 Alluvial Sediments

The alluvial deposits occur along the narrow floodplains of the NW-flowing tributaries of Caddies and Cattai Creeks. These sediments reflect the character of their catchment geology - fine sandy and silty clay in the shale areas, silty sand in the sandstone areas. Because of the limited lateral extent and shallow depth of the alluvial sediments, and their locally clay-rich nature, they are not significant sources of groundwater. Nevertheless, they are at risk of contamination from track spills and wastes carried along drainage lines by stormwater discharge. They may also give rise to nuisance inflows to bridge foundations and other excavations during construction on the floodplains. The deposits are shallow, limited laterally, and they are not significant sources of groundwater. Notwithstanding, they must be protected from contamination.

5.3 Igneous Dykes

Subsurface igneous dykes are a feature of the Sydney Basin and their direction reflects the joint direction in the bedrock. Igneous dykes can have two possible effects on the groundwater system, acting as groundwater dams, or as vertical aquifers. The potential impacts of these two effects can be significant. The nearest igneous dyke to the NWRL corridor shown on the published 1:100,000 geological maps is located about 2.5km north of the line, at Thornleigh, and appears to have intruded along the minor ESE-trending joint direction in the area (SKM 2002). The lack of mapped dykes possibly reflects their poor outcrop rather than their absence in the subsurface. It would be prudent to allow for the presence of one or two dykes 1-3m wide for every kilometre of tunnel length, and to assume that these follow the regional joint trends, either NNE or ESE.

Dykes can act as groundwater dams, holding water back on the up-gradient side. In the Sydney Basin dykes are typically weathered to depths of 10-30m, but greater depths of weathering are known. Secondly, fresh dyke rock (generally basalt) at greater depths can be fractured and saturated, causing it to function as a vertical aquifer. Groundwater flows in the order of 10L/s may occur; being greater than normal inflows from the sandstone.

5.4 Ashfield Shale

Ashfield Shale is the geological unit that provides the majority of the topographical expression for the NWRL route. The shale is an aquitard in a hydrogeological sense forming an impervious confining bed, but its hydrogeological characteristics vary with the degree of weathering and jointing.

The weathered shale profile is significant because of its lateral extent, covering most of the ground surface within the railway corridor. The weathering profile is typically 3-6m deep, with the topmost metre or so being residual soil and the remainder extremely to moderately weathered shale. The uppermost weathering profile can degrade to reactive clays capping the surface and restricting infiltration of precipitation or movement of groundwater. The lower portion of the weathering profile can include rock that is fractured. This zone can be a transport pathway dictated by intensity of fractures. The variability within the weathered shale profile can lead to a localised perched water table forming lenses of low permeability and low storage capacity. This is indicated by lines of seeps, which appear along the fresh/weathered bedrock interface in road cuttings after heavy rains. The shale is also responsible for the ephemeral nature of existing waterways within the vicinity of the rail corridor. A high degree of run off due to the low hydraulic conductivity of weathered and unweathered shale, can impede recharge to underlying sandstone where it is present.

The groundwater within a weathered shale aquifer is of fairly low salinity, say 500-1000 mg/L total dissolved salts (TDS), though not necessarily of potable quality. Most of the water temporarily stored in the weathering profile following rain is later lost as base flow in minor watercourses or by trees through evapo-transpiration. During normal rainfall little or no water penetrates below the root zone, probably less than 1% of total precipitation.

5.5 Hawkesbury Sandstone

As reported by SKM 2002, this is the only potential source of groundwater in significant volumes close to the proposed NWRL corridor. In some parts of the Sydney Basin this formation contains aquifers, with bore yields typically 1-5 L/s and potable quality (<500 mg/L TDS. The Hawkesbury Sandstone is a quartz rich sandstone generally orange – yellow in colour, which is caused by migration of iron rich groundwater. Inherent permeability is relatively low due to the cemented nature of the sandstone. Hydraulic conductivity within the sandstone is dominated by secondary structural features such as bedding plane seams and joint sets. As such, inflow rates are likely to vary as construction proceeds and various structures are intersected.

5.6 Seepage

The tunnels are to be excavated within the upper strata of the Hawkesbury Sandstone, the Mittagong Formation and the Ashfield Shale. It is expected that some inflows will occur at locations where permeable bedding plane seams, joint plane defects, dykes or faults are intersected.

Experience gained from tunnelling within the Sydney Basin in recent years within geological terrains similar to that likely to be encountered during construction of the NWRL suggests that groundwater seepage within the tunnel is not likely to cause a significant problem for operational use. Arbitrary inflow limitations adopted during these projects, which are based on empirical inflow assessments have generally provided conservative inflow estimates. In the absence of any contrary data it seems reasonable to assume that conditions experienced during construction and operation will be similar to those previously experienced in other rail tunnel infrastructure projects.

The yield of seepage within the tunnel when operational is provisionally expected to be within expected design limits of 0.1 to 1 L/s/Km which translates to a range of approximately 2.5 – 25 L/s for the entire tunnel length. Higher intermittent rates could be expected when these structures are encountered during construction. Where the tunnels are driven beneath valleys (Devlins Creek) or shallow cover areas, groundwater inflows are anticipated to be more prevalent with the possibility of higher rates of inflow.

Estimation of seepage volumes is difficult given the limited aquifer testing carried out along the route to date and is in part based on experience gained from other tunnelling projects constructed in the Sydney Basin. Groundwater seepage into the tunnel during operation is provisionally expected to be similar to allowances made in other tunnelling projects with rates in the general range of 1 to 5 L/s/Km. Higher rates are expected intermittently during construction and this will be dictated by the joint and fracture structures which are encountered with flow rates possibly an order of magnitude higher than estimated operational seepage rates. High flow rates experienced when structures are intersected should be limited to relatively short periods of time as available groundwater head is removed. Intensity and time for increased seepage rates to dissipate will be dependent on interconnectivity of joint and fracture structures and the head, which is available. However, it would generally be expected that high inflow rates should dissipate by around 50% within days and to operational levels within weeks or months.

