22 January 2016

WRL Ref: WRL2015051DJA P20160122

Mr Kane Winwood
NSW Department of Planning and Environment
23-33 Bridge Street
Sydney NSW 2000
By email: kane.winwood@planning.nsw.gov.au

UNSW AUSTRALIA

Water Research Laboratory

Dear Kane,

Stage 2 Northern Beaches Hospital Connectivity and Network Enhancement Works (SSI 6622) – Independent Review of Groundwater Impact Assessment

The Water Research Laboratory (WRL) of the School of Civil Environmental Engineering at UNSW Australia is pleased to provide this peer review report for the groundwater impact assessment (GIA) submissions report and responses to reviewer comments submitted by NSW Roads and Maritime Services (RMS) as part of the Environmental Impact Statement (EIS) for State Significant Infrastructure (SSI) Project #6622. SSI 6622 details the preliminary concept design for the Stage 2 Northern Beaches Hospital Connectivity and Network Enhancement Works.

In summary, there is a degree of uncertainty associated with the groundwater impact predictions provided by the proponent and limitations in the baseline data supporting the proponent's conclusions that groundwater impacts are highly unlikely to have a significant or irreversible impact upon the environment. It is WRL's considered opinion that additional baseline data, ongoing monitoring and appropriate environmental management plans are required so that the groundwater related environmental risks posed by the proposed project can be adequately managed.

WRL's review comments are attached to this letter, structured as follows:

1. Scope of Works
2. Project Background
3. Adequacy and Completeness of the Groundwater Impact Assessment
4. Compliance with Legislation, Guidelines and Best Practice Measures
5. Adequacy of Management and Mitigation Measures
6. Recommended Actions and Conditions of Approval

WRL's reviewer for the project was Principal Engineer for Groundwater and Modelling, Mr Doug Anderson. Mr Anderson has declared that he has no conflict of interest, perceived or otherwise, in providing the advice contained within this review. Mr Anderson's CV is available online at: http://www.wrl.unsw.edu.au/staff/doug-anderson.

Yours sincerely,

G P Smith
Manager
Attachment: Detailed Review Comments

1. Scope of Works

The commissioned scope of works was to prepare a final report on the previously commissioned Preliminary Review and Post-Exhibition Document Review to address the:

a) "*Adequacy and completeness of the groundwater assessment provided in the EIS and Submissions Report;*

b) *Compliance of the project with applicable legislation, guidelines and best practice measures;*

c) *Adequacy and appropriateness of the management and mitigation measures recommended for the project; and*

d) *Recommended actions and conditions of approval that could be applied to avoid, minimise mitigate, and/or manage groundwater impacts (should the Department recommend approval of the project)*".

1.1 Preliminary Review

The commissioned scope of works for the Preliminary Review was:

a) "*A peer review of the EIS groundwater assessment in the EIS. The peer review shall take into account the technical adequacy and completeness of the assessment, including compliance with relevant guidelines, requirements and best practice measures;*

b) *An assessment of the adequacy of groundwater monitoring and modelling that have been carried out as part of the assessment;*

c) *Consideration of the potential short and longer-term groundwater impacts during construction and operation of the project, including any impacts on groundwater dependent ecosystems and surface water flows;*

d) *A review of the appropriateness and effectiveness of the proposed management and mitigation measures recommended for the project, taking into account relevant guidelines, industry best practices and research;*

e) *Consideration as to whether additional information is required to address any inadequacies/gaps in the groundwater assessment. In preparing the gap analysis, the consultant shall take into account any relevant guidelines and comments provided by the Department regarding its review of the groundwater assessment;*

f) *Preparation of a report on the findings of the Preliminary Review*"; and

g) *Consideration of the connected nature of groundwater and surface water.*

1.2 Post-Exhibition Document Review

The commissioned scope of works for the Post-Exhibition Document Review was:

a) *"Review agency, council and public submissions in relation to groundwater impacts received during public exhibition of the EIS; and*

b) *Review the Proponent's Response to Submissions Report, including -*

   i. *the RMS' response to groundwater issues raised in submissions received on the proposal…*

   ii. *the Proponent's response to the gap analysis".*

2. Project Background

Section 2 of this letter introduces the project, the possible groundwater related impacts and summarises the proposed groundwater environmental practice measures reported in the EIS.

2.1 Project Description

SSI 6622 proposes to upgrade the Warringah Road corridor between Fitzpatrick Avenue East and Allambie Rd. This will involve the widening of the existing roadways by up to 40 m in places and the cutting of a slot approximately 1.3 km long and 18 m wide slot into the sub-surface to depths of up to 8 m below ground level (~RL 142 m to 150 m AHD). A previous application for the hospital involving dewatering and sealing of basement works is also relevant to the assessment of cumulative impacts.

2.2 Receptors and Assets

The Stage 2 project area influences three surface water catchments:

- Curl Curl Creek Catchment: About 9.5 ha (53%) of the Study Area drains to Manly Dam and thence to Manly Creek. The entire Curl Curl Creek catchment has an area of about 700 hectares. Land use is a mixture of forest, commercial, residential and recreational;
- Middle Creek Catchment: About 4.2 ha (24%) of the Study Area drains to Middle Creek via two sub-catchments of about 92.6 ha and 60.8 ha out of a total catchment area of 1500 ha. Land use is a mixture of residential, public use, retail, forest and National Park;
- Bantry Bay Catchment: About 4.2 hectares of the study area (24%) drains to Bantry Bay. Land use in this catchment includes residential, schools, retirement villages, an aquatic centre, and a National Park.

