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WRL Ref: WRL2017011DJA L20180228 Final

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**Water Research
Laboratory**

Dear Naomi,

WestConnex M4-M5 Link Independent Groundwater Review Report

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Sydney has completed its review of the Groundwater Impact Assessments provided within the Environmental Impact Statement (EIS) and the supplementary assessment materials for the WestConnex M4-M5 Link proposal. The review was completed in accordance with the review scope of works described in the Department of Planning and Environment (DPE) contract PROC-2000251.

The independent groundwater review was completed by Mr Doug Anderson (the reviewer) with the assistance of Mr Toby Tucker. Mr Anderson is considered by his peers to be an expert in groundwater processes and modelling. The comments provided here are Mr Anderson's professional opinions on the groundwater assessment. Mr Anderson has no conflict of interest in this matter. Mr Anderson's CV is available at: <http://www.wrl.unsw.edu.au/staff/doug-anderson>.

1. Background and Report Structure

The reviewer's comments on the groundwater assessment work in the EIS were provided previously in WRL letters with reference WRL2017011 L20170718 and WRL2017011 L20170905. Our letter with reference WRL2017011 L20180221 provided comments on the draft conditions of project consent.

This report summarises the reviewer's revised peer review comments following receipt of:

1. Additional model reporting in response to our earlier peer review comments; and
2. Submissions on the EIS and the proponent's response to submissions.

This review report is structured as follows:

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|------------------------------|---|
| 1. Documents Reviewed | 6. Groundwater Resource Assessment and Management |
| 2. Review Methodology | 7. Key Stakeholder Submissions |
| 3. Review Limitations | 8. Response to Submissions |
| 4. Summary Review Comments | 9. Preferred Infrastructure Report |
| 5. Project Groundwater Model | |

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2. Documents Reviewed

In the completion of this review, WRL's review team considered the following primary EIS materials that cross-reference to numerous other chapters and technical annexures of the EIS:

- Chapter 19 Groundwater; and
- Appendix T - Technical working paper: Groundwater.

The following sections of the EIS were also briefly reviewed for content:

- Chapter 5 Project Description;
- Chapter 6 Construction Work;
- Chapter 12 Land Use and Property;
- Chapter 15 Soil and Water Quality;
- Chapter 16 Contamination;
- Chapter 18 Biodiversity;
- Chapter 18 Flooding and Drainage;
- Chapter 24 Climate change and Risk Adaptation;
- Appendix Q – Technical Working Paper: Surface Water and Flooding;
- Appendix R – Technical Working Paper: Contamination;
- Appendix S – Technical Working Paper: Biodiversity; and
- Appendix X – Technical Working Paper: Climate Change Risk Assessment.

WRL's reviewer subsequently examined the results of the *WestConnex Sensitivity and Uncertainty Study*. The results of this study were provided to WRL by the Department of Planning and Environment (DPE) in a letter sent to Andrew Cook, Technical Director of AECOM by Cassie Turvey of HydroSimulations on 22 December 2017 with reference HS2017/44 [AEC008]. This study was undertaken after the exhibition of the EIS documents described above and was not subsequently exhibited in the Response to Submissions (RTS) Document issued by the proponent. The header of *WestConnex Sensitivity and Uncertainty Study* letter bears a "Commercial in Confidence" stamp in bold red letters that prevents WRL's reviewer from re-presenting the study results herein.

Following the review of the above documents WRL's reviewer considered the key stakeholder submissions documents by DPI, NSW EPA, City of Sydney and the Inner West Council and the proponent's responses to these submissions and all the public submissions.

3. Review Methodology

Mr Anderson completed his review as per the following methodology:

1. A general review of the primary EIS documents (Chapter 19 and Appendix T).
2. Supervision of a WRL Engineer who read the primary and related EIS chapters (refer Section 4) and then prepared a groundwater modelling checklist for the project in accordance with the Australian Groundwater Modelling Guidelines (as none was provided within the EIS submission).
3. Review of the modelling checklist prepared by the WRL Engineer.
4. Supervision of a WRL Engineer who analysed borehole water level data presented in the EIS using the water table fluctuation method to estimate ratios of rainfall to water table rise (as no such analysis was reported within the EIS).
5. Comparison of the estimated ratios of rainfall to water table calculated above to the specific yield values and percentages of rainfall as recharge modelled in the EIS.

6. Supervision of a WRL Engineer who analysed borehole water chemistry (chloride) data presented in the EIS using the general chloride mass balance method to prepare estimates of groundwater recharge rates (as no such analysis was reported within the EIS).
7. Comparison of the groundwater recharge estimates calculated as described above to the percentages of rainfall modelled as groundwater recharge in the EIS.
8. Provision of review comments to DPE as described in Section 1.
9. Meeting with DPE and the proponent (including RMS, AECOM and the project groundwater modeller) to clarify various aspects of the modelling work and to request further modelling with revised model inputs including groundwater recharge, aquifer hydraulic conductivity and storage. The additional modelling and reporting was requested by WRL to provide the proponent (RMS) and NSW Government Agencies with a range of predictions to facilitate the development of robust environmental management plans for the project.
10. Review of the "WestConnex Sensitivity and Uncertainty Study" that provided a revised set of model predictions for the project with adjusted values of groundwater recharge, aquifer hydraulic conductivity and storage.
11. Review of the public and agency submissions pertaining to groundwater and the proponent's response to submissions document.