5.7 Groundwater Levels

Groundwater levels measured within the limited geotechnical drilling program to date (ARUP 2002) indicated significant head available to potential seepage at various locations along the proposed rail corridor. SKM (2002) suggests there is some uncertainty to this data when considered with DLWC / DIPNR groundwater data from nearby bores. For example, water levels in the seven geotechnical boreholes measured 3-5 weeks after drilling indicated that the water table could be as shallow as 2-6m below ground. Yet DLWC water bores suggest that the regional water table is generally at depths of 10-30m, and sometimes deeper than 50m.

However, within the variable weathering profile that exists within the Ashfield Shale, localised perched water tables could explain the variable nature of the groundwater level data that has been encountered from the various sources. Further field investigations are required to accurately assess the risk from relatively high groundwater pressures within the Hawkesbury Sandstone or perched systems within the Ashfield Shale. Seasonal variations in groundwater levels will occur in response to rainfall and may also affect seepage rates. Variations of levels in the order of 10 m within the Hawkesbury Sandstone may occur.

The regional water table within the Hawkesbury Sandstone 'outcrops' in the beds of low-lying permanently flowing streams in the Beecroft-Castle Hill area. The water table rises away from these watercourses, following the topography but in a more subdued fashion - deep between ridges, shallow close to streams. Its level may fluctuate by several metres between wet and dry seasons, especially beneath ridges. Recharging water is believed to enter the system along the upper, non-perennial tributaries of these streams, and to ultimately discharge at sea level.

5.8 Impact of seepage on groundwater levels

Seepage may cause localised drawdown within a narrow corridor in which the tunnel is centred. The extent of possible impacts will vary and depend on the interconnectivity of fractures within the rock mass. When tunnel headings are located within the Ashfield Shale, low intrinsic formation permeability will generally restrict lateral migration of a drawdown cone.

With the localised extent of draw down dependent on hydraulic parameters of the surrounding rock masses, long-term local groundwater levels can expect to fall to levels governed by the level of drainage infrastructure.

6. Groundwater Chemistry

The Assessment of Environmental Issues Report for the North West Rail Link was completed in March 2003. The report included two Working Papers on surface water and groundwater:

- Working Paper No 3 – Hydrology & Hydraulic Assessment (April 2003); and
- Working Paper No 4 – Groundwater Assessment (April 2003).

6.1 Working Paper No 3 – Hydrology & Hydraulic Assessment

6.1.1 Identified Catchments and Water Quality

Working Paper No 3 identified the following catchments and sub-catchments that could be impacted by the proposed rail line.

Catchment	Sub-catchment
Lane Cove Creek	Devlins Creek
Berowra Creek	Pyes Creek
Upper Parramatta River	Darling Mills Creek
	Bellbird Creek
	Excelsior Creek
	Toongabbie Creek
Cattai Creek	Strangers Creek
	Smalls Creek
	Cattai Creek
	Second Ponds Creek
	Caddies Creek
	Elizabeth Macarthur Creek

An assessment of the water quality in the catchments and sub-catchments is included in the working paper. The following should be noted:

- Water quality is generally considered to be very poor to fair in Devlins Creek (a Lane Cove Creek sub-catchment);

- Overall water quality in Pyes Creek (a Berowra Creek sub-catchment) had poor compliance with the environmental values of aquatic ecosystems and primary contact recreation;
- Water quality is generally poor in the Cattai Creek system, largely due to urban runoff, agricultural development and increased sewage effluent flow from Rouse Hill STP.
- Stormwater runoff within the Upper Parramatta River catchment is likely to influence the waterways within the catchment by contributing to increased levels of nutrients, faecal coliforms, suspended solids and turbidity, and toxic chemicals.

Thus the water quality in the receiving waters that may be impacted by the proposed rail line is generally poor to fair. It can therefore be anticipated that, in the short to medium term, the quality of water discharged to these waterways from the proposed works will need to be of a high standard to ensure that the receiving water quality does not worsen from an already poor condition. In the longer term, environmental agencies may require even higher water quality objectives as part of a program of works to improve the environmental values of the waterways in the area. Quality standards for water to be discharged to the environment will need to be considered carefully.

6.2 Working Paper No 4 – Groundwater Assessment

6.2.1 Identified Issues

The working paper identified that the main groundwater issue affecting feasibility of the NWRL is the possibility that inflows to the tunnel would eventually lower the regional water table, causing some creeks to cease flowing, and some wetlands to dry out. The long-term extent of the problem will depend on the relationship between the tunnel invert and the height of the water table, and the type of lining adopted.

Other groundwater-related problems which could arise during construction and operation, included:

- Disposal of turbid, saline or contaminated water collected within the tunnel;
- Contaminants leaking down to the water table where the tunnel is above the water table;
- Alternatively, the water table could rise several metres during unusually wet years and flood previously dry sections of the tunnel invert;
- Land subsidence could result from under drainage of shallow aquifers, especially unconsolidated alluvial aquifers;
- The lowering of the water table could result in loss of output from wells in the vicinity of the rail line;
- Leakage into a deep cutting and into the Rouse Hill Town Centre station excavation.

In addition two site specific issues were identified, one south of Castle Hill Road relating to soil stability, and one in the vicinity of Second Ponds Creek relating to land salinisation.

