Additional information for the NSW Parliamentary Inquiry into the Western Harbour Tunnel and the Beaches Link, Submission 364 – Baringa Bush Resident Group

Overview – see GIPA documents attached

Independent experts have found Transport for NSW (TfNSW) failed to properly assess serious risks to sensitive groundwater, freshwater and marine waters posed by the proposed Beaches Link tunnel and road works – and that extensive, long term studies must be carried out before construction proceeds.

The experts, **commissioned by the Department of Planning, Industry and Environment (DPIE)** , concluded the state's transport agency, TfNSW, did not use best practice, nor the most recent data to determine the project impacts on water systems. These include groundwater drawdown up to 16 metres across Seaforth and Balgowlah and 36 metres in Northbridge, drastically reducing water flows in natural catchments and creeks, as well as the contamination of, or changes in, multiple sensitive freshwater and marine environments.

The experts concluded the gaps and inadequacies in the TFNSW's EIS meant it **did not meet the NSW Government's standards for state significant infrastructure, under the Standard Secretary's Environmental Assessment Requirements (SEARs)**, and identified a list of additional studies that should be undertaken.

Unlike other parts of Sydney's toll road network that were built through former industrial landscapes, the Beaches Link tunnel impacts large areas of otherwise protected bush, including Manly Dam, Burnt Bridge Creek and Flat Rock Gully and the waters of Middle Harbour, with flow on impacts on the rich biodiversity they support.

At least 40 threatened species will be affected during the construction and operation of the tunnel, ranging from the last 60 or so breeding pairs of Fairy Penguins on the NSW mainland that forage in Middle Harbour to the extraordinary galaxias climbing fish that has survived in the Manly Dam region since the Gondwana era some 60 million years ago.

In particular, the experts highlight the massive draw down of ground water required for the construction and operation of the tunnel. At Seaforth, this will remove up to 96% of the water from Burnt Bridge Creek - running from Seaforth to Manly Beach via Manly Lagoon. The de-watering of this catchment will have unquantified impacts on a multitude of water dependent species, ranging mature street trees to home gardens to the numerous native species within the creek itself and its protected riparian zone, including a large colony of endangered flying foxes that rely on its waters.

TfNSW's Environmental Impact Statement for the Beaches Link project - that identifies impacts and presents plans to mitigate environmental harm – said the groundwater drawn was 'unlikely to result in a complete loss of aquatic habitat' from the creek. The expert report countered that 'such statements are unacceptable and further modelling and assessment is required'.

The experts also stated that at least a year of continuous assessment of the water column in Middle Harbour was required to determine risks to vital dissolved oxygen levels upstream of the tunnel due to the disruption in tidal water exchanges when tunnel tubes are laid on the sea floor.

The use of outdated data was also singled out, potentially leading the impacts being underestimated. Likewise, given the limits of the modelling used, the complexity of groundwater in urban environments was not adequately considered. This means, the real impact of pumping out up to 36 metres of ground water (Northbridge) could not be confidently predicted. Modelling also failed to take into account forecast periods of low rainfall and drought.

Review of the Beaches Link and Gore Hill Freeway Connection Environmental Impact Assessment, Feb 16, 2021.

Groundwater Solutions Inc was retained by the Water Research Laboratory (WRL) at University of New South Wales' School of Civil and Environmental Engineering to review the Groundwater Impact Assessment of the Environmental Impact Statement (EIS) that supports the Beaches Link and Gore Hill Freeway Connection (the project) for the NSW Department of Planning, Industry and Environment which is part of the Western Harbour Tunnel and Beach Link program of works. The review was conducted by Dr. Kevin Hayley, who is regarded by his peers as an expert in groundwater processes and modelling.

1. Introduction

The Beaches Link and Gore Hill Freeway Connection involves construction of a new tolled motorway tunnel connection from the Warringah Freeway to Balgowlah and Frenchs Forest, and upgrade and integration works to connect to the Gore Hill Freeway. An EIS was completed by Jacobs on behalf of Transport for NSW.

