Transport
Roads & Maritime
Services

9 September 2014

Mitchell Isaacs
Manager Strategic Stakeholder Liaison
NSW Office of Water
227 Elizabeth Street
Sydney NSW 2000

RE: NorthConnex Supplementary Groundwater Information

Dear Mitchell,

In recent discussions with the NorthConnex project team and the Department of Planning and Environment, the NSW Office of Water has raised a number of questions with regards to the groundwater assessment. These questions were related to:

- The rationale behind designing the project as a drained tunnel.
- The rationale behind the inflow criterion of one litre per second per kilometre.
- The scope of the hydrogeological investigations and was this adequate to inform the EIS.
- The adequacy of the impact assessment and are the potential impacts acceptable.

The NorthConnex project team have drafted a supplementary memorandum to address the above questions and it is attached for your information.

In addition to addressing the above questions that the Office of Water had, the NorthConnex team have included a section outlining the Director-General's Environmental Assessment Requirements for the project and how the NorthConnex Environmental Impact Statement satisfies them. Also included in the memorandum is an overview of how the project has been assessed in accordance with the NSW Aquifer Inference Policy. In this regard, although NorthConnex is considered a minimal impact aquifer interference activity in accordance with the policy, the project has undertaken a more detailed consideration of the potential groundwater impacts than required by the policy.

Thank you for your input to date and should you have any further enquiries please do not hesitate to contact me on 8588 4940 or Nicholas Francesconi on 8588 4372.

Yours sincerely,

Daniel Powrie
Principal Manager Motorway Delivery

NorthConnex Groundwater Memorandum

1.0 Hydrogeology of the NorthConnex project area

The geology and hydrogeology of the project area is described in Section 7.8.2 of the environmental impact statement. This section provides a summary for context in reading this memorandum.

The geology along the project corridor is dominated by Ashfield Shale and the underlying Hawkesbury Sandstone. The Ashfield Shale corresponds to the ridge line and ranges in thickness up to a maximum of around 60 to 70 metres. Hawkesbury Sandstone is present at depth along the corridor with outcropping within the valleys to either side of the project. The geology of the area was influential in determining the vertical alignment of the tunnels. Hawkesbury Sandstone is high strength and is an excellent tunnelling and excavation medium. As a result, the tunnel has been designed to maximise the length of tunnel within the Hawkesbury Sandstone.

Aquifers are present in both the Ashfield Shale and the Hawkesbury Sandstone. The project is likely to encounter both aquifers in different sections. The aquifer associated with the Ashfield Shale is a fractured rock aquifer with low hydraulic conductivity (ie low water flow). Water flow occurs along the bedding layers within the rock as well as obliquely along joints or faults. Due the low hydraulic conductivity, the shale has little groundwater flowing into it and creates a partial barrier to groundwater flowing into the underlying Hawkesbury Sandstone.

The aquifer in the Hawkesbury Sandstone is a generally confined fractured rock aquifer and has variable hydraulic conductivity. The majority of the groundwater flow is via saturated vertical or sub-vertical features such as joints, shear zones and dykes. Traditionally, these features are grouted when they are encountered on tunnelling project to minimise the groundwater inflow into the tunnels and minimise potential groundwater drawdown impacts. This is also proposed for the NorthConnex tunnels. Some intra-granular flow also occurs, however the conductivity is much lower.

2.0 Rationale for drained tunnel

Drained tunnels allow the ongoing inflow of water into the tunnel which then needs to be captured and appropriately managed. Undrained tunnels limit groundwater inflows to very small volumes through the installation of a structural lining combined with a waterproofing system. These tunnels are also sometimes referred to as 'tanked' tunnels.

Undrained tunnels are only specified, or required in the following circumstances:

- To limit groundwater drawdown where:
    - There would be unacceptable environmental outcomes such as loss of baseflow to creeks or impacts to the viability of groundwater dependent ecosystems. Typically, this would involve a section of the tunnel being undrained such as where it passes directly underneath a watercourse. This is further considered in Section 6.0 of this memo in relation to the NorthConnex tunnels.
    - In areas of compressible soils where drawdown may result in damage to existing infrastructure. The NorthConnex tunnels are located in high strength sandstone. There are no compressible soils in the vicinity of the project tunnels.