6.2.2 Water Quality

Only limited data is available on groundwater quality. The salinity of sandstone groundwater east of Castle Hill could be expected to be generally in the range 1,000 to 3,000 mg/L, and west of Castle Hill it should be less salty, perhaps 500 to 1,000 mg/L. It was also noted that sandstone groundwater can tend to be acidic, with pH values of 5.5 or less. The unweathered shale is generally impervious, though small quantities of groundwater may be encountered with salinities in the range 5,000 to 20,00 mg/L, and up to

32,000 mg/L. Unweathered shale is generally overlain by weathered shale to a depth of 3 to 6 metres. The weathered shale is relatively pervious, and the groundwater within the shale is of fairly low salinity, or the order of 500 – 1000 mg/L TDS.

7. Groundwater Quality / Water Treatment

7.1 Working Paper No 4

As noted above, Working Paper No 4 identified that sandstone groundwater tended to have elevated levels of TDS, and tended to be acidic, with pH values of 5.5 or less.

7.2 Groundwater Quality in Existing Tunnels

The quality of groundwater inflowing into existing tunnels in the Sydney Basin is generally high in iron, may contain manganese, may contain other contaminants, has a relatively high TDS and a low pH. Typical parameters are as follows;

- Energy Australia Cable Tunnel: Iron 110 mg/L; TDS 10,000 mg/L; pH 5.9
- Sydney Harbour Tunnel: Iron 40 mg/L;
- Parramatta to Chatswood Rail link: Iron 90 mg/L; TDS 1,300 mg/L average to 6,000 mg/L max; pH 5.9; ammonia 4 mg/L to 50 mg/L;
- Cross City Tunnel: Iron 50 mg/L

The iron in groundwater is usually present in a soluble colourless form, which converts to an insoluble rust coloured form on contact with oxygen. Water discharged to waterways containing concentrations of iron of the magnitude set out above would result in heavy rust staining for some considerable distance downstream of the discharge point. In general, these waters need treatment to reduce the iron content to less than 1 mg/L prior to discharge to receiving waters. The specific level of treatment required will depend on the sensitivity of the particular receiving water, or the requirements of Sydney Water for the receipt of such discharge. Typical treatment processes are discussed below.

7.3 Typical Water Treatment Processes

Iron and Manganese

The conversion of soluble iron to insoluble iron is achieved by oxidation. This is most commonly achieved in an aeration tower, which raises the oxygen level in the water. The effectiveness of this process is dependent on the pH of the water. Only relatively low levels of conversion are achieved at pH levels of 5 to 6; the pH of acidic water is usually raised to 8 prior to the aeration process.

Typical treatment processes include:

- Raising the pH by the addition of caustic;
- Aeration to convert soluble iron to insoluble iron;
- Flocculation and sedimentation to remove the particulate iron particles;
- Filtration to remove the finer particles.

Chemical addition is required to adjust the pH, and coagulants may be required to aid flocculation and sedimentation. An inert sludge is produced in the process and this can be removed by a private contractor, or discharged to the sewer under a trade waste agreement with Sydney Water.

Actual treatment processes recommended for any particular water will depend in part on the receiving waters and the effluent quality required allowing discharge. Pilot plant testing of proposed processes is normally required because of the variable response of the iron to oxidation and the subsequent sizing of treatment processes.

Similar processes are used for the removal of manganese; however, a stronger oxidant may be required. In these cases potassium permanganate, a strong oxidant, may be used.

Other Contaminants

Other contaminants could include hydrocarbons and pollutants associated with sewage or sewage effluent. The presence of other contaminants would significantly increase the complexity of the treatment processes.

Total Dissolved Solids

Groundwaters with high TDS are unsuitable for discharge to inland waterways. It is economical to discharge small volumes of high TDS water to the sewer. The treatment or disposal of large volumes of high TDS water can be a significant difficulty.

7.4 NWRL Treatment Plant(s)

It is most likely that a treatment plant(s) will be required to treat groundwater inflowing to the tunnel and deep open cut sections of the rail line.

The Epping to Chatswood rail tunnel (13 kilometres) is of a similar length as the proposed NWRL tunnel (16 kilometres). For the Epping to Chatswood tunnel consideration was given to providing a number of treatment plants; the final choice lay between one plant and four plants. The final decision was to provide a single plant with a single point of discharge. The treatment plant was located at a railway station. It should be noted that the provision of a single plant required the transfer of water over considerable distances within the tunnel.

Single or multiple treatment plants may be required for the NWRL.

The business plan for the NWRL will need to include the cost of operation and maintenance of the plant(s). Environmental assessment will need to address the use of chemicals and the disposal of sludges.

7.5 Discharge location options

Seepages can be expected to occur locally throughout most of the tunnel route, depending on localised groundwater conditions and as such, discharge to the surface will be required.

Potential water retention / sump areas within the excavated tunnel can be located at low point tunnel inflections and therefore subject to possible gravity drainage within the tunnel during operation. Possible groundwater collection areas are situated at the following locations:

- Below Devlins creek (CH27.500);
- Castle Hill Station (CH32.600);
- Near Hills Centre Station (CH34.900);
- Northwest Station (CH37.500); and
- Near Burns Road Portal (CH40.700).

Discharge from Burns Road Portal and the Cheltenham Dive structure will be required with additional discharge options including Castle Hill, Hills Centre and Northwest Stations. However, availability of suitable area for a small treatment plant which will include a settling pond may be difficult to acquire, particularly at Castle Hill Station, due to the high density of development which has already been established. Design considerations may enable total discharge to be removed by way of the both the Cheltenham Dive structure and the portal near Burns Road. Pumping between sumps over short distances may be required to cross over inflections in vertical alignment, which are located at stations.