A draft EIS was reviewed by Groundwater Solutions Inc in October 2020, to determine if it was consistent with the Secretary's Environmental Assessment Requirements (SEARs) which are used to assess state significant and high priority infrastructure projects. A report, *Consistency Review of Groundwater aspects of the Beaches Link and the Gore Hill Freeway Connection Environmental Impact Statement*, containing an initial methodology review was delivered to NSW Department of Planning, Industry and Environment on October 30th, 2020. A final EIS document titled "*Beaches Link and Gore Hill Freeway Connection Environmental Impact Statement"* was completed by Jacobs and submitted for public exhibition on December 9th, 2020, and is the subject of this review.

2. Scope of Work

The scope of work for this review as provided by NSW Department of Planning, Industry and Environment was as follows:

- **EIS Methodology and Assessment Review**

  Review the groundwater and hydrological impact assessments in the EIS and comment on the technical adequacy, completeness and conclusion of the impact assessments. The methodology review shall take into account relevant impact assessment guidelines, requirements and legislation.

  The review shall include, but is not limited to:

  i. Assessment of the methodology and approach (including methods of baseline monitoring and collation of baseline data, and selection of model/calculation approach); and

  ii. Analysis of the results of the groundwater and hydrological impact assessments, with reference to applicable legislation, guidelines and comparable projects.

- **Management and Mitigation Review**

  Review the appropriateness and effectiveness of management and mitigation measures recommended for the project, taking into account expected impacts, relevant guidelines and policies, industry best practice and research or monitoring evidence (preferably published).

- **Gap Analysis**

  Prepare a Gap Analysis, requesting additional information required to address gaps in the groundwater and hydrological impact assessments. In preparing the Gap Analysis, the review shall take into account relevant statutory and non-statutory guidelines and requirements for the assessment of impacts.

3. Summary

The final EIS reviewed in this report has not substantially changed from the draft version and, most of the issues raised in the previous consistency review are still outstanding. The impact assessment methodology used in the EIS is based on a numerical groundwater modelling study. It is this reviewer's opinion that while the work meets the standards of the Australian Groundwater Modelling Guidelines, and is likely consistent with historical practice, it is not consistent with more recent guidance documents on modelling and uncertainty analysis (Middlemis & Peeters, 2018) and this reviewer's opinion of current best practice.

Specifically, the following deficiencies, have been identified:

- While the conceptual model of groundwater flow and numerical model development are reasonable, the model parameterization does not reflect the complexity of groundwater recharge in an urban environment, or the heterogeneity shown in the conceptual model and hydraulic testing data. The current model parameterization limits the application of quantitative uncertainty analysis by simplifying parameters to a small number of large zones that cannot represent heterogeneous and largely unknown groundwater system described in the conceptual model.
- The groundwater level observation dataset used for model calibration is inadequate to constrain the uncertainty in parameter values and predicted impacts because water level data is only informative to a combination of model parameters, and there is significant uncertainty in the transient groundwater recharge in urban environments.
- The impact assessment is based on model predictions from a single set of parameters. However, there is a wide range of alternative parameters that could result in a wide range of model predictions. The alternate model predictions produced by different parameter values cannot be discounted based on the current observation dataset because it does not contain enough information to uniquely identify parameters.
- The impact management strategies presented are all based on groundwater monitoring and adaptive management. The modelling provides no evidence that adverse groundwater impacts can be mitigated through monitoring and adaptive management.

4. EIS Methodology Review

The project EIS consists of a main document with 29 chapters and 25 appendices. The assessment of the groundwater impacts of the project is presented in Chapter 16 of the main EIS document supported by a technical paper in Appendix N. The project groundwater impact assessment has been reviewed with respect to the SEARs, and other relevant guidelines and has been based primarily on the results of numerical groundwater modelling presented in the EIS. As such, the methodology used for the project impact assessment has been reviewed based on the Australian Groundwater Modelling Guidelines (Barnett et al., 2012), as well as more recent documents (Middlemis & Peeters, 2018) that provide guidance for risk based groundwater modelling, and finally, upon the reviewer's understanding of best current professional practice. It is this reviewer's opinion that the assessment methodology is consistent with the minimum standards defined in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012), and the methodology of previous impact assessments. However, in this reviewer's opinion, the methodology is not consistent with current leading practice which is focused on the predictions of interest (Hermans, 2017; Scheidt et al., 2015), and seeks to quantify the uncertainty in the predicted impact to enable risk based decision-making (Middlemis & Peeters, 2018; Scheidt et al., 2018). The description of the groundwater system, model development and calibration, and the use for impact assessment presented in the EIS, are discussed in Sections 4.1 through 4.5 to highlight the uncertainty in the model predictions and the limited consideration of uncertainty in the impact assessment.