- To limit inflow of groundwater into the tunnel to minimise:
  - Damage to internal tunnel assets due to corrosive groundwater. In the case of the NorthConnex project, this is effectively managed by in-tunnel drainage to direct groundwater away from the crown of the tunnel where services would be located. The project has been designed to accommodate the potentially corrosive effects of groundwater.
  - Maintenance requirements where groundwater is naturally high in iron and manganese. Groundwater quality in the area around NorthConnex is not particularly high in iron or manganese. The project has been designed to accommodate expected groundwater quality, including concentrations of iron and manganese.
  - High water treatment costs where groundwater is contaminated, has high salinity or very low pH. Groundwater quality in the area around NorthConnex is not contaminated, high in salinity or very low in pH. Water treatment costs are not particularly high. The water treatment plant for the project has been designed to accommodate expected groundwater quality, with some redundancy to allow for variability in water quality over time.

Historically, tunnels constructed within Sydney have been drained tunnels including road, rail and services tunnels. Most of these tunnels are excavated in Hawkesbury Sandstone and Ashfield Shale, similar to the geology in the area of the NorthConnex tunnel. Sections of some tunnels, however, have been constructed as undrained in order to mitigate unacceptable environmental impacts and/ or ongoing operational and maintenance issues. For example, a short section of the M5 Motorway tunnel is undrained where it passes underneath Wolli Creek. This was to mitigate the groundwater drawdown and significant potential impact to baseflow where the tunnel was directly underneath a watercourse.

The only identified undrained tunnels are NWRL (rail tunnels), the City East Cable Tunnel (high voltage electrical cable tunnel) and the New Southern Railway where is crosses the airport (rail tunnels), all of which were designed as undrained structures primarily as the result of a whole of life cost assessment, and to mitigate maintenance and operation issues.

The NWRL underground station boxes, which are significant underground excavations in themselves, are drained. This includes the following stations and depths to the station platform:

- Cherrybrook around seven metres below ground level.
- Castle Hill around 25 metres below ground level.
- Showground around 20 metres below ground level.
- Norwest around 20 metres below ground level.
- Bella Vista around 6 metres below ground level.

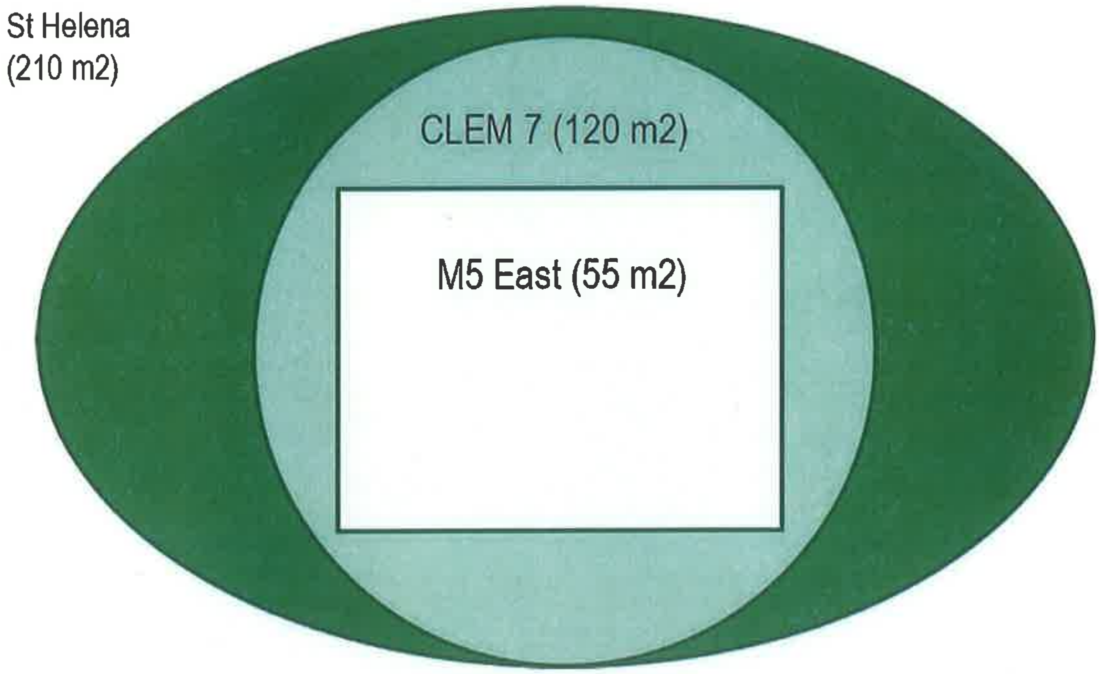
Of particular note, Showground Station is located adjacent to and at a lower elevation than Cattai Creek. As these station boxes are generally rectangular in nature, they do not conform the near circular profile which lends itself to an undrained tunnel solution (further explained the following paragraph).