There are a limited number of registered groundwater works with proximity to the project area.

Water sensitive (and potentially groundwater sensitive) ecological receptors have been identified. These include breeding and foraging habit for the Endangered Red-Crowned Toadlet in Curl Curl Creek and Trefoil Creek (Middle Creek Catchment) near Wakehurst Parkway, and stands of endangered Duffys Forest Ecological Community (DFEC).

2.3 Changes to Key Environmental Variables

Road widening will increase impervious area of the catchments by about 7.9 ha (Table 3 of GHD, 2015) and result in the removal of native vegetation and green space that serve to intercept rainfall (reduce storm runoff) and transpire soil moisture and groundwater. The slot will also intercept some shallow groundwater that would ordinarily feed base-flow to seeps, creeks and streams and possibly provide water to support evapotranspiration by trees.

2.4 Proposed Environmental Management Practice

RMS propose to capture road runoff and groundwater discharge intercepted by the roadway slot, treat this water to an acceptable level and discharge the treated water to surface water within the Curl Curl Creek and Bantry Bay Catchments. The EIS also suggests sealing the slot as an alternative design option to limit groundwater interception, drawdown impacts and negate the need for treatment of groundwater; however, currently, this is not the preferred option.

Detailed design of the surface water and groundwater treatment facility is not reported in the EIS, however, it is understood that sub-surface detention basins are proposed at Aquatic Drive (Curl Curl Creek Catchment) and Fitzpatrick Avenue East (Bantry Bay Catchment) to improve water quality and

mitigate peak stormwater flows. Similarly surface water and groundwater monitoring programs and management plans are also proposed, however details are yet to be finalised.

2.5 Potential Environmental Impacts

Groundwater: Reductions in pervious area from SSI 6622 is likely to reduce groundwater recharge to the aquifers adjacent to and down hydraulic-gradient of the proposed road works. Groundwater recharge from up hydraulic-gradient areas will flow towards the roadway slot to be intercepted, treated and discharged. This will result in either a gradual or sudden long-term reduction in groundwater levels immediately around the project, depending on the sub-surface conditions. The interception of groundwater in the slot will change the migration pathways of any existing sub-surface contamination and may reduce the rate of groundwater discharge to some more distant receptors. Given that the geology of the site includes dual porosity media (including the Hawkesbury Sandstone which contains joints, bedding planes and fractures), the groundwater table may be somewhat discontinuous and, therefore, reductions in groundwater level may be spatially variable and difficult to correlate between individual monitoring locations.

Surface water: SSI 6622 will permanently alter flows to surrounding creeks and streams due to increased rainfall runoff volumes and altered runoff timing from road pavements and construction areas, and decreased residence time of groundwater in aquifers. Peak flows to surface water receptors would increase (subject to mitigation in detention basins) and base flows (from groundwater discharge) to surface seeps, creeks and streams following rainfall would reduce (subject to detention basin operational practices). The quality of water discharging to surface water receptors would also change (subject to treatment outcomes).

Biodiversity: Changes to groundwater water levels and flow regimes (levels, velocities, timing of flows and water quality) would have consequences for various down-gradient water users including licenced water and groundwater users, Groundwater Dependent Ecosystems (GDEs), and social and ecological communities that make opportunistic use of groundwater or surface water.

2.6 Environmental Impacts to Assets and Receptors Predicted by the Proponent

The project will slightly reduce the rate of groundwater seepage (baseflow) to Treefoil Creek, Curl Curl Creek and the Bantry Bay Catchment (in the weeks and months following rainfall). However, the discharge of treated stormwater to Curl Curl Creek and the Bantry Bay Catchment will increase. This will provide an opportunity to manage some of the predicted reductions in baseflow. Some stands of DFEC will be maintained, possibly with decreased groundwater levels in the underlying permeable zones (aquifers) within the sandstone. Marginal reductions in groundwater levels within nearby water supply bores may also result; however, the reductions are predicted to be less than one metre. This is within the minimal impact criteria of two metres specified by the NSW Aquifer Interference Policy. The proponent also acknowledges a degree of uncertainty in their predictions given the nature of the dual porosity media.

Depending on time since construction and incorporating the predictive uncertainty in estimated groundwater recharge, the EIS groundwater model predicts that the project will:

- Increase runoff, reducing annual groundwater recharge over the footprint of the project by between 0.14 mm to 7 mm (estimated by WRL to be 0.02 to 1.2 m^3/d);
- Intercept less than 0.6 L/s (52 m^3/day) of groundwater in the slot and discharging this to Curl Curl Creek and/or Bantry Bay tributary;
- Reduce groundwater baseflow to:
    - Curl Curl Creek by between 0.9 to 27 m^3/day;

    - Bantry Bay tributary by between 0.5 m³/day to 15.5 m³/day
    - Middle Creek South West tributary by between 0.6 to 9.7 m³/day;
    - Treefoil Creek by between 0.2 to 3.0 m³/day;
- Drawdown the groundwater table generally less than two metres, except in the immediate vicinity of the roadway where larger drawdowns may be observed;
- Drawdown groundwater levels at identified Red-crowned Toadlet habitat by generally less than one metre, but possibly as much as two metres close to the proposed roadworks.