4. Review Focus and Limitations

This review of groundwater impacts addresses matters of predicted tunnel inflows, predicted changes in groundwater levels and predicted changes in surface water – groundwater interactions.

This review does not constitute a formal review of matters of:

1. Ground settlement and subsidence due to groundwater interception (this is a matter to be addressed by geotechnical engineering specialists); or
2. Treatment, discharge and/or re-use of groundwater intercepted within the tunnels at ground surface (this is a matter to be addressed by the Department's surface water specialist); or
3. Soils including Potential Acid Sulphate Soils (as per commitments provided by the proponent, these matters can be addressed through the application of well-established environmental management plans that consider the relevant guidance documents); or
4. Altered mobilisation of pre-existing sources of groundwater contamination due to changes in groundwater flow rates or directions caused by tunnel construction and operation (the proponent acknowledges that if the project is approved, further work will be required to address these matters).

This groundwater impacts review was completed without access to the following sources of information that may or may not have been compiled by the proponent:

1. Site specific geological investigation reports, engineering logs and geophysical survey works;
2. Details of investigative drilling, logging, testing and/or analysis of geology and hydrogeology below the proposed depth of tunnelling;
3. Comprehensive reports of monitoring records of groundwater inflows into past and present tunnelling constructions in the Sydney; or
4. Aquifer pumping tests and data analysis to determine subsurface hydrogeological properties along the tunnel alignment; or

5. Analyses of collected groundwater level and water quality data via first principles hydrogeological data analysis techniques to constrain the inputs entered the predictive numerical models developed for the project; or
6. Knowledge of whether groundwater levels recently observed around the existing tunnelling networks in Sydney within or near the boundary of the numerical model developed for this assessment of M4-M5 link impacts have reached a new steady-state equilibrium or are still responding to the historical construction of tunnels.

5. Summary Review Comments

1. A suitable assessment of groundwater assets and surface water assets (e.g. wells, creeks, streams, rivers, wetlands) has been undertaken and presented by the proponent. A limited number of groundwater assets and surface water receptors were identified within the predicted zone of groundwater impact of the project. The project impacts on these receptors are predicted to be either negligible or manageable and the proposed management measures are considered appropriate.
2. A suitable assessment of groundwater level impacts has been undertaken and presented by the proponent, however, there are some areas for improvement that could be addressed when preparing the relevant environmental management plans for the project. Some of these improvements are described below. WRL's letter with reference WRL2017011 L20180221 that reviews the draft conditions of consent for the project provides additional recommendations.
3. The EIS groundwater impact assessment assumes that long-term average groundwater inflows into the tunnels can be limited to less than 1 L/s/km. This is based on typical Departmental requirements and DPI advice that engineering measures be implemented to limit tunnel inflows to less than 1 L/s/km. It is also stated to be based on typical engineering tunnelling experience elsewhere in the Sydney Basin and the Hawkesbury Sandstone Formation that, with appropriate engineering measures in place, long-term average tunnel inflows decrease to less than 1 L/s/km.
4. The EIS and supplementary modelling reports provide estimates of the likely range of groundwater level impacts arising from the development for the given commitment that a range of engineering measures including tunnel-tanking, pre-grouting, grouting and shot-creting will constrain long-term average groundwater inflows into the tunnels to less than 1 L/s/km for each kilometre of tunnel.
5. The supplementary modelling marked "Commercial-In-Confidence" addresses scenarios requested by WRL's reviewer to incorporate groundwater recharge rates that are higher and aquifer storage coefficients that are lower than those values anticipated by the project modellers when preparing the modelling predictions presented in the EIS.
6. Also simulated in the supplementary modelling are scenarios with higher tunnel inflow rates caused by increasing the "calibrated" numerical model drain-cell conductance parameters around the tunnels by a factor of 1.5 to examine the effect of any minor failures in engineering measures to control tunnel inflows. The drain cell conductance parameter can be thought of as a numerical tweak to represent the tunnel grouting and shot-creting treatments and any zones of partial desaturation.
7. The proponent's groundwater modellers have stated that the revised model with all the changes described above is equally well calibrated to the available groundwater observation data. Therefore, in the opinion of WRL's reviewer, the revised modelling predictions are informative for further supporting engineering design and environmental management.
8. However, noting the limitations of this review as described in Section 4, it would be more informative if the proponent could have confirmed that their revised predictions of tunnel inflows of up to about 1.6 L/s/km during tunnel excavation and 0.83 to 0.93 L/s/km during operation are

consistent with the anecdotal reports of tunnel inflows observed in other tunnelling constructions in Sydney where there has been some difficulty with water-proofing measures.