Undrained tunnels typically require circular or near circular tunnel profiles and relatively thick concrete linings (depending on the size of the tunnel, and the depth) to resist groundwater pressures. In some cases such as rail tunnels, the tunnel cross-section requirements lends itself to a small, compact, circular profile which is structurally efficient under hydrostatic pressures and does not typically necessitate large increases in excavation volumes and concrete lining thicknesses to achieve undrained conditions. This profile is also usually consistent throughout the tunnel alignment, with limited wider points which would require increases to excavation and lining. These were key factors informing and justifying the decision to adopt an undrained tunnel design for the NWRL.

In the case of a three lane road tunnel (initially marked for two lanes) such as the NorthConnex project, the tunnel cross-section requirement lends itself to a wide, rectangular profile. In competent Hawkesbury Sandstone (the majority of the NorthConnex alignment) the ground can be supported without significant over excavation of this profile. To achieve an undrained tunnel in this scenario, a significant increase in excavation volume is necessary (significantly above the excavation requirements currently envisaged for the NorthConnex project) to create a near circular profile which would enable the concrete lining to withstand groundwater pressure. The tunnel would also require a significant increase in concrete lining thickness. In addition to the standard profile, the NorthConnex project also includes several locations of very wide spans, such as Y-Junctions where on and off-ramps connect to the three lane road tunnel. Large excavations and thick concrete lining thicknesses would be required at these locations to achieve undrained conditions.

This over-excavation would result in additional environmental, sustainability and social impacts over and above those already identified and assessed in the NorthConnex EIS. This would be mainly associated with the increased spoil generation which would give rise to increased heavy vehicle movements, increased impacts on the surrounding road network, increased construction traffic noise and longer tunnelling timeframes. The additional costs associated with over-excavation of the tunnel, additional concrete lining and waterproofing would also affect the financial viability of the project in its current form. A financially viable undrained tunnel would require cost savings to be found elsewhere, such as a reduction in tunnel length. This would have the potential to further increase environmental impacts (including for example, through additional land acquisition and surface disturbance) and may reduce the road network benefits of the project in the case of a significantly shortened tunnel.

This approach was adopted for the Tintenbar to Ewingsdale 'St Helena' tunnel which is a three lane road tunnel on the NSW North Coast. This approach has required significant over excavation to a cross-sectional area of around 210 square metres (this compares the NorthConnex three lane road tunnel cross-section area of around 85 square metres) and a concrete volume for lining of 38,000 cubic metres for 434 metres twin tunnels. Under such a scenario for NorthConnex, the volume of spoil generated would be likely to at least double the current estimate of 2.6 million cubic metres. The relative shape and area of the Tintenbar to Ewingsdale 'St Helena' tunnel in comparison to the CLEM 7 tunnel and the M5 East Motorway tunnel is shown below.



In the case of Tintenbar to Ewingsdale, the existing hydrogeology and potential environmental impacts led to the decision to construct an undrained tunnel. This included:

- Layered columnar basalt geology with significant faulting leading to high hydraulic conductivity.
- The location of the tunnels with a drinking water catchment.
- The presence of an already degraded endangered ecological community which is reliant on water flow from a perched water table.

This compares to the NorthConnex tunnels which are located within a hydrogeological area with low hydraulic conductivity, not within a drinking water catchment and no endangered ecological communities reliant on groundwater.

3.0 Rationale for 1 L/s/km inflow limit

An inflow limit of one litre per second per kilometre was set as a design criterion for the NorthConnex tunnel during the tender phase.

Similar limits have been adopted for other Sydney tunnels. This limit is considered to be a reasonable limit to achieve through design based on the hydrogeological characteristics of the Hawkesbury Sandstone.

Inflows into various tunnels within the Hawkesbury Sandstone have been measured in recent years as summarised in Table 1 (after Hewitt, 2005). Any major inflow zones which were encountered during the construction of these tunnels were grouted to reduce the inflows to small volumes. This approach will also be adopted for the NorthConnex project. Table 1 shows that an inflow design criterion of one litre per second per kilometre is consistent with the performance of existing tunnels across Sydney.

Table 1 Measured drainage rates from other Sydney tunnels

Tunnel	Type	Width (m)	Length km	Drainage inflow (L/s/km)	Reference
Eastern Distributor Tunnel	3 lane road	12 (Double deck)	1.7	1	Hewitt, 2005
Cross City Tunnel	Twin 2 lane road	8 (twin)	2.1	<3	Best and Parker, 2005
M5 East	Twin 2 lane road	8 (twin)	3.8	0.9	Tammetta and Hewitt, 2004
Epping to Chatswood Rail Tunnel	Twin rail	7.2	13	0.9	Best and Parker, 2005
Lane Cove Tunnel	Twin 3 lane road	9 (twin)	3.6	0.6/1.7*	Coffey, 2012
Northside Storage Tunnel	Sewer storage	6	20	0.9	Coffey, 2012

Note: * measured inflow in Lane Cove Tunnel varied from 0.6 L/s/km (2011) to 1.7 L/s/km (2001 - mid 2004)

Drainage inflow as summarised in Table 1 varies from 0.9 L/s/km to less than 3 L/s/km. In all cases (including the Cross City Tunnel and Lane Cove Tunnel where inflows have been measured at times to exceed 1 L/s/km) there are no known adverse environmental impacts from groundwater drawdown caused by tunnel inflow. This includes tunnels which pass directly under watercourses such as the Epping to Chatswood Rail Tunnel which passes under the Lane Cove River, and the Lane Cove Tunnel which passes under Stringybark Creek.