GHD (2015) provides an interpretation that impacts are likely to be less than, or at the lower range of, the predictions summarised above. This is one plausible interpretation. Given the duration, frequency and methodology of site observation it is also plausible that some impacts above the lower range of the predictions might also be observed. Additional commentary on modelling approach and parameter optimisation provided in Section 3 of this letter lends support to an argument that the larger impacts predicted by the high recharge scenario may be overly conservative in many locations throughout the project area.

For additional detail on predictions, refer to Appendix M of the groundwater impact assessment by GHD (2015).

3. Adequacy and Completeness of the Groundwater Assessment

3.1 Modelling Approach

The proponent has adopted an Equivalent Porous Media (EPM) modelling approach to provide predictions of impact. For this approach, the proponent simulates the hydraulic properties of the inferred hydro-stratigraphic units within each EPM model zone with spatially invariant average values derived from a steady state calibration and validation to historical groundwater level observations for two hypothetical recharge scenarios; a high groundwater recharge case and a low groundwater recharge case. Packer test and other values published in the literature from other sites in the Sydney Basin informed the initial parameter values for calibration. No transient calibration was provided. The baseline data record for steady state calibration is short and the record for validation is shorter.

Given the complexity of the geological environment and the uncertainty in the field measurement data and analysis that is available, WRL considers this approach acceptable if practitioners and regulators incorporate an additional level of consideration when interpreting the EIS model output for engineering design and environmental management decisions, as detailed below.

Firstly, since the proponent adopts an EPM modelling approach with spatially invariable hydraulic parameters within broad geologic zones, persons considering the EIS should not rely upon any single table or figure within the EIS to infer the likely groundwater impacts of the development. Rather, the EIS provides bounded predictions of groundwater inflow, drawdown and baseflow impact for a reasonably assumed degree of uncertainty in groundwater recharge. Specifically, persons relying upon the EIS modelling should expect that impacts of the project at any particular place and time might reasonably fall somewhere between the upper and lower bounds of prediction reported within the EIS, rather than at any particular point such as the minimum or the mean.

Secondly, persons relying upon the EIS should also be aware that the bounded predictions do not incorporate specific consideration of the impact of horizontal or vertical variability in hydraulic properties. Spatial variability in hydraulic conductivity and specific yield will be present across the study site in the form of joints, bedding planes, fractures etc. within the weathered/fresh rock mass. So, while the model predictions may provide a reasonable prediction of the uncertainty in the

average impact of the development, the impact at any one location might be greater or smaller than that predicted by the model (this is typical for all groundwater models).

3.2 Groundwater Impact Predictions

The upper and lower bound predictions of groundwater impact provided by the proponent falls within the range of potential impacts predicted from a desktop assessment by WRL's reviewer. However, WRL's reviewer considers that inflows and groundwater drawdown rates might plausibly be greater than the lower bound values reported by the proponent if unfavourable geological conditions are encountered.

In their comment on the Submissions Report, NSW DPI Water has advised RMS that:

- the project "*will require adequate monitoring, review and potentially adaptive management*"
- "*the impact assessment to the baseflows of Curl Curl Creek could be improved and additional assessment and development of monitoring is recommended*"
- "*BACI analysis proposed in the draft Surface Water Quality Management Plan would require appropriate select of a control/reference site. However this has not been proposed*"
- It "*supports the development of a Soil and Water Management Plan and a Groundwater and Dewatering Management Plan prior to construction*"
- "*Comprehensive groundwater and surface water monitoring (construction and operation), which is to include monitoring of groundwater inflows will be essential to review the impact predictions and enable implementation of appropriate mitigating measures*"
- "*the groundwater model be updated at the completion of construction to compared predicted and actual impacts and to verify mitigation or remediation options*".

WRL's initial review endorsed these recommendations. In subsequent meetings DPI Water and RMS agreed that BACI analysis was no longer considered necessary.

3.3 Site Water Balance

The EIS for the project provided predictions of groundwater impact and during the review process a numerical model mass balance was provided to WRL's reviewer demonstrating that the numerical model conserved mass. However, WRL's reviewer was unable to identify within the EIS any clear reporting of tables and figures of a hydrological and a hydrogeological water balance for the site.

A water balance is a conceptual model documenting the percentages and volumes of rainfall, interception, evaporation, infiltration, runoff, evapotranspiration, groundwater recharge and baseflow occurring within the study area. Annual water balances can be prepared for pre and post construction activities and for average, dry and wet years. A site water balance report would well inform the environmental management of the project.

3.4 Numerical Model Calibration

3.4.1 Adequacy of Parameter Estimation

The "calibration" applied to the model for the high recharge scenario with the Parameter ESTimation tool, PEST, simulated:

- Recharge values at the upper bounds established for vegetated areas (182.5 mm/yr);
- Recharge values at the lower bounds established for low density residential areas (182.5mm/yr); and

- Hydraulic conductivity at the lower bounds established for Ashfield Shale (1×10^{-9} m/s).