8. Further Studies / Investigations

8.1 Areas of Further Study / Investigation

Groundwater levels have to date been inferred from remote monitored bores and from a recent limited preliminary drilling program. However the available data sets do not correlate. A detailed investigation of standing water levels along the alignment will be required, as part of a more detailed hydrogeological investigation, which should include.

- Assessment of standing water levels along the alignment from multiple horizons during more detailed geotechnical drilling.
- Testing of rock mass hydraulic characteristics.
- Selected site pump testing.
- Groundwater modelling with particular attention to expected problem areas.
- The establishment of a monitoring program to provide understanding of seasonal variations and possible construction impacts.

Working Papers Nos 3 and 4 have identified potential surface water and groundwater environmental issues associated with the NWRL. These issues need to be investigated in detail, and where potential impacts are identified the impacts need to be mitigated or removed. The information gathered will also impact on the design development for the tunnel.

Further studies and investigations must be designed to address all the issues identified to date. The proposed studies and investigations have been grouped into a number of areas:

- Studies / investigations providing information on a regional basis;
- Studies relating to existing water quality;
- Studies relating to future water quality objectives;
- Identification of potential inflows to the tunnel and sections of deep open cut, and the assessment of potential pollutants;
- Studies relating to the treatment and disposal of groundwater;
- Interactions with tunnel and station cavern design;
- Identification of potential impacts and mitigation methods.

The extent of these studies and investigations are discussed below.

8.1.1 Regional Studies

Additional and more detailed information is required on the regional geology of the area, and the hydrogeological setting along the route of the proposed rail line.

8.1.2 Water Quality and Water Quality Objectives

A study needs to be carried out to determine the present and future environmental values for the waterways in the area and water quality criteria required to meet these values. The water quality objectives will be governed by receiving water discharge areas. Trigger values are to adhere to appropriate guidelines, which need to become a commitment of further studies.

8.1.3 Inflows and Pollutants

Studies / Investigations need to be carried out to evaluate the potential for inflow to the tunnel and deep open cut areas, and the likely pollutants in these waters. The investigations should include drilling and inflow measurements along the alignment of the rail line.

8.1.4 Treatment and Disposal

Samples of polluted water should be gathered and subjected to testing to determine the most suitable treatment processes to meet the required water quality standards, refer Section 7.2.

8.1.5 Interface with the Tunnel Design

The above studies will provide a database for the tunnel designers. Interaction is required between the tunnel and station cavern designers and the groundwater specialists to identify lining options and outcomes (eg reduced inflows), identify a site for the treatment plant(s), and sites for the disposal of treated water. Transfer systems within the tunnel will need to be taken into account, as well as the disposal of water from fire hydrants.

8.1.6 Identification of Potential Impacts and Mitigation Methods

At the completion of the above studies and investigations the potential impacts and methods of mitigation will be tabulated. It is to be noted that this is not a linear process but rather one of iteration. If a high impact activity is identified during the design development stage them it is normal practice to mitigate this impact by design. At the completion of the design development stage, all impacts should be appropriately mitigated.

8.2 Detailed Program of Study / Investigations

A detailed program of study / investigations has not been developed to date.

9. Geotechnical Requirements

Only minimal geotechnical information has been defined along the proposed NWRL route to date. A number of detailed and project-specific geotechnical requirements need to be addressed, which should become project commitments:

9.1 Site Investigations

Geotechnical site investigations should be carried out at locations to be confirmed though more detailed geotechnical route assessments. Locations requiring site investigations will include:

- The new rail bridge over the M2, and other sites as necessary along the 3 km long surface quadruplication of the Main North Line between Epping and Beecroft.
- Each of the six new station sites at Franklin Road, Castle Hill, Hills Centre, Norwest, Burns Road, and Rouse Hill.
- Locations to be identified along the 16 km section of tunnel from the Main North Line to north of Norwest Business Park.
- Locations to be identified along the 4 km section of surface rail from north of Norwest Business Park to Rouse Hill.
- Other infrastructure sites to be identified along the route.

Site investigations should be planned and include subsurface drilling, vertical and inclined core sample recovery, core orientation, borehole permeability testing, piezometer installations, borehole instrumentation, detailed logging and laboratory testing of rock cores.

9.2 In-situ Stress Field Determinations

In-situ stress levels within the subsurface strata at each of the six new station sites and at selected locations along the 16 km tunnel route, as well as at deep excavation sites, will be determined. These investigations can be carried out as part of the site investigations outlined above or as a separate campaign of drilling and testing.

9.3 Geotechnical Modelling

Information derived from the site investigations and in-situ stress determinations should be compiled, assimilated and interpreted by suitably qualified and experienced geotechnical practitioners. Geological and geotechnical models should be compiled for each station site and each of the delineated tunnel or excavation locations. Computer modelling for design purposes can then be carried out.

9.4 Ground Support For Tunnels And Excavations

The geological models and the results of computer modelling at excavation sites and for running tunnels will enable the design of ground support systems. For example, the selection of a suitable roof support strategy for tunnel excavations in shale will require detailed geotechnical consideration. Temporary and permanent excavation support requirements can be identified and options modelled, in association with 9.5 below.

9.5 Construction Methodologies And Sequencing

Computer Modelling derived for 9.3 and 9.4 above should also incorporate assessments of varying construction methodologies and sequences, in order to optimise stability and long-term performance.

9.6 Potential Surface Settlements

Maximum surface settlement criteria should be confirmed along the route. Computer modelling for 9.3, 9.4 and 9.5 above should include analysis of surface settlements for the various construction sequences and roof support types assessed. The selection of optimised construction sequencing, and roof support will subsequently also satisfy surface settlement allowances where applicable.