Historically, the one litre per second per kilometre limit has been set as an average across the entire length of a tunnel. In order to drive improved design and environmental outcomes, this limit was set as an average measured across any single kilometre of the tunnels for the NorthConnex project.

The majority of groundwater inflow into the NorthConnex tunnels would be derived from the Hawkesbury Sandstone. The Hawkesbury Sandstone is a dual porosity aquifer where groundwater flows via the rock matrix voids (primary porosity) and features such as saturated joints fractures, shear zones and dykes (secondary porosity). The majority of groundwater inflow from the Hawkesbury Sandstone is via saturated vertical or sub-vertical structural features. If encountered during excavation of the tunnels these major inflow zones would be grouted to reduce tunnel inflow and to achieve the specified inflow design criterion. Thus long term groundwater inflow would be from rock matrix seepage and minor fractures.

Based on the above information it was considered to be reasonable to specify a limiting groundwater inflow of 1 L/s/km for the NorthConnex project, noting that this is more stringent than the design criteria set for previous Sydney tunnels. This would limit inflows to volumes which have been measured for other tunnels in similar geology, and for which no known unacceptable impacts have occurred.

4.0 Scope and adequacy of the hydrogeological investigations

Hydrogeological investigations along the NorthConnex project alignment have been conducted as part of the geotechnical investigations to provide technical data for pre-tender documentation. The investigations included:

- Collating hydrogeological data from previous major infrastructure investigations.
- Construction of 23 groundwater monitoring wells with screens placed at the proposed tunnel depth.
- Monitoring wells constructed in Ashfield Shale (eight), Mittagong Formation (two), fill (one) and Hawkesbury Sandstone (12).
- Water pressure (packer) testing in 16 boreholes with up to three tests in each borehole.

- Groundwater level monitoring (six events between July and October 2013).
- Groundwater quality monitoring in July and August 2013 for a series of field parameters and analytes to characterise groundwater quality.

The hydrogeology through which the NorthConnex tunnels pass is well understood through previous studies and investigations for infrastructure projects. The range of hydraulic conductivity values obtained from packer tests for the Ashfield Shale, Mittagong Formation, and Hawkesbury Sandstone are consistent with other results obtained from nearby infrastructure projects and are considered adequate for the NorthConnex hydrogeological investigation. Based on the well understood hydrogeological characteristics of the area and the consistency of these results with the NorthConnex investigation results, additional testing such as air percussion drilling and pump testing was not considered necessary.