4.1 Description of Groundwater System and Conceptual Model

A conceptual hydrogeological model is the starting point to build a numerical model of groundwater flow that can be used to predict groundwater impacts. In order to develop the conceptual model, the groundwater system in the region of interest needs to be qualitatively understood and described including the nature of groundwater recharge, discharge, and relevant geology that will influence subsurface flow.

The existing groundwater system is described to a reasonable professional standard and appropriate revisions to figures and text from the draft document have been completed. However, the description of groundwater recharge includes only a limited discussion of how urbanisation and development of infrastructure alters groundwater recharge from the natural, undisturbed state. The effect of urbanisation on groundwater recharge is complex (Barron et al., 2013; Lerner, 1990) and has been found to cause net increases in recharge through irrigation and leakage from infrastructure, despite the increased surface runoff due to impervious pavement and rooftop surfaces. The current EIS describes groundwater recharge as a fraction of rainfall based on outcropping geology with adjustments in paved areas due to reduced infiltration. This highly simplified representation of recharge, which ignores the potential influence of infrastructure leakage and irrigation, is the basis of the numerical groundwater model. Structural errors due to overly simplified conceptual models and parameterisation, or incomplete representation of groundwater stresses, have been shown to propagate through model calibration and lead to biased, misleading predictions (Doherty & Christensen, 2011). Consequently, simplistic representation of recharge that omits potential important sources of groundwater recharge could lead to erroneous predictions.

The description and conceptual model of the hydrogeology consists of a highly heterogeneous groundwater system of fractured sandstone and shale with intrusive volcanic dykes and faulting of uncertain location. This hydrogeological interpretation, based on a review of background information and observation logs, is reasonable and has been completed to an acceptable standard.

4.2 Numerical Model Construction

Numerical groundwater model construction requires simplification of the conceptual model to represent the groundwater system in a computer model. This involves simplification of the hydrogeological structure to define separate layers or zones for differing interpreted geological units, specifying values for model boundaries such as recharge at surface and discharge in creeks and model parameterisation. The majority of necessary simplifications made in the EIS, including the separation of the model domain into two separate models for the portions of the tunnel north and south of Sydney Harbour, are reasonable decisions based upon the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). Only the northern model domain is referenced in the EIS for this portion of the project.

In addition to structural simplifications, model parameter simplifications are often applied to ensure a tractable model. Model parameterization refers to the way that the groundwater model inputs (hydraulic conductivity, storage, recharge, and boundary conditions) are specified in every cell of the model and are grouped or simplified based on the conceptual model of groundwater flow. In the EIS, model parameters (recharge and hydraulic conductivity) were assigned to a small number of fixed zones, which resulted in uniform parameter values being assigned across large areas of the model domains. A zone-based methodology is unable to capture the smaller-scale parameter variation that could have a much larger range of plausible values than bulk averages applied across large zones. Particularly in a highly complex system, such as this project area, the smaller-scale parameter variation may be important to predictions. In this reviewer's opinion, the model parameterization used in the groundwater impact assessment, does not reflect the highly heterogeneous nature of the conceptual model detailed in section 4.1. Consequently, the applicability of quantitative uncertainty analysis is limited by the parameterization and limited range of parameter values considered.

4.3 Model Predictive Simulations

The model predictions of interest are estimates of tunnel inflows and drawdown due to project construction and operation. To obtain these predictions, it is necessary to simulate the tunnel construction and operation. In this reviewer's opinion, the predictive simulations are based on reasonable simplifications to the project construction and operation. The scenarios for predicting the cumulative effects of the project and other proposed tunnel developments are appropriate.