9.7 Geotechnical Monitoring And Verification

The reporting and review phases of 9.1 to 9.6 above, should establish chains of communication and procedures, whereby it is accepted that ongoing geotechnical monitoring and verification are integral components of the NWRL project. Monitoring will commence with piezometers and borehole instrumentation installed at the site investigation phase, and continues through construction inspections and assessments. The progressive collection and review of geotechnical data will enable geotechnical models to be refined and critical design assumptions to be verified.

10. Conclusion

The project is assessed to be feasible from geological, geotechnical and hydrogeological perspectives. The proposed alignment requires further investigation to confirm the design and construction requirements of the Ashfield Shale, Mittagong Formation and Hawkesbury Sandstone strata that will be encountered.

Groundwater seepage will occur within the tunnel, however given the limited aquifer testing carried out to date, definitive seepage estimates are difficult to make. Seepage into the tunnel during operation is provisionally expected to be at similar rates to those allowed in other tunnelling projects in Sydney, that is within the general range of 1 to 5 l/s/KM. Higher intermittent groundwater inflow rates of up to an order of magnitude higher than operational flow rates will occur upon intersection with significant joint and rock fracture structures. These increased flow rates could expect to dissipate relatively quickly as available head is removed. Any reduction in groundwater levels in areas surrounding the tunnel will have a positive impact on slope stability of steeper terrains particularly in the Castle Hill area.

Treatment of groundwater seepage emanating from the tunnel will be required. The limited data available on groundwater quality and estimated seepage rates means definitive treatment process design is not possible at this stage. Interaction is required between the tunnel and station cavern designers and groundwater specialist to further delineate the expected flow volumes and the nature of treatment, which will be required. Following concept approval the activities outlined in section 9 above would be implemented to inform future project approvals

11. References

NWRL Assessment of Environmental Issues - Volume 1 - Sinclair Knight Merz

NWRL - Working Paper No 2 - Water Quality Assessment - Final - Sinclair Knight Mertz- April 2003

NWRL - Working Paper No 3 - Hydrology & Hydraulics Assessment - Final - Sinclair Knight Mertz 2003

NWRL - Working Paper No 4 - Groundwater Assessment - final - Sinclair Knight Mertz- 2003

NWRL - Volume 1-3 Assessment of Environmental Issues Report March 2003 - Sinclair Knight Mertz

NWRL - Stage 2 Geotechnical Investigation for civil Works at Rouse Hill Regional Centre Cnr Windsor and Commercial Roads Rouse Hill, NSW - Jeffery and Katauskas Pty Ltd 2005

NWRL – North West Rail Link Geotechnical Investigation - Geotechnical Report - Arup 2003

NWRL - 2004 Engineering Design Study, Final Report - ARUP 2004

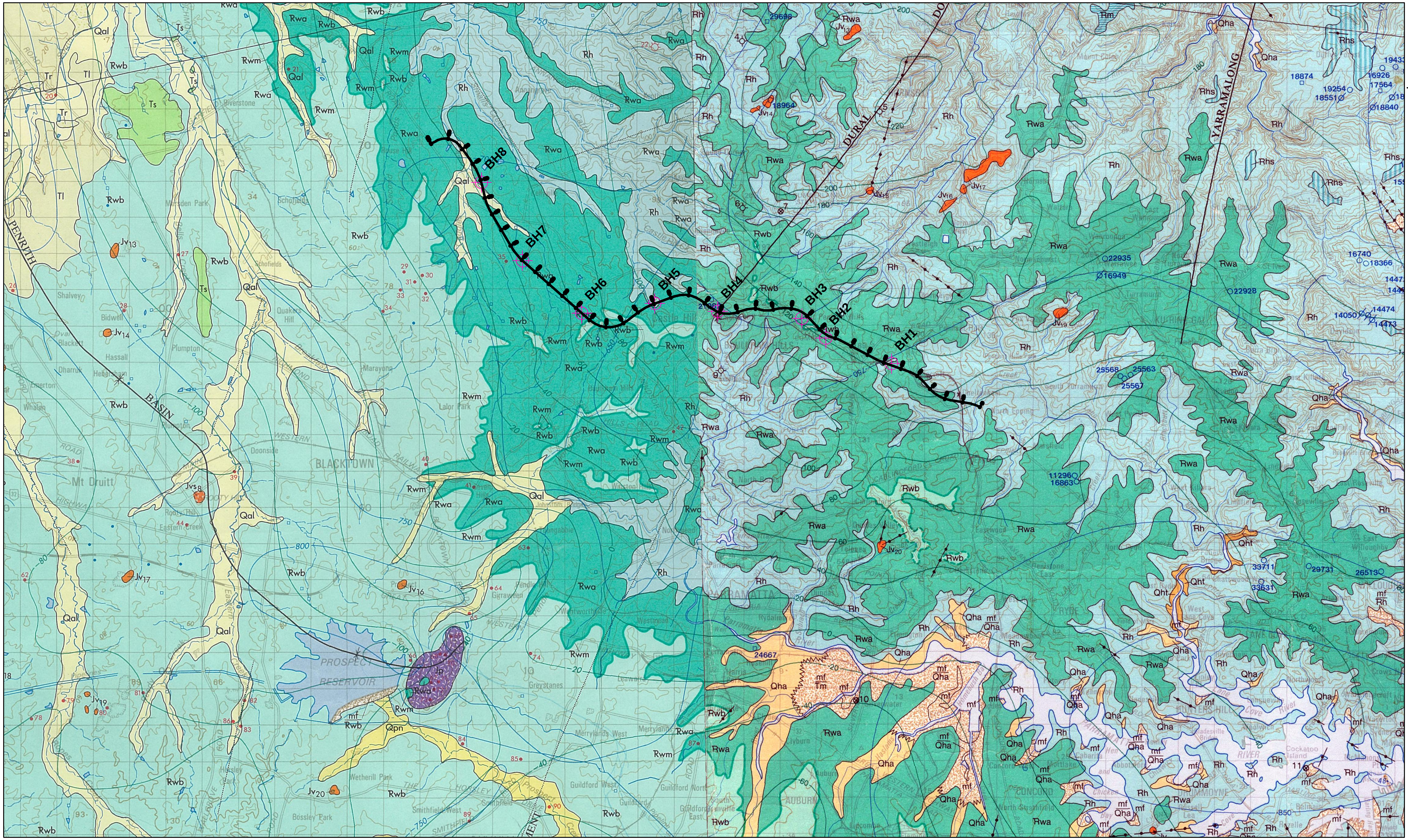
Geology of Penrith 1:100,000 Sheet 9030 – Geological Survey of New South Wales