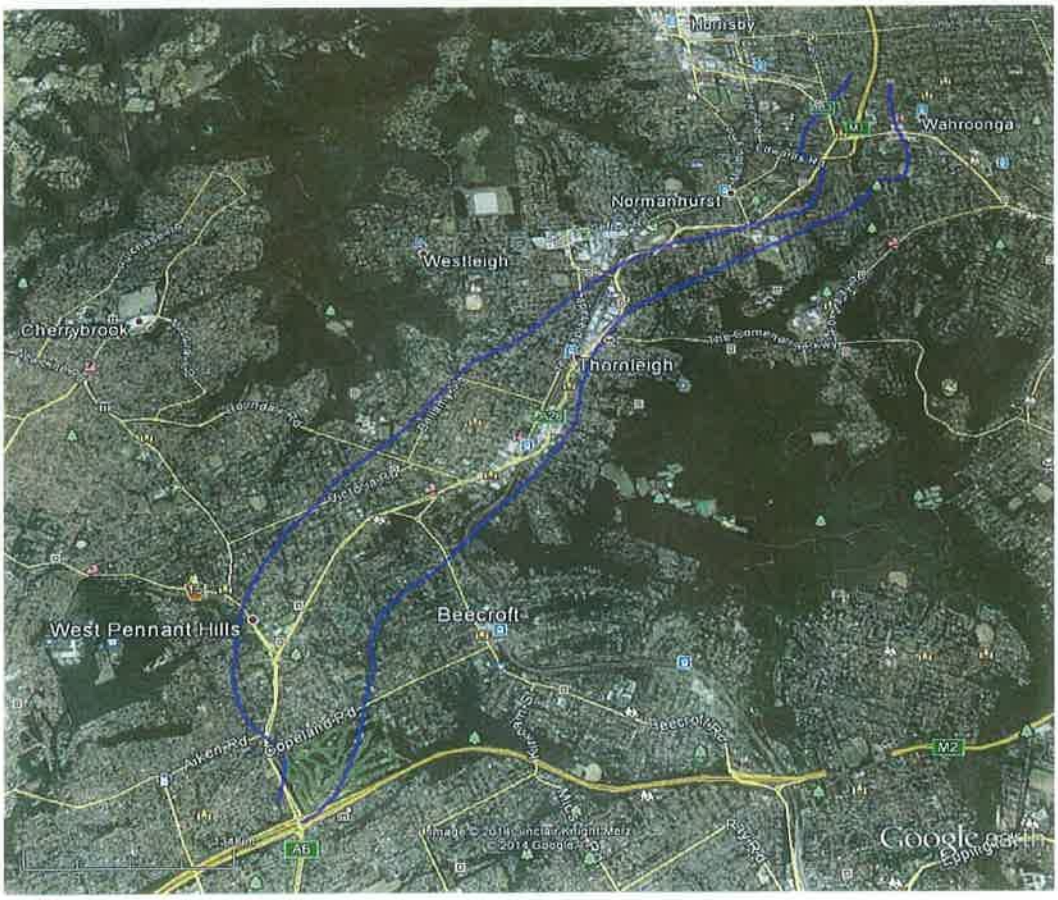
Additionally, air percussion drilling is not practical in an urban environment. This process results in cuttings and water that are airlifted under pressure from the boreholes and sprayed over the surrounding area. This is considered to be inappropriate in an urban, residential environment.

As part of the tender design an empirical assessment of the lateral limit to groundwater drawdown was undertaken. This is discussed further in Section 5.0. The potential impacts to groundwater dependent ecosystems as a result of changes in creek baseflow are discussed in Section 6.0 of this memorandum.

For the reasons outlined above, it is considered that the hydrogeological investigations conducted through the pre-tender design phase and the comments, qualifications and additional modelling proposed by the preferred tenderer are adequate to support the environmental impact statement.

5.0 Empirical assessment of drawdown

As part of the tender design, an empirical assessment of the lateral extent of groundwater drawdown in the Hawkesbury Sandstone was undertaken using the Perrochet and Musy (1992) empirical method. The assessment shows a long-term quasi steady state drawdown scenario. The results of this are shown below with the lateral extent of drawdown depicted by the blue lines.



The lateral extent of drawdown in the north is lower than in the south due to the shallower level tunnel and deeper incised watercourses, compared to the south with a deeper tunnel and shallower incised watercourses.

Groundwater outflow to creeks through springs (if they are present), would not be affected outside the area depicted by the blue line.

6.0 Adequacy of EIS assessment

The Director-General's environmental assessment requirements in relation to groundwater are:

> *groundwater impacts as a result of the project (including ancillary facilities such as the tunnel control centre and any deluge systems), considering local impacts along the length of the tunnels and impacts on local and regional hydrology. The assessment must consider: extent of drawdown; impacts to groundwater quality; discharge requirements; location and details of groundwater management and implications for groundwater-dependent surface flows, groundwater dependent ecological communities, and groundwater users. The assessment should be prepared having consideration to the requirements of the NSW Aquifer Interference Policy;*

The assessment of potential groundwater impacts from the NorthConnex project has been undertaken in accordance with this requirement as detailed in Table 2.