An uncertainty analysis, described in the groundwater modelling report (Appendix F of Appendix N), was conducted by varying model parameters by up to one order of magnitude in the zones assigned for hydraulic conductivity, recharge, storage, and the drain conductance boundary condition parameter used in simulating the tunnel construction and operation. This analysis provides insight to the sensitivity of model predictions to parameter values and showed that the model predicted drawdowns and inflows used in the impact assessment are highly sensitive to changes in hydraulic conductivity parameter values. Some predicted inflow values changed by one order of magnitude with a one order of magnitude change in hydraulic conductivity parameter value. This is consistent with this reviewer's experience that predicted tunnel inflows and associated drawdown impacts are strongly dependent on the hydraulic conductivity, and to a lesser degree storage, parameter values in the local vicinity of the tunnel. This analysis demonstrates that uncertainty in model parameters directly leads to significant uncertainty in model predictions. As further discussed in section 4.5, this uncertainty analysis does not provide a sufficient exploration of the range and likelihood of plausible groundwater impacts to enable decision makers to assess risk. The existing hydraulic testing data from packer tests shows greater than four orders of magnitude variability in local scale hydraulic conductivity, and the current uncertainty analysis only explores the effect of one order of magnitude. As a result, the uncertainty analysis does not assess the potential groundwater impact that could be caused by the project in this heterogeneous and largely unknown groundwater system.

4.4 Observation Data and Model Calibration

The purpose of groundwater model calibration is to find the model parameters that generate model simulations that match real world observations to a reasonable degree. It is conducted so that appropriate parameter values can be used in predictive simulations. Ideally, the calibration process reduces the uncertainty in model parameter values and subsequently, the uncertainty in model prediction values (Moore & Doherty, 2005).

The model calibration dataset used in the EIS, consisted of water level measurements at 61 locations and surface water baseflow estimates, derived from two water level measurements. Calibration was initially conducted using a steady state model, which simulates a groundwater system at equilibrium, where flow into the system is matched by flow out. Calibration to observed groundwater level data, recorded between 2015 and 2018, was completed using a transient model with time varying groundwater recharge based on the recorded rainfall.

Model calibration was conducted manually using a trial and error approach, where 16 hydraulic conductivity and recharge values applied at model zones were adjusted until a reasonable match to observation data was produced by the model. A highly parameterised model that can more realistically represent the heterogeneous conceptual model of hydrogeology and an automated, PEST (Doherty, 2015), calibration and uncertainty analysis would likely define the uncertainty margins of the parameters and subsequently, the predictions more efficiently than a manual approach. It has been shown that usage of highly parameterised models and regularised inversion can extract more information from an observation dataset than simple zone-based parameterisation (Moore & Doherty, 2006). However, in this reviewer's opinion further calibration efforts to the current groundwater observation dataset are likely to be of little value in reducing the uncertainty in predictions of groundwater impact. Justification of this opinion is detailed in the following sections.

Model calibration to groundwater level observation data alone cannot be used to uniquely identify hydraulic conductivity parameters because an infinite number of hydraulic conductivity and recharge parameter value combinations could lead to the same water level being simulated by a model (Knowling & Werner, 2017). However, calibration to transient water level changes (*drawdown*) can provide additional information to constrain model parameters because drawdown observations inform different combinations of model parameters (*hydraulic conductivity and storage*) than groundwater level data (*hydraulic conductivity and recharge*). But, in order to yield this additional information, the time varying stress causing the water level fluctuations, such as discharge from wells during a pumping test, must be known and simulated with a reasonable degree of accuracy. The only time varying stress simulated during the transient calibration described in the EIS, was recharge, and it was applied as a percentage of recorded rainfall at the different parameter zones. Stresses from other potential influences such as irrigation and leaking infrastructure were not represented. As previously discussed in section 4.1, the nature of groundwater recharge is complex and highly uncertain in an urban environment, and with few exceptions, the calibration hydrographs (Attachment 5 of the groundwater modelling report, Annexure F of Appendix N) for the transient calibration show very little correlation between simulated and observed changes in water level. This lack of correlation suggests that the background groundwater system is responding to a more complex system of stresses than the time varying rainfall recharge included in the calibration model.

Calibration to estimated groundwater discharge as baseflow in surface water systems, can constrain estimates of recharge parameter values because of the sensitivity of these observations to recharge. Three baseflow estimates were included in the calibration of the northern model. However, as discussed in Appendix N, data for recession curve analysis, which is considered the best way to estimate baseflow, was not available and the baseflow estimates are each based on single water level and consequently, have high uncertainty.