9. Given the limitations of the current industry standard groundwater modelling approaches in jointed and fractured Hawkesbury Sandstone as described further in Section 6, the proponent must make a concerted effort to measure, record or otherwise estimate groundwater inflows into the Westconnex tunnels during their construction and changes in groundwater levels directly above the tunnel alignments. This re-iterates the recommendations provided in WRL's letter with reference WRL2017011 L20180221. This monitoring is needed to improve future environmental impact assessments of the project, related future projects and to facilitate improved future management of the Sydney Basin Hawkesbury Sandstone Formation groundwater resource.
10. The modelling provides limited reporting of changes in groundwater conditions around various subsurface assets and liabilities. The proponent's groundwater modellers should liaise with relevant NSW Government Agencies including NSW EPA and Crown Lands and Water and local government stakeholders to ensure that predicted changes to groundwater levels, flow rates and directions near key assets and liabilities such as landfills, surface water bodies and groundwater wells are thoroughly documented in tables and figures and incorporated into plans of management for those assets. As discussed in Section 8.1.2 NSW EPA advises that by undertaking their project the proponent may become legally responsible for the contamination left behind in the subsurface soils and groundwater by other responsible parties.
11. The EIS reporting acknowledges that the project may cause some saline intrusion into alluvial and sandstone aquifers between the tunnel alignment and coastal / estuarine water bodies over the very long-term (many decades to centuries) but suggests that the design life of the WestConnex tunnels is only about one hundred years and the groundwater in this area presently has very little beneficial use.
12. The particle track modelling accompanying the supplementary assessment provides suitable information for establishing monitoring locations for groundwater salinity to verify the proponent's assessment of impacts on groundwater salinity.
13. The *NSW State Groundwater Quality Protection Policy 1998* encourages the conservation of the highest possible environmental value (beneficial use category) of groundwater regardless of its current use and any previous degradation due to anthropogenic activity.
14. A prediction that any part of a groundwater resource would be made more saline does, in the opinion of WRL's reviewer, trigger the more than minimal impact assessment provisions of the *NSW Aquifer Interference Policy 2012*.
15. If the project does slowly increase the salinity of the groundwater resource and relevant NSW Government Agencies are of the view that beneficial fresh-water groundwater resources exist within the sandstone and alluvium within the project footprint and it is expected these resources might conceivably be utilised in the future, then the proponent should be instructed to consult with NSW Government to obtain directions for further more detailed assessment work.
16. In previous WestConnex assessments the proponent's modellers prepared a map of changes in the evapotranspiration rates from the water table that might result from the project as an indicator of potential impacts on vegetation communities that might depend on or opportunistically utilise groundwater. No such map was provided for this assessment.
17. The proponent should verify the status and current use details of the registered groundwater wells identified during the study.
18. The proponent should verify that all groundwater supplies that might conceivably be impacted by the project can be managed by considering the economics of any additional pumping expenses, bore deepening and/or provisioning of an alternate supply of suitable quality water.

6. Project Groundwater Model

The groundwater model prepared for the project is a multi-layer, single-phase, single-porosity, single-permeability, lumped parameter MODFLOW model. A static recharge distribution was applied across the land surface based on a spatially coarse model of near-surface geology and land-surface cover comprising unpaved or paved (or partially paved) areas. Subsurface rock and sediment properties were assigned in zones on a layer by layer basis to provide a 'lumped' representation of the subsurface geology and its spatial variability.

The input parameters for the model were derived by running the model in steady state mode without climatic variability by tweaking initial estimates of the model inputs (derived from measurement and experience) until the project modellers were satisfied the model satisfactorily reproduced the groundwater levels observed during the field investigation program.

Following this peer review, this history matching (calibration to observation data) process was repeated to create a range of models with different parameter values that could be used in a sensitivity analysis. The sensitivity analysis was used to address some of the exploration constraints of the WestConnex field investigation program to provide a range of predictions for tunnel inflows and groundwater level changes that might be associated with the M4-M5 link project.

In the opinion of WRL's reviewer, noting the recommendations provided in Section 5 and the limitations discussed below, the modelling outputs presented by the proponent's groundwater modeller provide a plausible estimate of the likely range of groundwater level impacts arising from the development.

Groundwater managers and decisions makers relying upon the EIS and supplementary model predictions need to be aware of the following facts, groundwater model metrics, limitations and assumptions:

1. The Hawkesbury Sandstone Formation is often deposited as blocks of sheet and/or massive facies with length (height) scales on the order of 0.3 m to 10 m.
2. While there can be significant storage of water in the Hawkesbury Sandstone rock matrix, the most significant groundwater movements occur within the joints and fractures between the sheets and/or blocks of the sandstone.
3. The model predicts groundwater levels with an average accuracy of plus or minus one metre ($\pm 1\text{m}$) with known maximum errors at specific locations of up to $\pm 5\text{ m}$ to $\pm 10\text{ m}$.
4. The groundwater model does not explicitly simulate groundwater flow through the laminated shale and sandstone rocks of the Mittagong Formation which exists between the Ashfield Shale and Hawkesbury Sandstone Formation. It would be appropriate to assume that the predicted tunnel inflow rates and groundwater level impacts are more uncertain wherever the tunnel alignment is in close proximity to the Mittagong Formation.
5. Given the monthly model time-steps, the model mesh discretisation, the accuracy of the groundwater level calibration, and the current level of transient model calibration effort, the accuracy of the model simulated surface water - groundwater interactions are not known.
6. Engineering will constrain long-term averaged groundwater inflows into the tunnels to less than 1.0 L/s/km (EIS modelling) and no more than 1.5 L/s/km (supplementary modelling).
7. Tunnel inflows from individual rock defects encountered during construction are not represented within a single porosity, single permeability numerical model code.
8. The EIS reporting assumes that the inflows during construction will be similar to inflows previously observed during other tunnel constructions (the EIS makes reference to some limited observation summary data from previous tunnelling projects in the Sydney Basin).