Table 2 Director-General's Requirements

Requirement	How and where addressed
Extent of drawdown	The extent of groundwater drawdown is described in section 7.8.3 of the environmental impact statement. Further information on the lateral extent of drawdown is provided in Section 5.0.
Impacts to groundwater quality	Groundwater quality is considered in section 7.8.3 of the environmental impact statement. The project would be unlikely to impact the quality of groundwater. As such, this section focuses on the existing groundwater quality likely to be encountered by the project and the implications of this in terms of treatment and subsequent discharge of treated water.
Discharge requirements	Discharge requirements in terms of volumes during construction and operation are described in Section 7.8.3 of the environmental impact statement. The treatment, discharge locations, and potential impacts to surface water from the discharge are described in Section 7.9.3 of the environmental impact statement.
Location and details of groundwater management	Groundwater management measures are identified in Section 7.8.4 of the environmental impact statement.
Implications for groundwater dependent surface flows	Section 7.8.3 of the environmental impact statement identifies that groundwater may also naturally discharge to local freshwater creeks. Based on a review of groundwater dependent ecosystems (refer below), there are no groundwater dependent ecosystems in the vicinity of the project that rely on the surface expression of groundwater. Based on this, it is likely that there are no surface flows which are dependent on groundwater for recharge. Surface flows are likely to be reliant on overland flows paths, with groundwater being a small contributor to these surface flows.
Implications for groundwater dependent ecological communities	Potential impacts to groundwater dependent ecosystems are provided in the Biodiversity Technical Working Paper (Appendix J of the environmental impact statement) and Section 7.6.3 of the environmental impact statement. Further consideration of groundwater dependent ecosystems is provided in Section 6 .0 of this memorandum.
Implications for groundwater users	Table 7-170 of the environmental impact statement provides an assessment of potential impacts to existing groundwater bores in the area. This assessment concludes that impacts to the viability of existing bores are unlikely. Notwithstanding, the project has committed to make good provisions if unexpected impacts occur. This may involve the construction of a deeper bore, or provision of an alternative water source for the affected user.

The NSW Aquifer Interference Policy (Department of Primary Industries, 2012) document the NSW government's intention to implement the requirement for approval of 'aquifer interference activities' under the *Water Management Act 2000*. Although the project would intersect a groundwater aquifer (the main alignment tunnels and on and off-ramp tunnels would intercept a groundwater source) the requirement for aquifer interference approvals has not yet commenced and as such, this approval is not required. Despite this, an assessment of potential groundwater impacts was provided in Section 7.8 (Hydrogeology and soils) of the environmental impact statement.

Consideration of the project against the requirements of the Aquifer Interference Policy (AIP) has been undertaken as part of environmental impact assessment, by following the NSW Office of Water document 'Assessing a proposal against the NSW Aquifer Interference Policy – step by step guide'.

The first step in this guide is to ascertain if the activity requires a detailed assessment under the AIP. This consideration is provided in Table 3.

Table 3 Consideration of Aquifer Interference Policy

Consideration		Response
1	Is the activity defined as an aquifer interference activity?	**YES** If NO, then no assessment is required under the AIP. If YES, continue to Question 2.
2	Is the activity a defined minimal impact aquifer interference activity according to section 3.3 of the AIP?	**YES – the project meets the definition of 'caverns, tunnels, cuttings, trenches and pipelines (intersecting the water table) if a water access licence is not required'.** If YES, then no further assessment against this policy is required. Volumetric licensing still required for any water taken, unless exempt. If NO, then continue on for a full assessment of the activity.

Based on the results on this first step, the project is a defined minimal impact activity and does not require any further assessment.

The project has also considered the minimal impact considerations from the NSW Aquifer Interference Policy (refer to Table 7-168 of the environmental impact statement). This is reproduced in Table 4.

Table 4 Aquifer Interference Policy Minimal Impact Considerations

No	Consideration	Potential impact
Water table		
1	Less than or equal to 10 per cent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 metres from any: • high priority groundwater dependent ecosystem; or • high priority culturally significant site; • listed in the schedule of the relevant water sharing plan. A maximum of a two metre decline cumulatively at any water supply work.	The project would not be located within 40 metres of any high priority groundwater dependent ecosystems or high priority culturally significant site. The project may potentially result in a decline of the water table at existing bores in the vicinity of the project, however the impacts are considered to be limited.
2	If more than ten per cent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 metres from any: • high priority groundwater dependent ecosystem; or • high priority culturally significant site; listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister's satisfaction that the variation will not	In the event that drawdown of the water table does impact on the viability of existing bores consultation would be undertaken with the bore owner to develop appropriate mitigation measures which may include development of a new, deeper bore.

No	Consideration	Potential impact
	prevent the longterm viability of the dependent ecosystem or significant site. If more than a two metre decline cumulatively at any water supply work then make good provisions should apply.	
Water pressure		
1	A cumulative pressure head decline of not more than a two metre decline, at any water supply work.	The project may potentially result in a decline in head pressure at existing bores in the vicinity of the project, however the likelihood is considered low.
2	If the predicted pressure head decline is greater than requirement one above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the longterm viability of the affected water supply works unless make good provisions apply.	In the event that drawdown of the water table does impact on the viability of existing bores, including a decline in head pressure, consultation would be undertaken with the bore owner to develop appropriate mitigation measures which may include development of a new, deeper bore.
Water quality		
1	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	The project is not anticipated to result in impacts to groundwater quality.
2	If condition one above is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.	Not applicable.

Based on the above, the project is explicitly defined in the Aquifer Interference Policy as a minimal impact aquifer interference activity. Further, the project meets the minimal impact considerations under the Aquifer Interference Policy.