Figures

D01

D01a

D02



BH1 LEGEND

BOREHOLE

INDICATIVE ROUTE

REFERENCE: 1:100,000 GEOLOGICAL SERIES, PENRITH 9030, SYDNEY 9130.
NOTE: SEE FIGURE 1A FOR GEOLOGY MAP LEGEND

No	Revision	Drawn	Checked	Approved	Date
A	DRAFT ISSUE	HW			09/08/06

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 1 2 3km
SCALE 1:100000 AT ORIGINAL SIZE

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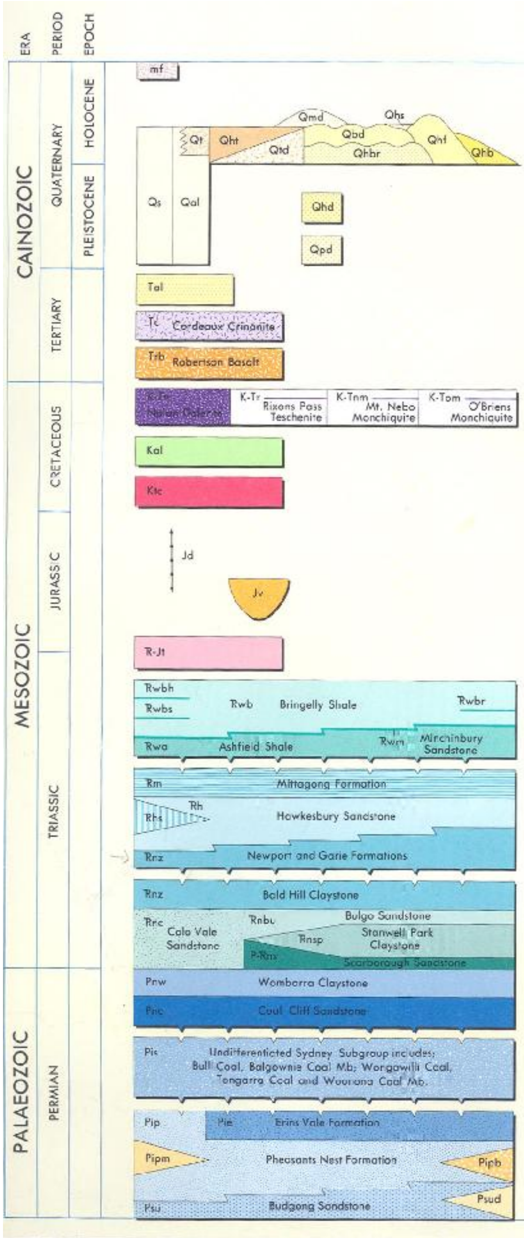
Drafting Check | Design Check
Approved
Date
Scale AS SHOWN
This Drawing must not be used for Construction unless signed as Approved

Client **TIDC**
Project **NORTH WEST RAIL LINE STUDY**
Title **GEOLOGY OF INDICATIVE ROUTE CHN 25km760.844 TO CHN 45km 658.445**

Original Size A3 | Drawing No: **2114856-GE-D01** | Rev: A

Plot Date: 19 October, 2006 - 3:04 PM   Cad File No: G:\Projects\21\14856\Geotech\CADD\Drawings\ 2114856_GE_D01.dwg