9. During tunnel construction, reductions in groundwater levels about the tunnel may proceed at rates faster than those predicted by the model because of depressurisation and drainage of water from rock defects that cannot be explicitly represented in the model.
10. Groundwater inflows into the tunnels during construction through rock defects may be higher than the stipulated 1.0 L/s/km until remedial works such as grouting and tunnel lining are implemented.
11. The potential locations of groundwater quality impacts from saline intrusion towards the tunnels have been inferred from particle tracking, however, no transport modelling has been presented to quantify these impacts in terms of timing and absolute concentration changes.
12. The project sensitivity and uncertainty analysis does not address the sensitivity of the model predictions to subsurface rock properties or water pressures below the tunnel alignment and between the model boundary conditions. The groundwater inflows into the tunnels and the groundwater levels about the tunnels will be sensitive to these rock properties and water pressures and will need to be re-assessed when more information is available.

7. Groundwater Resource Assessment and Management

A quantitative understanding of subsurface conditions is required to successfully manage a groundwater (hydrogeological) resource. This quantitative understanding is typically presented in the form of a conceptual model report in which diagrams, figures, tables and text are used to convey the current understanding of the subsurface rock properties and their hydrological boundary conditions. It is these properties and boundary conditions that determine rates and directions of groundwater flow, groundwater quality and the nature of any surface water - groundwater interactions.

Successful conceptual model development requires resource assessment work, including:

1. Desktop assessment of pre-existing surface water and groundwater records;
2. Borehole drilling and geological logging, which may include geophysical survey data;
3. Field investigations of groundwater by monitoring groundwater chemistry and levels, which may include responses to pumping groundwater;
4. Analysis of the field investigation data using new and/or established methods of hydrogeological and hydrological data analysis; and
5. Analytical and/or numerical modelling of groundwater quality and/or groundwater movements.

The objective of groundwater modelling work is to:

1. Estimate those properties and states of the subsurface system that are spatially variable and cannot be measured directly everywhere due to resource exploration constraints; and
2. Predict how water assets and receptors associated with the groundwater system will respond to future changes.

Typical outputs from a groundwater model include predictions of the amount of groundwater intercepted by an activity (possibly before treatment and discharge to surface water receptors) and consequential changes in: (a) groundwater quality, (b) groundwater recharge or discharge near water assets such as creeks, stream, wetlands and other groundwater fed ecosystems, (c) groundwater levels, and (d) rates and direction of groundwater movement.

Typically, model predictions are provided for a pre-project case (and compared to the baseline observation data) and then presented through time (as time-series plots and contour maps) from the

commencement of the project to long after the project is complete. Additional model outputs may also be provided or required depending on the site and the project specific circumstances.

In the context of environmental impact assessment, the objective of groundwater modelling is to furnish the project proponent and government agencies with estimates of the likely range of groundwater resource outcomes for a project to help the proponent select from project design options and for the proponent and government agencies to design management strategies to avoid, minimize and mitigate environmental impacts.

8. Key Stakeholder Submissions

This report addresses the following key stakeholder submissions that provided commentary and recommendations on groundwater:

1. NSW EPA
2. DPI (Now Crown Lands and Water)
3. City of Sydney
4. Inner West Council

8.1 NSW EPA

The NSW EPA has provided to Department on 16 October 2017 formal comments and recommendations that relate to the project and groundwater that include:

1. The adequacy of the assessment for constructed post water quality treatment wetlands;
2. Environmental management of contaminated sites; and
3. The general adequacy of the EIS methodology and proposed mitigation measures.

WRL's reviewer agrees with and supports all the EPA recommendations relating to groundwater.

8.1.1 Constructed Wetlands

The NSW EPA has recommended detailed modelling of the wetlands that are proposed to be constructed in Rozelle for post water-treatment-plant treatment of groundwater tunnel inflows prior to discharge to a receptor. The NSW EPA submission has stated that the proponent has not provided sufficient information regarding what pollutants may reach the wetlands. The NSW EPA states *"It is not appropriate for the above assessments to be deferred to the detailed stage given that there could be impacts to the receiving water body – this should be quantified as part of the impact assessment."*

WRL's reviewer recommends that all wetlands be designed, constructed and operated in accordance with the requirements of the NSW Government Agencies (e.g. NSW EPA, DPI, Crown Lands and Water) to prevent any contamination of the shallow groundwater aquifers. If the wetlands are to be constructed to recharge the shallow water table and/or any treated water is to be re-used for irrigation of green space the National Water Quality Management Strategy provides the necessary guidelines for the beneficial reuse assessment frameworks. The proponent should consult with the key project stakeholders to finalise these design and assessment impacts.

8.1.2 Environmental Management

Detailed recommendations for conditions of development consent in relation to contamination have been provided by NSW EPA. The advice and recommendations from NSW EPA includes:

1. *"The proponent must ensure that the proposed development does not result in a change of risk in relation to any pre-existing contamination on the site so as to result in significant contamination [note that this would render the proponent the 'person responsible' for the contamination under section 6(2) of the CLM Act]"*
2. Chlorinated hydrocarbons may be present in soil, groundwater and soil vapour in addition to those contaminants of potential concern that have already been investigated. NSW EPA recommends that chlorinated hydrocarbons be assessed as part of future investigation works associated with the project.

The recommendation of WRL's reviewer in relation to prediction of changes in groundwater level, flow directions and rates about contaminated sites was provided at Section 5, item 10.

8.1.3 EIS Methodology and Mitigation Measures

The NSW EPA states a broad concern that the environmental impact assessment is based on a conceptual construction methodology and alignment and that *"the impacts of the project have not been fully quantified, and the EPA cannot determine whether the mitigation measures proposed are appropriate"*. Based on the context in which this statement was made WRL's reviewer has interpreted that these concerns relate principally to noise, vibration and air but not groundwater. These aspects are therefore beyond the scope of this review engagement.