From a numerical modelling optimisation perspective, solution parameters that "hit" the upper or lower parameter bounds established by the modeller indicate a solution that did not reach a local or global minimum in solution space (that is an optimal sum of squares residual). While this does not invalidate the overall modelling approach, it does indicate that the optimisation software was having difficulty identifying an optimal solution to the steady-state high recharge case. Future updates to the numerical model might consider further analysis of field data to better constrain the uncertainty in the recharge, geological structure and spatial variation in hydraulic conductivity and storage values being simulated, if a risk-based assessment warrants this.

In contrast, the "calibration" applied to the model to the low recharge scenario with the Parameter ESTimation tool, PEST, simulated:

- Recharge values at the lower bounds established for vegetated areas (3.7 mm/yr);
- Recharge values for low density residential areas of 33.9 mm/yr;
- Hydraulic conductivity at the upper bounds established for Hawkesbury Sandstone units at the bottom of the model domain (9×10^{-7} m/s), well below the project area; and
- All other parameter values calibrated within the bounds provided to PEST.

Given the geological structure and parameter ranges simulated by GHD (2015) this suggests that, in comparison to the high recharge case, the low recharge case is a better fit to the current hydrogeological conceptual model. If a future risk-based assessment warrants additional modelling, updates to the model should consider spatially variable aquifer properties and optimisation based upon revised initial values of sandstone hydraulic conductivity considering site-specific data and/or upscaling of the available point scale data that has been sourced from the literature.

Overall the reviewer acknowledges that the modelling approach provides a reasonable envelope of steady-state predictions to address uncertainty in the potential range of impacts from the proposed project activity for high and low recharge cases. However, the apparent assessment of geologic uncertainty and groundwater related biodiversity impacts with qualitative rather than quantitative modelling techniques appears to be two limitations of the assessment. These limitations should be addressed by targeted monitoring and management plans for the proposed project.

3.4.2 Adequacy of Model Output

WRL's reviewer discussed the steep horizontal hydraulic gradients plotted in Figure 16 of the Groundwater Impact Assessment with GHD's modeller and was advised this was not a boundary condition or regional calibration effect, but rather an artefact of the mesh discretisation and reporting methods. Specifically, WRL's reviewer understood the steep gradients were caused by the methodology used to extract data points from the model along the transect where steep north-south topographical and hydraulic gradients and multiple water tables were present. The presentation of groundwater level output from any future modelling work should be improved.

3.5 Biodiversity Impact Predictions

WRL's reviewer did not identify any specific analysis or modelling of the groundwater impact predictions (see Section 2.6) within the EIS biodiversity assessment. However, at a meeting attended by the Department of Planning and Environment, RMS and GHD, the Project Development Manager for RMS advised WRL's reviewer that experts have considered this information and groundwater impacts were highly unlikely to affect biodiversity. The rationale provided for this evaluation was that species of concern, including Duffy's Forest Ecological Community (DFEC) and Red-crowned Toadlet, were highly likely to be dependent on soil moisture from rainfall and discharge

from perched water tables, rather than the deeper groundwater predicted to be intercepted by the project.

WRL's review considered that while select species and ecosystems might not be groundwater dependent, some opportunistic groundwater use of deeper groundwater might still occur, and if the project brought about changes that reduced access to this groundwater during drought periods when shallow soil moisture was unavailable, some short-term impacts might still be realised. For example, elsewhere in NSW the roots of some large eucalypt species are shown to draw on groundwater from up to 10 m depth and that the health of these trees can be affected by declining groundwater levels. WRL's review also considered whether it was plausible that during drought Red-crowned Toadlet might take refuge within elevated drainage lines where groundwater discharge maintains soil moisture. It is also known that leaf litter from trees provides habitat for Red-crowned Toadlet.

This consideration was based upon the following statements in the literature:

- NPWS (2001): "*Red-crowned Toadlets usually live in the vicinity of permanently moist soaks or areas of dense ground vegetation or leaf litter along or near head-water stream beds*".
- OEH (2012) reports that key threats to habitat are: "*clearing of habitat, particularly along ridge lines*", changes to flow rates and "*reduction in water quality flowing from ridges, particularly near urban areas*".
- Stauber (2006): "*Regular monitoring of breeding sites revealed increased reproductive success away from roads for both species probably because of relatively longer hydroperiods… In the laboratory, tadpoles responded to decreasing water levels by shortening their larval periods and metamorphosing earlier than siblings held at constant water level. Despite this plastic response, a number of pools in the field failed to produce metamorphs due to early drying, an observation also made on P. australis… P. australis formed small aggregations and predominantly selected leaf litter piles despite their relatively low availability. Leaf litter piles in creeks moved over time and the animals moved with these piles*".

During the course of the review, WRL's reviewer advised RMS that the provision of tree health, creek-flow and biodiversity monitoring might improve the understanding of baseline opportunistic groundwater use by trees and Red-crowned Toadlet. In their responses, RMS indicated that such monitoring was unnecessary because geological conditions at the site created perched water tables that were highly unlikely to be impacted. To support this interpretation, RMS provided an analysis of depth and elevation to water table data for the project area. The data tends to suggest the presence of multiple or discontinuous water tables within about 5 metres of any elevation. RMS also indicated that tree health is not impacted significantly at other road cuttings in the Sydney Basin.