LITHOLOGY

mf	*Man-made fill. Dredged estuarine sand and mud, coal washing, industrial and household waste.*
Qt	*Talus. Unsorted landslide material.*
Qs	*Clayey quartz sand with humic matter.*
Qal	*Quartz and lithic "fluvial" sand, silt, and clay.*
Qmd	*"Marine" quartz sand.*
Qhs	*Peat, sandy peat, and mud.*
Qht	*Organic-rich muddy, mostly "marine" sand.*
Qtd	*Clean to muddy, shelly, mostly "marine" sand, sometimes with low dunes.*
Qbd	*Medium to fine "marine" quartz sand with podsols.*
Qhbr	*"Marine" quartz sand, minor shell content, interdune (swale) silt and fine sand.*
Qhf	*"Marine" quartz sand, fine to medium, shelly. Leached to varying degrees.*
Qhb	*"Marine" quartz sand, medium to coarse, with shelly fragments.*
Qhd	*Medium to find-grained "marine" sand with podsols and shelly layers.*
Qpd	*Fine to very fine quartzose sand.*
Tal	*High-level alluvium.*
Tc	*Melanocratic crinanite, camptonite, and teschenite.*
Trb	*Alkali olivine basalt.*
K-Tn	*Mid-grey dolerite.*
K-Tr	*Fine-grained dark-grey teschenite.*
K-Tnm	*Mid to dark-grey monchiquite.*
K-Tom	*Mid to dark grey monchiquite.*
Kal	*Laterized sandy alluvium.*
Ktc	*Trachytic intrusion at Mt. Cotopaxi.*
Jd	*Basalt.*
Jv	*Basalt, dolerite, volcanic breccia.*
R-Jt	*Microsyenite, trachyte includes intrusions at Yerrinbool, Cuppitts Forest and Izards Knob.*
WIANAMATTA GROUP	Rw (undifferentiated)
Rwb	*Shale, carbonaceous claystone, laminite, coal in parts.*
Rwbh	*Mt Hercules Sandstone Member - fine to medium grained quartz lithic sandstone.*
Rwbr	*Razorback Sandstone Member - fine to medium grained quartz-lithic sandstone.*
Rwbs	*Unnamed sandstone member - fine to medium-grained quartz lithic sandstone.*
Rwm	*Fine to medium-grained lithic sandstone.*
Rwa	*Laminite and dark-grey siltstone.*
MITTAGONG FORMATION	
Rm	*Interbedded shale laminite and medium-grained quartz sandstone.*
HAWKESBURY SANDSTONE	
Rh	*Medium to coarse-grained quartz sandstone, very minor shale and laminite lenses.*
Rhs	*Claystone, siltstone, and laminite ("shale lenses").*
NARRABEEN GROUP	Rn (undifferentiated)
Gosford Subgroup	
*Rnz	*Undifferentiated interbedded quartzose and quartz-lithic sandstone and siltstone, clay pellet sandstone.*
Clifton Subgroup	
*Rnz	*Dominantly red brown claystone and shale*
Rnc	*Quartz-lithic sandstone.*
Rnbu	*Fine to medium-grained quartz-lithic sandstone with lenticular shale interbeds.*
Rnsp	*Red, green, and grey shale and quartz-lithic sandstone.*
P-Rns	*Quartz-lithic sandstone, pebbly in parts.*
Pnw	*Grey shale and minor quartz-lithic sandstone.*
Pnc	*Fine to medium-grained quartz-lithic sandstone.*
ILLAWARRA COAL MEASURES	Pi (undifferentiated)
Sydney Subgroup	
Pis	*Interbedded quartz-lithic sandstone, grey siltstone, and claystone, carbonaceous claystone, clay, laminite, and coal.*
Cumberland Subgroup	
Pip	*Interbedded lithic sandstone, coal, carbonaceous claystone, siltstone, and claystone.*
Pie	*Fine to medium-grained bioturbated lithic sandstone.*
Pipm	*Minnamurra Latite Member - glomero-porphyritic latite.*
Pipb	*Berkeley Latite Member - fine-grained mid-grey latite.*
SHOALHAVEN GROUP	Ps (undifferentiated)
Psu	*Red, brown, and grey lithic sandstone.*
Psud	*Dapto Latite Member - melanocratic, coarse-grained and porphyritic latite.*

*Newport Formation and Garie Formation (Gosford Subgroup) and Bald Hill Claystone are all designated by the same symbol (Rnz) as these units could not be differentiated over much of the map area.

GEOLOGICAL SYMBOLS

Geological boundary – *position accurate*
– *position approximate*
– *submarine, interpreted from seismic surveys.*

Disconformity *(reference and rock relationship diagram only)*

Folding – *syncline*
– *anticline*

Fossil locality : plant; vertebrate

Dyke

Structure Contours *(in metres, relative to M.S.L.)*
– *Base of Wianamatta Group (Top of Hawkesbury Sandstone)*
– *Base of Narrabeen Group (Top of Permian Coal Measures)*

Bores – *coal bore*
– *petroleum bore*
– *water bore*
– *well*
– *abandoned water bore*

See table below

Numbers shown are Water Resources Commission registered numbers

REFERERENCE: 1:100,000 GEOLOGICAL SERIES, PENRITH 9030, SYDNEY 9130.