8.2 DPI (Now Crown Lands and Water)

For other linear infrastructure projects, DPI has previously provided a series of specialist technical reports by the various divisions of DPI including DPI Water accompanied by a two-page summary letter of high level recommendations. For this project a two-page letter was exhibited and addressed high level matters of saline intrusion, tunnel inflows and groundwater monitoring.

The proponent's responses to these submissions were provided in Section B5.1 of the RTS document. A summary of the opinions of WRL's reviewer on these matters is provided below. WRL's reviewer agrees with and supports all the high-level DPI recommendations provided to the Department on 16 October 2017. Management and monitoring commitments beyond those provided by the proponent are recommended.

8.2.1 Saline Intrusion

The DPI has advised the Department that the un-tanked sections of the proposed tunnels will cause continuous dewatering of the groundwater system and this will result in water quality (salinity) impacts that trigger the *NSW Aquifer Interference Policy 2012* Level 2 assessment requirement.

In accordance with the Policy, DPI recommended the proponent *"demonstrate where salt water intrusion from tidal areas will occur and then re-analyse these impacts on sensitive uses of the groundwater"*. DPI also sought clarification from the proponent on whether the particle tracking modelling provided as part of the Level 1 assessment was sufficient to analyse the overall impacts of salt water intrusion as part of a Level 2 assessment.

In the opinion of WRL's reviewer, particle tracking provides a reasonable preliminary assessment of the water particle travel times and locations that should be monitored for water quality changes. However, particle tracking alone cannot predict the changes in salinity that will occur. Predicting salinity changes would require the application of analytical methods and/or the development of a new and much more numerically complex groundwater model incorporating among other features:

1. Results of measurement of drill core samples for porosity;

2. Additional geological layers to simulate water movements through the Mittagong Formation;
3. Revised transient calibration to groundwater level data; and
4. Simulation of density dependent flow.

While such modelling would be useful and informative for giving effect to the *NSW Aquifer Interference Policy 2012* and the *NSW State Groundwater Quality Protection Policy 1998*, WRL's reviewer has noted that previous tunnelling assessments have been approved by the Department based on particle tracking without density dependent groundwater flow and transport modelling.

Given this established practice and the limited number of beneficial groundwater uses currently identified within the project footprint (refer Section 5, Item 1), in the opinion of WRL's reviewer:

1. There is no need for density dependent flow modelling currently; and
2. Monitoring of groundwater salinity will provide adequate forewarning to implement any adaptive management strategies that may be required.

However, WRL's reviewer does recommend the need for any further modelling be established now if:

1. The proponent advises current beneficial groundwater uses in the saline intrusion risk areas cannot not be replaced by a town water supply on economic, water quality or town water supply availability grounds (this would require establishing the status and current use of the registered groundwater wells identified during the study); or
2. NSW Government Agencies advise there are perceived future beneficial groundwater uses of the groundwater in the sandstones between the depth of the tunnel alignment and tidal water bodies where saline intrusion might occur; and
3. The economic value of this ground water resource is significant; and
4. NSW Government Agencies advise this future beneficial use would be degraded by some saline intrusion over the life of the tunnels; and
5. The proponent advises this degradation could not be avoided by appropriate management strategies to prevent saline intrusion (e.g. managed aquifer recharge).

8.2.2 Tunnel Inflows

In relation to tunnel inflows the DPI has requested the Department:

1. *"continue to condition groundwater tunnel inflows so they do not exceed 1 L/sec/km"*.
2. Obtain further details of *"how the long-term tunnel inflow rates will be maintained below the recommended rate of 1 L/sec/km specifically for the areas where the juxtaposition of sandstone and alluvium occurs"*. This request was made because *"there is a high risk of fracture and a high degree of connection to the overlying alluvium" "where tunnelling is designed to occur through shallow sandstone"*.

The recommendation for the condition and the provision of further information is appropriate given that WRL's reviewer has heard anecdotal reports of higher than expected inflows into some recent tunnelling constructions in Sydney and because detailed tunnel inflow data from past and present constructions was not provided for review as described in Section 4.

As described at Section 5, Items 5-8 above, the proponent's updated groundwater impact assessment considers the impacts on groundwater levels of a revised set of model inputs which includes tunnel inflows that can be greater than 1 L/s/km. No comments were received by WRL's reviewer from DPI Water, Crown Lands and Water or NSW EPA in relation to this revised modelling.

8.2.3 Groundwater Monitoring

In relation to environmental management, DPI has recommended that the proponent consult with Crown Lands and Water on design and development of the groundwater monitoring measures and the construction and operational environmental management plans. In relation to groundwater monitoring, DPI has recommended:

- *“Increased monitoring of groundwater salinity at key monitoring bore sites (acknowledging the Level 2 trigger).*
- *Use of open monitoring bores to monitor groundwater level impacts as well as groundwater quality.*
- *Monitoring during construction and the post-construction operational phase for the life of the development. This will allow gauging of the predicted impacts, allowing mitigation measures to be undertaken in the case of exceedances.*
- *Continuation of baseline groundwater monitoring post EIS until the handover to the construction phase. This background information will assist in assessing groundwater impacts and trigger level guidelines outside seasonal variation.”*