WRL's reviewer agreed that perched water tables are a common occurrence in the Sydney Basin geological environs and that the available data and observations supported the view of the RMS that groundwater drawdowns are unlikely to impact vegetation. However, WRL's review did note an absence of nested piezometer groundwater level measurements confirming this and modelling reports documenting the changes in flux rates from the perched water tables to the deeper aquifers. Based on available observations collated by GHD (2015), WRL's reviewer agrees that the risk of negative outcomes appears unlikely although the absence of directly measured vertical hydraulic gradient data appears to highlight a small degree of uncertainty.

4. Compliance with Legislation, Guidelines and Best Practice Measures

The *Water Management (General) Regulation 2011* exempts roads authorities from the need to obtain a water access licence and a water use (aquifer interference) approval in relation to water

required for road construction and road maintenance. RMS is consulting with NSW DPI Water to obtain appropriate licences for groundwater use at the site.

4.1 Environmental Planning and Assessment Act 1979

The Secretary's Environmental Assessment Requirements (SEARs) requires RMS to comply with Part 3 of Schedule 2 of the Environmental Planning and Assessment Regulation 2000. The SEARs are available online at:

http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=6622

Section 5(vii) of the *Environmental Planning and Assessment Act 1979* requires proponents to consider the key principles of Ecologically Sustainable Development (ESD) in the design of their projects. The principles of ESD are defined within the Protection of the Environment Administration Act 1991. This Act defines the precautionary principle and the principles of inter-generational equity, conservation of biological diversity and ecological integrity. The precautionary principle is defined as:

> "*if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation*".

WRL's reviewer has noted that Section 1.6 of the GHD (2015) report has reproduced only some of the content requirements for an EIS from the SEARs and clause 7 of the Environmental Planning and Assessment Regulation (2000). The clauses that were not listed were:

1. "*An analysis of any feasible alternatives to the carrying out of the development*";
2. "*Where relevant, the assessment of key issues… must include: adequate baseline data*";
3. "*A detailed description of those aspects of the environment that are likely to be significantly affected*"; and
4. "*detailed contingency plans for managing any significant risks to the environment*"

The majority of these items are addressed in the EIS with statements or commitments, however, based on WRL's review and the review comments provided by NSW DPI Water, it is the assessment of WRL's reviewer that there are some gaps in the baseline data and reporting. These gaps limit the confidence that WRL's reviewer applies to the conclusions provided by the proponent with respect to significant groundwater related risks to the environment. However, WRL's reviewer also considers that the groundwater related risks to the environment from this project can be adequately managed with additional data collection, analysis and appropriate conditions of approval thus satisfying the ESD objects of the Act.

4.2 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy by DPI Water (NSW Government, 2012) states:

> "*A risk management approach to assessing the potential impacts of aquifer interference activities will be adopted, where the level of detail required to be provided by the proponent is proportional to a combination of the likelihood of impacts occurring on water sources, users and dependent ecosystems and the potential consequences of these impacts.*"…
>
> "*Proponents of any project that may be defined as an aquifer interference activity under the Water Management Act 2000 will also be required to provide estimates of all quantities of water that are likely to be taken from any water source during and following cessation of the activity and all predicted impacts associated with the activity, based on the following minimum requirements:*
>
> - *if a development consent under Part 4, Division 4.1 of the EP&A Act applies… estimated based on complex modelling platform that is:*

- *calibrated and validated (where practical) to the available baseline data that has been collected at an appropriate frequency and scale and over a sufficient period of time to incorporate typical temporal variations. In instances where an activity has a high likelihood of causing more than minimal harm to a "reliable water supply", at least 2 years of baseline data is required; and*
- *consistent with the Australian Groundwater Modelling Guidelines; and*
- *independently reviewed and determined to be robust and reliable, and deemed fit-for-purpose to the satisfaction of the Minister"*

WRL's assessment of the proponent's adherence to the principles of the NSW Aquifer Interference Policy is summarised in Table 1.

Table 1: Adherence to the Principles of the NSW Aquifer Interference Policy

Principle	**WRL Assessment**
Estimates of quantities of water taken	The proponent provides a bounded prediction of the groundwater quantities likely to be intercepted, treated and discharged, plus an estimate of the reductions in baseflow to nearby creeks. This information could be presented more concisely in table form.
Complex Modelling Platform	The proponent has employed a complex modelling platform to provide predictions.
Calibrated and Validated to Baseline Data	The proponent has provided a bounded calibration and validation to baseline data. While no transient calibration is provided, this may be reasonable given the risk-based assessment procedure described within the policy. Transient calibration is helpful for validating the storage parameters of aquifers and aquitards, which determines the volumes of groundwater released from storage within the capture zone of the development.
Baseline Data Collected at an Appropriate Frequency and Scale	The baseline data has been collected at a limited frequency and scale. Data collections are continuing and the need for any additional monitoring should be reviewed with DPI Water from time to time.
Consistent with the Australian Groundwater Modelling Guidelines	The Australian Groundwater Modelling Guidelines (Barnett et al, 2012) encourage sensitivity testing and uncertainty analysis. While a formal sensitivity and uncertainty analysis is not provided, the bounded modelling approach adopted by the proponent provides a measure of uncertainty to recharge and fixed model layer hydraulic conductivities. This is considered acceptable given the risk-based assessment procedure described within the policy.
Independently Reviewed	RMS have indicated that the EIS groundwater modelling was internally review by a competent groundwater modeller, however, no review checklist was reported as recommended in the Australian Groundwater Modelling Guidelines.
Robust and reliable, and deemed fit-for-purpose the satisfaction of the Minister	WRL's reviewer has sighted a number of NSW DPI Water communications to RMS and the NSW Department of Planning and Environment containing comments, requests and recommendations in relation to the project. There are no statements that suggest issues with model reliability, robustness or suitability.