Notwithstanding and following good environmental impact assessment practice, the environmental impact statement undertook a more detailed consideration of potential groundwater impacts. A detailed consideration of the proposal against the Aquifer Interference Policy is provided in Attachment A to this memorandum.

7.0 Acceptability of the environmental impacts

Potential environmental impacts from groundwater drawdown are relevant in the context of groundwater dependent ecosystems and existing groundwater users. Existing bores and the potential impacts to these groundwater users are assessed in Table 7-170 of the environmental impact statement. This assessment concludes that impacts to the viability of existing bores are unlikely to occur. Notwithstanding, the project has committed to make good provisions if unexpected impact do occur. This may involve the construction of a deeper bore, or provision of an alternative water source for the affected user.

The locations of groundwater dependent ecosystems have been identified through a review of the Groundwater Sharing Plan for the Greater Metropolitan Region and the Australian Government's Groundwater Dependent Ecosystem Atlas.

The groundwater dependent ecosystems mapped as part of the Groundwater Sharing Plan for the Greater Metropolitan Region are shown in Attachment B. This mapping shows that the closest groundwater ecosystems to the project are located:

- To the north-west around Windsor.
- To the south-west around Salt Pan Creek at Padstow and within the Botany Sands Aquifer.

The project would not impact any of the aquifers associated with these groundwater dependent ecosystems.

The Groundwater Dependent Ecosystems Atlas (2013) provides more detailed mapping of groundwater dependent ecosystems. The results of this mapping are provided in Figure 9 of the Technical Working Paper: Biodiversity (Appendix J of the environmental impact statement). This figure is reproduced in Attachment C to this memorandum.

Key findings of the mapping from the Groundwater Dependent Ecosystems Atlas are:

- *There are no groundwater dependent ecosystems in the vicinity of the project which are reliant on the surface expression of groundwater.* Therefore any groundwater drawdown which results in a change in baseflows to surface water would not impact any groundwater dependent ecosystems.
- *The only significant area of vegetation identified with a high dependence on groundwater is along the Hills M2 Motorway.* The NorthConnex tunnel is not expected to result in groundwater drawdown in this area. Further, the Technical Working Paper: Biodiversity identified that these groundwater dependent ecosystems would be unlikely to be reliant on the deep sandstone aquifer and are more likely to be reliant in a superficial alluvial aquifer.
- Some minor patches of highly dependent groundwater dependent ecosystems are located along Devlins Creek and along Coups Creek. Again, based on the location of these ecosystems in the landscape, directly adjacent to creeklines, it is likely that these groundwater dependent ecosystems are reliant on a superficial alluvial aquifer rather than the deeper sandstone aquifer. Further, as noted above, these groundwater dependent ecosystems are not reliant on the surface expression of groundwater. Notwithstanding, further consideration is given to these groundwater dependent ecosystems below.

Coups Creek

The groundwater dependent ecosystem along Coups Creek is located south of the Commenarra Parkway and directly along the creekline. Based on this position in the landscape, it is likely that this groundwater dependent ecosystem utilises a shallower alluvial aquifer rather than the deeper sandstone aquifer.

An analysis of the elevation of this groundwater dependent ecosystem in relation to the depth of the tunnel has also been undertaken. The reduced level (RL) relative to mean sea level elevation of the groundwater dependent ecosystem is around 100 metres at the highest point near the Commenarra Parkway, dropping to the south to a low point of around 50 metres. In this location the RL of the tunnel is around 120 to 150 metres. As the level of the tunnel is above the groundwater dependent ecosystems, there is no potential for drawdown impacts to this groundwater dependent ecosystem.

Further, the lateral extent of drawdown (refer to section 5.0 of this memorandum) indicates that groundwater drawdown would not extend near the vicinity of this groundwater dependent ecosystem.

Devlins Creek

The groundwater dependent ecosystem along Devlins Creek is located east of Pennant Hills Golf Course and directly along the creekline. Based on this position in the landscape, it is likely that this groundwater dependent ecosystem utilises a shallower alluvial aquifer rather than the deeper sandstone aquifer.

An analysis of the elevation of this groundwater dependent ecosystem in relation to the depth of the tunnel has also been undertaken. The reduced level (RL) relative to mean sea level elevation of the groundwater dependent ecosystem is around 100 metres at the highest point near the golf course, dropping slightly to the west. In this location the RL of the tunnel is below 100 metres. Based on this, an empirical assessment of groundwater drawdown has been carried out to determine the likelihood and potential extent of drawdown in this area (refer to Section 5.0 of this memorandum).

The empirical assessment indicates that the lateral extent of drawdown would not extend to the area of this groundwater dependent ecosystem. As such, it is considered that the NorthConnex tunnels would be unlikely to impact the viability of this groundwater dependent ecosystem.