Recommendations for groundwater monitoring were including in WRL’s letter with reference WRL2017011 L20180221 reviewing the draft approval conditions for the project. In relation to the groundwater monitoring WRL’s reviewer recommends the following additional monitoring requirements be factored into the approval conditions and environmental monitoring management plans for the project:

1. Groundwater level monitoring utilises existing wells wherever possible and new wells wherever requested by NSW Government Hydrogeologists.
2. Groundwater level monitoring continues not for the standard three (3) to five (5) years but until groundwater levels reach a new steady state equilibrium (as determined by a qualified hydrogeologist or environmental engineer with groundwater monitoring, desktop groundwater data analyses, numerical modelling and groundwater impact assessment experience).
3. Groundwater level monitoring be undertaken with pressure sensor data loggers that record groundwater levels at a regular interval at least six times a day. This enables a thorough analysis of the groundwater level monitoring data to be undertaken.
4. Groundwater quality monitoring sites be established for saline intrusion in key risk areas wherever there may be a current or future beneficial groundwater use and automated data loggers be deployed at these sites to monitor groundwater electrical conductivity for the life of the project.
5. Groundwater contamination monitoring and plans of management at existing groundwater assets (e.g. groundwater wells) and liabilities (e.g. contaminated sites and landfills) are updated to take into consideration the predicted changes in groundwater levels, flow rates and directions as reported in the EIS and/or as provided subsequently by the proponent’s groundwater modellers.
6. All monitoring data be provided to NSW State and Government agencies in an industry standard electronic data format.

8.3 City of Sydney

The City flagged that detailed proposals for groundwater monitoring during construction and operation were not exhibited. Issues relating to groundwater monitoring and the analysis of groundwater monitoring data were also flagged during this review. These issues are addressed in Sections 5 and 8.2.3 above and in WRL’s letter with reference WRL2017011 L20180221. Note that

WRL's reviewer recommends that groundwater level monitoring continues not for three (3) years as suggested by the City but until groundwater levels reach a new steady state equilibrium.

The submission from the City also requests that groundwater captured by the project not be discharged into the stormwater system. The submission provided detailed recommendations for conditions for the project water quality plan, the monitoring program and a groundwater and stormwater reuse strategy. The City's requests for the stated groundwater conditions are in accordance with best practice and aligned with the recommendations for beneficial reuse provided by WRL's reviewer when commenting on previous stages of the WestConnex project.

8.4 Inner West Council

The Inner West Council has requested the *"determination of the project be withheld until such a time as detailed design, plans and modelling can be provided, with Council, the community, and other key stakeholders permitted to review and comment"* stating that the *"existing level of detail provided by the design ins (sic) insufficient to provide further extensive and reliable comment"* and a *"detailed set of conditions and constraints"*

Page 76 of the Inner West Council submission suggests that *"there is potential for elevated soil salinity and induced water table changes resulting from both tunnelling activities (during construction) and the long term presence of deep tunnels. Such impacts could include impacts on local aquifers, potential for an elevated water table and redirection of groundwater flows."* However, no specific details are provided by the Inner West Council and no reference is made to specific sections of the EIS. The Inner West Council also raises the issue of saline intrusion and states that the impact of sea level rise was not been assessed.

Attachment 1 to the Inner West Council submission is an independent review by the Beca consultancy. This review provides commentary on a number of groundwater matters but states generally *"This groundwater assessment is generally comprehensive, addresses the content of the SEARS and utilises appropriate guidelines for assessing impacts. Surface water runoff contributions to the watercourses should be presented in tandem with baseflow contributions and the proportion of decrease compared again to assess significance. Lack of a geotechnical model to predict ground movement is a shortfall in the study and exclusion at this stage is not justified"*.

The proponent's responses to the Inner West Council submissions on groundwater can be found in Section B11.19 (page B11-159) and Section B12.19 (page B12-176) of the RTS document. A summary of the issues and the responses of WRL's reviewer to the comments prepared by or on behalf of the Inner West Council are provided under the following sub-headings:

1. Local Aquifer Impacts;
2. Groundwater levels and flow directions;
3. Sea level rise;
4. Saline intrusion;
5. Model domain;
6. Alluvium hydraulic conductivity;
7. Groundwater level decline; and
8. Groundwater dependent ecosystems.

8.4.1 Local Aquifer Impacts

WRL's reviewer has not been apprised of any activities that might result in elevated water tables in the Hawkesbury Sandstone Formation and the groundwater impact assessment provided by the proponent indicates that the groundwater table will be decreased by the development. It is acknowledged that the proponent's groundwater impact assessment is not designed to predict the locations of perched water tables in Ashfield Shale or in the Hawkesbury Sandstone Formation. Local water tables could rise if treated groundwater was discharged into a local aquifer and there may be some minor increases and decreases in perched, shallow groundwater tables about tunnel portal works and any foundation works below the water table.

WRL's reviewer recommends:

1. The Inner West Council provide more specific details of where they are concerned the development may raise the groundwater table;
2. The proponent ensures that any near surface construction works and any discharge of treated groundwater into the ground is managed so that it does not raise any perched water tables to a point where it impacts existing infrastructure, land or water use.

8.4.2 Groundwater levels and flow directions

The recommendations of WRL's reviewer in relation to changes in regional groundwater levels and flow directions was provided in Section 5.