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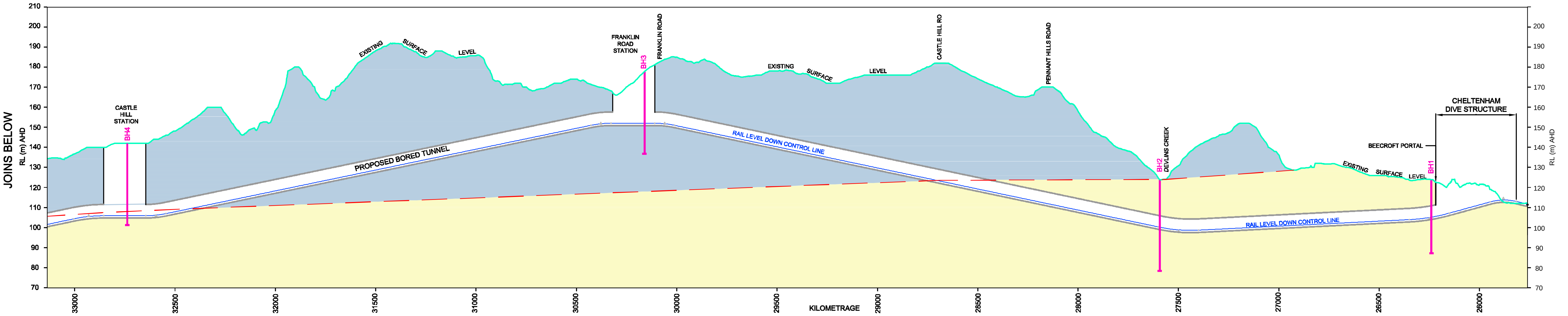
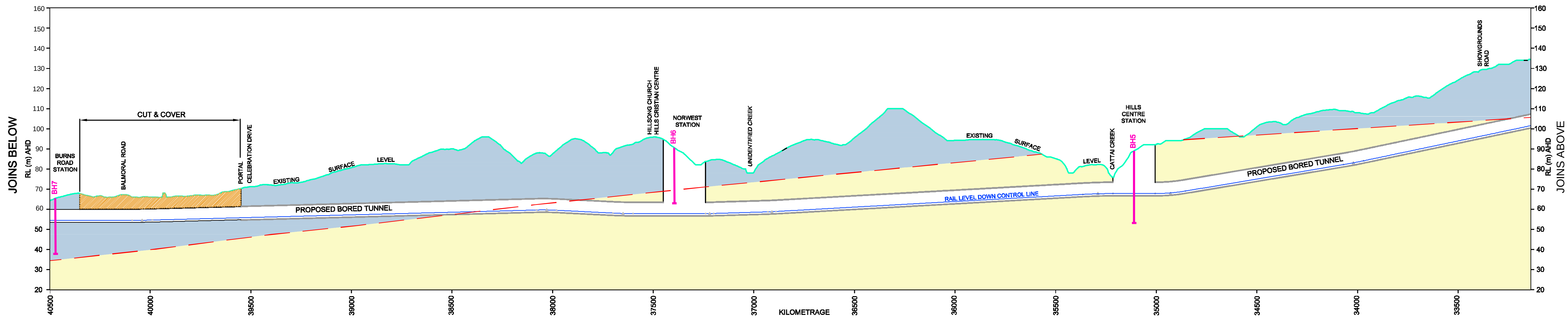
TIDC
NORTH WEST RAIL LINE STUDY
GEOLOGY LEGEND
1:100,000 SERIES
scale | 1:100 for A4 date | August 2006

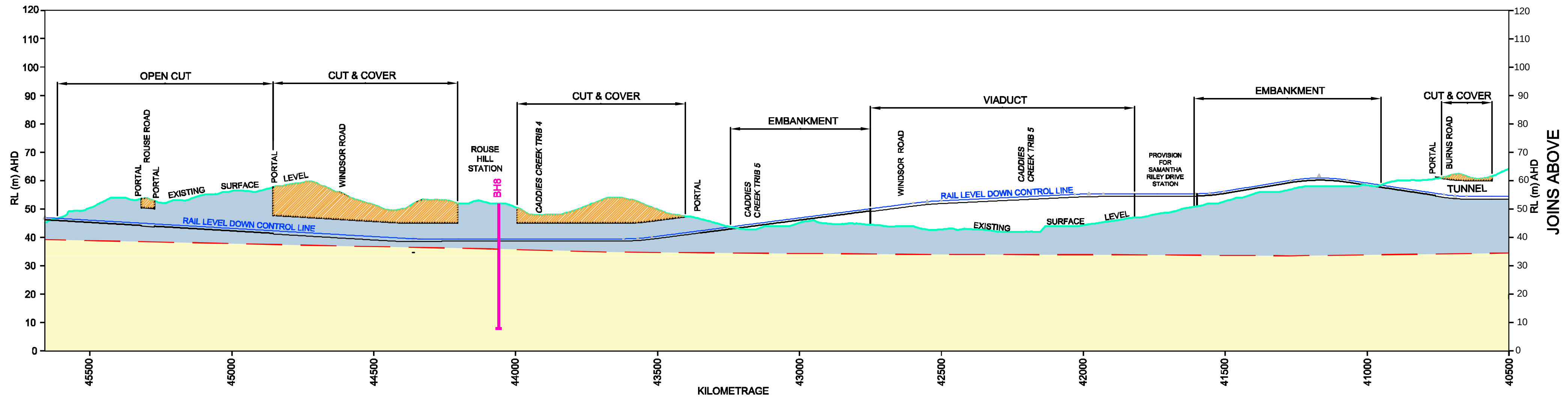
job no. | 21-14856
rev no. | A

Figure 1A





Approximate contact between the Ashfield Shale and the Hawkesbury Sandstone, also delineating the approximate position of the Mittagong Formation that ranges from 0 to 6m in thickness.



LEGEND

ASHFIELD SHALE (with some overlying Minchinbury Sandstone and Bringelly Shale)

HAWKESBURY SANDSTONE

Indicative Cut and Cover Construction

LONG SECTION

1: 2000 VERTICAL
1: 20000 HORIZONTAL
VERTICAL EXAGGERATION 10:1

No	Revision	Drawn	Checked	Approved	Date
A	DRAFT ISSUE	HW			10/08/06

Note: * indicates signatures on original issue of drawing or last revision of drawing

0 200 400 600m
SCALE 1:20000 AT A3 SIZE
HORIZONTAL

0 20 40 60m
SCALE 1:2000 AT A3 SIZE
VERTICAL

SHEET 1 VIEW

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Drafting Check | Design Check
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Date
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Client **TIDC**
Project **NORTH WEST RAIL LINE STUDY**
Title **GENERALISED GEOLOGICAL LONG SECTION**
CHN 25km760.844 TO CHN 45km 658.445

Original Size A1 Drawing No: **2114856-GE-D02** Rev: A

Plot Date: 19 October 2006 - 3:14 PM Cad File No: G:\Projects\21\14856\Geotech\CADD\Drawings\2114856_GE_D02.dwg

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	Andrew Fulton	G.P. Kotze	G.P. Kotze	J. Ardis	J. Ardis	19/10/06