This groundwater dependent ecosystem is also located in a localised low point and would receive flows from the north-west (the location of the project), and flows from the south of the Hills M2 Motorway which would be unaffected by the project.

8.0 Conclusion

This memo has demonstrated that:

- A drained tunnel is an appropriate design solution based on a consideration of the hydrogeological characteristics of the area and a balanced consideration of the potential groundwater impacts against the likely additional environmental impacts and the financially viability of an undrained tunnel.
- The adoption of an inflow criterion of one litre per second per kilometre is appropriate and its application is more stringent than the criteria set on previous Sydney tunnels.
- The hydrogeological investigations undertaken to inform the EIS were adequate considering the extent of hydrogeological information known in the area.
- The potential impacts associated with groundwater drawdown of constructing a drained tunnel for the NorthConnex project are acceptable.

9.0 References

AECOM (2012a); F3-M2 Groundwater Monitoring Factual Report. Transurban Limited, dated 29 October.

AECOM (2012b); F3-M2 Geotechnical Factual Report Phase 2. Transurban Limited, dated 4 November.

Best, R.J. and Parker, C.J., (2005). Groundwater in Sydney: - tunnel inflows and settlement – theory and experience, 12th Australian tunnelling conference, Brisbane, 5-3.

Coffey Geotechnics (2012). Geotechnical Interpretative Report. North West Rail Link. Transport for NSW. Dated 18 May.

Hewitt, P., (2005). Groundwater control for Sydney Rock tunnels. AGS AUCTA Mini-Symposium: Geotechnical Aspects of Tunnelling for /infrastructure Projects. October

Perrochet P and Musy A (1992) A simple formula to calculate the width of hydrological buffer zones between drained agricultural plots and nature reserve areas. Irrigation Drainage Systems 6:69–81

Tammetta, P., and Hewitt, P., (2004). Hydrogeological properties of Hawkesbury Sandstone in the Sydney region, Australian Geomechanics. 39(3), 93-108.

Attachment A – Consideration of the Aquifer Interference Policy

AIP requirement		Proponent response
1	Described the water source(s) the activity will take water from?	The water source has been identified as the Sydney Basin Central ground water source in Section 7.8.3 of the EIS.
2	Predicted the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	The water take for both construction and operation (a as a predicted worst case) has been identified in Section 7.8.3 of the EIS. The water take is based on groundwater inflow limits that have been set for the project as part of the design requirements.
3	Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity?	Not applicable – the project does not have a post-closure phase.
4	Made these predictions in accordance with Section 3.2.3 of the AIP? (refer to Table 3, below)	Predictions have been made based on the results of the ground investigations undertaken for the project and the design requirement that has been set for the project.
5	Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources?	Section 7.8.3 of the EIS identifies the water sources from which this water will be taken.
6	Described how any licence exemptions might apply?	Yes – the project is exempt from licencing requirements under the *Water Management Act 2000* and the *Water Act 1912.*
7	Described the characteristics of the water requirements?	Not applicable – the water take is incidental to the tunnelling process. Water is not being taken for any project requirements.
8	Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	Not applicable – the project is exempt from licencing requirements. Notwithstanding, the ground water source is not extensively used and the take of water would be returned to the environment or beneficially re-used.
9	Considered the rules of the relevant water sharing plan and if it can meet these rules?	The rules of the relevant ground water sharing plan are considered in Table 7-167 of the EIS.
10	Determined how it will obtain the required water?	Not applicable - the water take is incidental to the tunnelling process. Water is not being taken for any project requirements.
11	Considered the effect that activation of existing entitlement may have on future available water determinations?	Not applicable – the project is exempt from licencing requirements. Notwithstanding, the ground water source is not extensively used and the take of water would be returned to the environment or beneficially re-used.
12	Considered actions required both during and post-closure to minimize the risk of inflows to a mine void as a result of flooding?	Not applicable – the project is not a mining project and does not have a post-closure phase.
13	Developed a strategy to account for any water taken beyond the life of the operation of the project?	Not applicable - the project does not have a post-closure (or 'beyond the life of') phase.
Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users? **No – the project has set groundwater inflow design requirements. As such, there is no uncertainty in the predicted inflows.** If YES, items 14-16 must be addressed.		

AIP requirement		Proponent response
14	Considered any potential for causing or enhancing hydraulic connections, and quantified the risk?	Not applicable.
15	Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity?	Not applicable.
16	Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the project, and how these requirements will be accounted for?	Not applicable.

Attachment B – Groundwater Sharing Plan – GDE Mapping

Attachment C – Groundwater Dependent Ecosystem Atlas Mapping