8.4.3 Sea Level Rise

It is generally accepted by hydrogeologists that:

1. Climate change will result in more variable and, at times, more elevated groundwater levels in aquifers;
2. Sea level rise will result in some elevation of coastal groundwater levels, some minor additional saline intrusion wherever there is no groundwater extraction and slightly more severe saline intrusion wherever there is a pre-existing saline intrusion issue.

While the proponent did not prepare a climate change scenario in which the sea level boundary condition was increased by one (1) metre nor a density dependent groundwater transport model, a qualitative assessment of this matter was provided by the proponent to WRL's reviewer following the provision of initial review comments. In summary, it can be reasonably expected that the impacts of climate change and sea level rise on WestConnex will include:

1. A slight reduction in the severity of the water table drawdown on the aquifers between the tunnels and the tidal water bodies;
2. An increase in the salinity and rate of groundwater discharge leaking into the tunnel workings which must then be treated and discharged; and
3. More variable tunnel inflows and post-treatment groundwater discharges in response to variable climate.

The proponent has advised WRL's reviewer that the treatment systems will be designed to manage groundwater inflows of more than 1 L/s/km to account for any uncertainties in the numerical modelling assessment.

8.4.4 Saline Intrusion

This issue was raised as part of WRL's review and are addressed in Sections 5, 8.1.1 and in our review letter with reference WRL2017011 L20180221.

8.4.5 Model Domain

The groundwater review by the consultancy Beca raised a minor concern that *"there was no justification for study area / model domain spatial extent is (sic) provided. This should be based on potential receptor impacts"*. Comments on model boundary conditions were provided during the WRL review process and the final recommendation of WRL's reviewer in relation to testing the suitability of the model boundary conditions is provided at Section 6, item 12.

8.4.6 Alluvium Hydraulic Conductivity

On page 141 of their review, Beca states the proponent did not collect hydraulic conductivity data for the alluvium and states that *"This is important as it controls connectivity in valleys associated with drainage channels that could potentially discharge contaminated groundwater into the surface water environment"*. Beca recommends *"Justification for not using literature values for hydraulic conductivity in alluvium required."*

Based on the information supplied in the EIS and in the supplementary materials provided to WRL's reviewer the alluvium and Botany Sands were modelled with horizontal hydraulic conductivity values determined through automated parameter calibration to observation data. The calibration determined that the average horizontal hydraulic conductivity values in alluvium and Botany Sands were on the order of 1 m/day a 20 m/day, respectively. In the opinion of WRL's reviewer, these values are consistent with accepted scientific values for alluvium and sands commonly published in the literature. It is recommended that the submission be clarified.

8.4.7 Groundwater Level Decline

On page 141 of their review, Beca raise a comment that *"It is difficult to interpret if changes to baseflow are significant to local watercourses without also knowing flows derived from surface water runoff"* and recommends *"Flows from surface water runoff should also be presented and the significance of reductions in baseflow should be re-evaluated on the basis of proportion of overall flow"*. Giving consideration to the review comments on the groundwater model limitations provided in Section 6 at item 5, WRL's reviewer agrees with this recommendation.

Beca also raise a comment in relation to Section 19.3.3 of the EIS and Figure 19-6 that *"No quantification of groundwater level drawdown is provided. Figure is difficult to interpret and no baseline water table elevations are provided for comparison"* and recommends *"Summarise drawdown levels predicted and provided percentage change in drawdown levels on map"*. Since groundwater drawdown is a difference in groundwater level between two points in time and percentage change in predicted drawdown would imply a comparison of two different future prediction scenarios, it is apparent some clearer communication of the various groundwater impacts of the project for different modelling scenarios are being requested by the Inner West Council. WRL's reviewer refers the Inner West Council to the summary comments and recommendations provided at Section 5 of this review.

Beca also raise a comment that *"Rozelle Rail Yards vegetation may be shallow rooted and dependant on groundwater"* and recommend *"This groundwater dependency should be considered in the selection of appropriate plants for the open space area"*. It is suggested that Inner West Council liaise directly with the proponent in relation to this matter to confirm that the shallow roots of the

existing vegetation are dependent not on shallow soil moisture from rainfall but on: (a) deeper roots extending down to the water table in the sandstones which are predicted to be impacted by the project or (b) a zone of local groundwater discharge from the sandstone aquifer.

8.4.8 Groundwater dependent ecosystems

On page 141 of their review, Beca requests "*Justify range of potential impact and therefore exclusion of Botany Wetlands / Lachlan Swamps GDE's from assessment.*" and recommends "*Clarification required based on connectivity and scale of physical / chemical impacts.*". WRL's reviewer understands that Botany Wetlands and Lachlan Swamps were excluded based on distance and the predicted groundwater impacts. See also the review comment provided at Section 5, item 16.

Beca also comments in relation to "*Rationale for no groundwater dependence needs more detail - low flows from Whites Creek - does not necessarily preclude inflows from groundwater being important as well*" and recommends "*further information on lack of groundwater dependence required*". This comment is accepted, and a response is required.

9. Proponent's Response to Submissions

WRL's reviewer has assessed the proponent's responses to the public submission concerns relating to groundwater impacts provided in their Response To Submissions (RTS). The opinions of WRL's reviewer on the various groundwater concerns addressed by the proponent are provided below.

9.1 Adequacy of information in the EIS on groundwater impacts

The public concerns on *inadequate information in the EIS on groundwater impacts* are summarised in Section C19.1.1 of the proponent's response to submissions (RTS) document. As described in this review, the proponent has provided supplementary modelling and comments to WRL's reviewer to address information gaps in the original submission. WRL's reviewer has also provided recommendations in his correspondence with DPE that other information gaps be addressed prior to construction works (refer Section 1).