4.3 RMS Environmental Impact Assessment (EIA) Guidelines

An RMS Environmental Impact Assessment Practice Note states that public and private decisions should be guided by:

1. A fundamental consideration for conservation of biological diversity and ecological integrity;
2. Careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and
3. An assessment of the risk-weighted consequences of various options.

WRL's assessment of the proponent's adherence to the RMS principles of EIA with respect to potential groundwater related impacts are summarised in Table 2.

Table 2: Adherence to the Principles of the RMS EIA and ESD Guidelines

Principle	**WRL Assessment**
A fundamental consideration for conservation of biological diversity and ecological integrity	The proponent has undertaken both a groundwater and biodiversity impact assessment. Details of surface water impacts are provided for peak and base flows but not for other times. Section 6.4 of the surface water report provides some commentary in relation to average flows.
Careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment	The proponent reports careful evaluation and consideration of biodiversity impacts arising from predicted changes in groundwater conditions for two project options and concludes that serious or irreversible damage to the environmental for both options is highly unlikely. The proponent's assessment is based on: • The modelling approach generating an envelope of predicted impacts given uncertainty in the steady state recharge condition. • The model having limitations in simulating localised fracture flow conditions and to calibrate to variable groundwater conditions. • The conceptual conditions at the site suggesting fracture dominated flow with isolated fracture networks and the likely presence of intermittent isolated aquifer systems vertically. • Some lines of evidence suggesting that drawdown will be less than the predictions for the high recharge case. • Some lines of evidence suggesting a low likelihood of groundwater dependence of DFEC and Red-crowned Toadlet. • Consideration of a lined and an unlined roadway slot option for managing groundwater impacts. The proponent has concluded that the unlined slot option is the most cost-effective option for managing the environmental risks of the project. RMS has also proposed to develop management plans in consultation with government agencies to manage any residual risk. This letter provides initial technical recommendations for groundwater management to NSW Department of Planning and Environment to address limitations identified within the assessment.
Is there a risk the project will cause serious or irreversible harm?	The project will cause an irreversible lowering of the groundwater table with the magnitude of the impact diminishing with distance from the proposed roadway upgrade. In the majority of locations near the proposed development, this impact is predicted to be lower than the minimal impact provisions of the NSW Aquifer Interference Policy. The assessment by RMS considers that the lowering

	of the groundwater table is unlikely to cause irreversible harm to the environment and development of management plans is proposed to manage any residual risk.
Is there a lack of scientific knowledge of the nature of environmental harm?	There is sufficient scientific knowledge to understand the nature of the uncertainty in the predictions of groundwater impacts. The general impacts of lowered groundwater tables on vegetation and the impacts of reduced streamflow on ecological communities are well understood in the literature. However, thresholds for specific species such as DFEC and Red-crowned Toadlet are not quantified. While the EIS does not report the groundwater derived water requirements of endangered species and ecological communities near the proposed road upgrade using site-specific investigations, RMS has indicated that impacts are highly unlikely based upon expert consideration of visual site observations, a review of the scientific literature and the management programs being proposed. In relation to the Red-crowned Toadlet, it would be interesting to see whether future research could help optimise and refine the management plans currently being proposed by RMS.
Is there adequate scientific knowledge of the subject to evaluate perceived threats?	WRL's reviewer considers that sufficient scientific knowledge is available to evaluate, monitor and manage any residual risk of irreversible harm proposed by the development.
An assessment of the risk-weighted consequences of various options	WRL's reviewer has not inspected a risk weighted economic assessment of the consequences of the preferred project option versus the alternative option that would require less environmental management and monitoring. RMS have proposed various management measures such as targeted grouting, wall treatments (i.e. shotcreting) and enhanced recharge to manage residual risk.

4.4 Best Practice Measures

Best practice measures are considered to be adherence to the NSW Aquifer Interference Policy (NSW Government, 2012), the Australian Groundwater Modelling Guidelines (Barnett et al., 2012), RMS EIA procedures and the recommendations provided by hydrogeologists from NSW DPI Water.

5. Adequacy of Management and Mitigation Measures

The NSW Aquifer Interference Policy (2012) indicates that the NSW Government (DPI Water) assesses impacts using an "*account for, mitigate, avoid/prevent and remediate*" approach.

5.1 Approach to Management and Mitigation

RMS have proposed two different management and mitigation options for groundwater management for the project (Section 3.3) indicating that the unlined roadway slot option with potentially perpetual groundwater treatment is preferred over the sealed slot option which minimises groundwater impacts and treatment volumes in perpetuity.

The RMS Response to Submissions Report justifies this preference as follows:

- *"Detailed investigations involving collaboration between the biodiversity and hydrogeological experts informed conclusions that identified the Red-crowned Toadlet and Duffys Forest Ecological Community vegetation is highly unlikely to be dependent on groundwater flows.*

- *Based on this, while the groundwater model predicts drawdowns greater than the negligible impact criteria, impacts to groundwater dependent ecosystems are not expected.*
- *All seepage will be treated and returned to Curl Curl Creek and or Bantry Bay catchment, thereby minimising downstream impacts to the flows in these catchments associated with groundwater baseflow loss or changes to downstream water quality.*
- *With the potential for impacts therefore expected to be minimal, the additional cost associated with lining the slot is not considered warranted or justifiable*."

DPI Water has advised RMS that, "*if long term savings can be made by adopting an unsealed design, it is recommended that some of these savings are directed towards environmental programs to offset the increased impacts of this design choice*".

To manage residual risks RMS have proposed various actions, including:

- *"Construction based actions to minimise seepage into the slot (i.e. target grouting of significant seeps or other wall treatments as required to reduce impacts)".*
- *"Additional surface water flow monitoring in Curl Curl Creek to understand the impacts to habitat in the area of low potential impact risk (i.e., between the subsurface detention basin and the slot)".*
- *"Monitor flows in Curl Curl Creek to identify the base flow conditions, on which changes can be identified, between the slot and the sub surface detention basin".*
- *"Ongoing monitoring of groundwater, as currently being undertaken, which includes the use of automated water level monitoring".*
- *"Ongoing groundwater and surface water quality monitoring, including in all creeks potentially in hydraulic contact with the Stage 2 Project. This will be coupled with water quality monitoring of groundwater seepage water quality to inform treatment requirements before discharge to surface water".*
- *"Further assessment of impacts with groundwater modelling, if it is considered necessary, to better understand any adverse impacts identified by monitoring or to inform the effectiveness of any mitigation measures to be implemented."*

These proposed management measures are acceptable and might be refined or expanded further in consultation with the government agencies during the detailed design of the management plans. It is strongly recommended that monitoring and management plans be designed to identify and manage any species that opportunistically use groundwater within the zone of groundwater impact to ensure they are not impacted by the combination of project activity and drought.

5.2 Adequacy of the Proposed Management and Mitigation Measures

WRL's reviewer generally considers the proposed management and mitigation measures to be appropriate, subject to review of the environmental management plans being developed. Section 6 of this report provides recommended actions and conditions of approval that address any concerns.

6. Recommended Actions and Conditions of Approval

In the event that the Department decides to approve this project, and based on the information from this review and the comments provided by other NSW Government Agencies, the following additions to the conditions of approval recommended by NSW DPI Water are recommended to address the WRL review. If any of these recommendations do not allow for a streamlined development process by NSW Department of Planning and Environment or RMS, they should be provided to RMS and DPI Water as requirements for consideration during the development of the management plans for the project.

Expand Clause 1:

"A Surface Water and Groundwater Monitoring Plan shall be prepared prior to construction and implemented to monitor impacts on surface and groundwater resources, during construction and operation of the project. The plan shall be developed in consultation with DPI Water and shall include:"

Expand subclause 1a:

A publicly available description of the monitoring program including identification of:

- *The monitoring program objectives;*
- *The hydrological and hydrogeological site water balance for dry, wet and average years;*
- *Tables and statistics of baseline groundwater levels in depth below ground and m AHD;*
- *Rainfall deficit and trends at the time of baseline investigation;*
- *The expected groundwater level seasonal variations for dry, wet and average years;*
- *Hydrogeological contour maps and north-south and east-west hydrogeological cross sections;*
- *Surface and groundwater monitoring locations (including coordinates, depth and elevation);*
- *Any discontinued monitoring locations and an appropriate justification;*
- *Geological and completion logs* at all groundwater monitoring locations;
- *Baseflow conditions in Curl Curl Creek both upstream and downstream of the sub-surface detention basin;*
- *The trigger levels for initiating contingency and ameliorative measures;*
- *The review frequency for the plan and a plan of actions to support the review.*

Expand sub-clause 1d:

A detailed assessment of the quality of each creek and the capacity of the creeks to receive groundwater seepage that considers both dry and wet weather conditions.

Insert sub-clause 1i:

A more detailed quantification and assessment of flows in Curl Curl Creek to inform management plans ensuring protection of environmental assets:

- *Installation of a weir (e.g. v-notch) to gauge base-flow below an elevation of 140m AHD*
- *Data collection sufficient to characterise base-flow and runoff from rainfall bursts*
- *Reporting of pre- and post-construction base-flow separation analysis*
- *Reporting of pre- and post-construction flow- event and duration curves*
- *Ongoing life-of-project monitoring to be reassessed during project operation*

Insert sub-clause 1j:

The following groundwater and surface water triggers for biodiversity management should be considered further during the development of project management plans:

- *Changes in water quality outside the tolerance of any sensitive receptor if such information becomes available, otherwise in relation to the appropriate ANZECC criteria; or*
- *A lowering of the groundwater table below 6m and then 10m depth near any potentially sensitive receptor for more than 12 months unless:*
    - *saturation remains within the soil profile or a more elevated aquifer, or*
    - *it can be demonstrated through application of a water budget and an uncertainty analysis of groundwater modelling predictions that project drawdown has not contributed to the loss of soil moisture and the groundwater level declines.*