9.2 Adequacy of groundwater settlement predictions

The public concerns on *groundwater settlement predictions* are summarised in Section C19.1.2 of the proponent's response to submissions (RTS) document. WRL's reviewer recommends that all concerns regarding settlement are addressed by qualified geotechnical engineering professionals.

9.3 Groundwater impacts and treatment in tunnels

The public concerns on *groundwater impacts and treatment in tunnels* are summarised in Section C19.2.1 of the proponent's response to submissions (RTS) document. The proponent's responses to these concerns are accepted.

In relation to concerns regarding soil moisture levels, tunnelling construction and operation activity is unlikely to influence near surface soil moisture levels except hypothetically in any locations close to the tunnels where there is an aquifer and a regional water table within a few metres of ground surface and the soils overlying this aquifer comprise silt and clay. Note also that the proponent's groundwater model is designed to predicted changes in groundwater levels in the regional Hawkesbury Sandstone formation and not changes in shallow perched water tables on low permeability lenses of material close to ground surface. In the opinion of WRL's reviewer impacts on shallow perched water tables are much less likely to be impacted by the tunnelling activity. Nonetheless, management plans for the project need to be based on mapping data that shows the locations of all shallow groundwater tables within the footprint of the project impacts.

9.4 Groundwater quality and contamination

The public concerns on *groundwater quality, contamination and salinity* are summarised in Section C19.3.1 of the proponent's response to submissions (RTS) document. While WRL's reviewer has not examined the issues of pre-existing contamination and hydrogeology about each landfill, contaminated site, groundwater well and surface water receptor near the project footprint (refer Section 4), WRL's reviewer has recommended that more detailed information and diagrams be obtained from the proponent's groundwater modellers prior to any construction work and prior to the finalisation of the project design and environmental management plans (refer Section 5). This additional information is to include further details of the predicted changes in groundwater flow rates and directions near all contaminated sites and groundwater and surface water receptors.

As a more general comment, the WestConnex project provides an opportunity for any pre-existing contaminated groundwater within the subsurface to be captured by the WestConnex tunnels or appropriately designed interception wells, treated to meet NSW Water Quality Objectives and then discharged into surface water receptors or back into the subsurface in an appropriate manner. Within this context, the proponent's responses to the concerns in the public submissions regarding groundwater quality and contamination are accepted.

With regard to salinity concerns, refer to Sections 1, 5, 8.2.1, 8.4.3 and 8.4.4 of this report.

9.5 Cumulative groundwater impacts

The public concerns on *cumulative groundwater impacts within the Western Harbour Tunnel* are summarised in Section C19.4.1 of the proponent's response to submissions (RTS) document. The proponent will be required to predict these cumulative impacts through a separate EIS process scheduled for Q2, 2018.

9.6 Groundwater monitoring network to assess groundwater contamination

The concern summarised in Section C19.5.1 of the proponent's response to submissions (RTS) document is that no monitoring wells were installed specifically for the purposes of monitoring groundwater contamination.

A detailed groundwater monitoring and management plan will need to be prepared if the project proceeds. The NSW EPA has specified requirements for further assessment of contamination (refer Section 8.1.2 of this report for a brief summary) and this report provides recommendations for the transfer of additional information on predicted impacts to the relevant stakeholders (refer Section 5, item 10). Wherever contaminated sites are known to exist within the footprint of predicted groundwater impacts of the tunnels and wherever these contaminated sites do not already have dedicated groundwater monitoring wells, and a risk assessment warrants further action, WRL's reviewer recommends that these plans include installation of dedicated monitoring wells.

9.7 Reduction in groundwater flow to Whites Creek

The concern summarised in Section C19.5.2 of the proponent's response to submissions (RTS) is that there could be a 60 percent reduction in groundwater contribution to Whites Creek. The proponent's response to this concern is accepted, however, note the limitations of the project groundwater model as described in Section 6 of this report.

9.8 Environmental management measures for groundwater quality

The concerns summarised in Section C19.5.3 of the proponent's response to submissions (RTS) relate to environmental management measures for groundwater quality. WRL's groundwater reviewer has not examined the specific details of all pre-existing contaminants in groundwater about the project, matters of groundwater treatment to alleviate this contamination nor the surface water impacts resulting from the discharge and/or reuse of treated groundwater (refer to Section 4).

The WestConnex design engineers will need to ensure that management of pre-existing contamination and the discharge or beneficial reuse of treated groundwater meets the requirements of NSW EPA, Crown Lands and Water, Councils, Sydney Water and the relevant water quality objectives and water quality guideline requirements. Within this context, the proponent's approach to addressing matters of groundwater treatment and discharge as described in Section C19.5.3 of the RTS is considered satisfactory.

10. Preferred Infrastructure Report

The preferred infrastructure report describes changes to the White Bay Civil Site and the bioretention facility. The proponent assesses that no further assessment of groundwater impacts from these changes are required. Based on the supplied information and the breadth of the existing assessment WRL's reviewer agrees this conclusion is reasonable.

11. Questions and Comments

If you have any questions or comments regarding this report please contact Mr Doug Anderson (d.anderson@wrl.unsw.edu.au) in the first instance.

Yours sincerely,

Grantley Smith
Manager