Insert sub-clause 1k:

Evidence in the public domain that the monitoring program has been reviewed by the relevant agencies and the reviewer confirms:

- *A suitable quantity of baseline data is available to inform all management objectives; and*

- *The requirements of subclause 1a are met and are appropriate given the uncertainty in the predicted range of impacts with consideration to the predicted and observed impacts of the development highlighted in any modelling post-audits that may be undertaken.*

Insert sub-clause 1l:
Actions to support any reviews of the plans to inform environmental management of the project will include government agency review that considers:

- *A hydrological and hydrogeological analysis of post-construction / operational data*
- *A post-audit of the EIS numerical model tool*
- *Any proposed updates to the site geological and hydrogeological conceptual models*
- *The need for any further numerical or analytical modelling*
- *The suitability of any changes proposed to the monitoring program*

Expand Clause 2:
A Life-of-Project Groundwater and Dewatering Management Plan shall be prepared prior to construction and implemented to manage the impacts of groundwater drawdown due to seepage into the slot. The plan is to be prepared in consultation with DPI Water and shall include:

Insert sub-clause 2j, 2k and 2l:
Updated during construction to document the location, strike, dip, width and aperture of rock defects contributing groundwater inflow into the construction, including estimates of total inflow corrected for evaporation effects and volumes of individual inflows from each structure following at least one large rainfall event that generate inflow.

Provisions to trigger a review of the plan.

Protocols for informing surface and groundwater monitoring actions if inflows to the slot are higher than predicted or lower than daily evaporation rates.

Add Clause 4
Recording of surface water and groundwater levels at project monitoring locations will be with automatic data loggers from pre-construction through to project operation. This data will be collected in a manner that supports correction and/or elimination of barometric pressure and earth tide effects. While impacts to private groundwater bores are not predicted and appear unlikely, it may be precautionary to monitor such bores at least quarterly during construction and for the first three years of project operation. The need to monitor private groundwater bores can be assessed in more detail during the design of the monitoring program.

References

Barnett B., Townley L.R., Post V., Evans R.E., Hunt R.J., Peeters L., Richardson S., Werner A.D., Knapton A. and Boronkay A. (2012) *Australian groundwater modelling guidelines, Waterlines report*, National Water Commission, Canberra.

Dryburgh, M. (2014) *Concept Design Geotechnical Investigation Report – Northern Beaches Hospital Enabling Roadworks, Frenchs Forest*, NSW Transport, Roads and Traffic Authority, Road Pavement and Geotechnical Engineering Science Division, January 2014.

SMEC (2015a) *Northern Beaches Hospital Road Connectivity and Network Enhancement Project Stage 2 Environmental Impact Statement* (SSI 6622), Report for NSW Roads and Maritime Service, July 2015

SMEC (2015b) *Biodiversity Assessment Report Northern Beaches Hospital Connectivity and Network Enhancements Stage 2 (SSI 6622)*, Prepared for NSW Roads and Maritime Services, May 2015.

GHD (2015a) *Northern Beaches Hospital Network Enhancement - Stage 2 Groundwater Assessment* (SSI 6622), Report for SMEC Australia Pty Ltd, July 2015. GHD Project 21/24063/01.

GHD (2015b) *Northern Beaches Hospital Network Enhancement - Stage 2 Environmental Impact Statement: Surface Water Assessment* (SSI 6622), Report for SMEC Australia Pty Ltd, July 2015. GHD Project 21/24063.

NCGRT (2012) Media Release: Trees offer early warning of water shortages, Available Online: http://www.groundwater.com.au/news_items/media-release-trees-offer-early-warning-of-water-shortages

NSW Government (2012), NSW Aquifer Interference Policy - NSW Government policy for the licensing and assessment of aquifer interference activities, Department of Primary Industries Office of Water.

NPWS (2012) Environmental Impact Assessment Guideline – Red-crowned Toadlet, NSW National Parks and Wildlife Service, Available Online: http://www.environment.nsw.gov.au/resources/nature/RedcrownedtoadletEia0501.pdf

OEH (2012) *Red-crowned Toadlet Threatened Species Profile*, Available Online: http://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10692

RMS (2014) Environmental assessment and decision-making by NSW Roads and Maritime Services Strategic Assessment – under Part 10, Environment Protection and Biodiversity Conservation Act 1999 (Appendix B EIA Practice Note – ESD), Available Online: http://www.rms.nsw.gov.au/documents/about/environment/planning-and-assessment/strategic-assessment-report-appendix-b.pdf

Stauber, A.G. (2006) *Habitat requirements and habitat use of the red-crowned toadlet Pseudophryne Australis and the giant burrowing frog Heleioporus Australiacus in the Sydney basin*, Thesis submitted for the fulfilment of PhD, University of Technology Sydney, Faculty of Science.

Zolfaghar S., Villalobos-Vega R., Cleverly J., Zeppel M., Rumman R. and Eamus D. (2014) "The influence of depth-to-groundwater on structure and productivity of Eucalyptus woodlands", Australian Journal of Botany 62, 428–437.