It is this reviewer's opinion that model calibration to the current observation dataset does very little to reduce the uncertainty in hydraulic properties near the proposed tunnel that will have the largest influence on predicted impact. This means that the predicted impact upon groundwater will also be highly uncertain.

4.5 Impact Assessment

The purpose of a groundwater impact assessment is to present information about the potential adverse impacts of a project and allow informed decisions for project approvals. The assessment of impact presented in Chapter 16 and in Appendix N of the EIS is based on a single deterministic simulation of the proposed construction and operation of the project using one calibrated model parameter set. Deterministic simulations, in contrast to stochastic simulations, only utilise one potential combination of model parameters to make predictions and consequently, the prediction is only one possible prediction within an infinite continuum of alternatives. Models are unable to predict what *will* happen, but, are able to predict what likely *will not* happen based on observation datasets (Doherty, 2015). Uncertainty analysis provides an indication of how likely a particular prediction (*based on particular parameters*) is compared to other potential predictions. In this case, only one predictive scenario was presented in the EIS and there are many more potential scenarios that cannot be discounted by the current observation dataset. Informed decision-making requires an exploration of the alternate predictive scenarios (*or uncertainty*).

Generally, there are three alternative methods of uncertainty analysis used for hydrogeological applications (Middlemis & Peeters, 2018) and they include:

1. Deterministic scenario analysis with subjective probability assessment
2. Deterministic modelling with linear probability quantification
3. Stochastic modelling with Bayesian probability quantification

The predictive uncertainty analysis documented in the groundwater modelling report (Appendix F of Appendix N) was based on three alternative parameter combinations that individually varied input parameters by up to one order of magnitude. Such an approach would be categorised as deterministic scenario analysis with subjective probability assessment. This method of uncertainty analysis is considered to be the least rigorous and most subjective of the three alternatives (Middlemis & Peeters, 2018). Linear probability quantification was recommended by the Australian groundwater modelling guidelines but in this reviewer's opinion, stochastic modelling represents current best practice and has become an increasingly commonly applied technique. The results of the predictive uncertainty analysis that was conducted are not referenced outside section 10 of Annexure F of Appendix N. The uncertainty in predicted impacts is not discussed in the main EIS document, nor is the uncertainty in predicted groundwater drawdown carried into predictions of ground settlement.

Hydraulic conductivity values from packer tests in both model domains are variable, and span more than four orders of magnitude. Furthermore, the hydrogeological conceptual model is of a highly heterogeneous system of fractured sandstones, shales and contains multiple faults and intrusive dykes. The understanding of the highly heterogenous groundwater system, that varies across at least four orders of magnitude, is not reflected in the predictive uncertainty analysis which altered homogenous parameter zones by up to one order of magnitude.

As discussed in section 4.3 the groundwater impacts predicted by the model are sensitive to model parameter values, and as discussed in section 4.4, the model parameter values have significant uncertainty and are not well constrained by the current observation dataset. This leads to large range in plausible tunnel inflow and drawdown values that are only minimally explored in the EIS. Due to these gaps in data and analysis, the actual groundwater impact of the project is currently difficult to assess. It is this reviewer's opinion that the analysis of predictive uncertainty used in the impact assessment does not reflect best current practice and is not presented in an appropriately prominent manner when discussing potential groundwater impacts in the current document.

5. Management and Mitigation Review

As stated in Section 7 of Appendix N, the purpose of impact management and mitigation strategies is to *mitigate and minimise the potential impacts for both the construction and operational phases of the project*".

The impact management and mitigation measures presented in section 7 of Appendix N of the EIS consist of:

- Plans to collect additional data and revise the numerical modelling as required.
- Manage groundwater impacts as they are observed.

  In particular:
  - Groundwater inflows are proposed to be managed by adaptively revising the tunnel waterproofing measures as groundwater inflow rates are observed and/or revised modelling provides refined predictions.
  - Groundwater impacts on other users are proposed to be managed by monitoring and implementing make good measures if necessary.
  - Groundwater impacts on surface water systems are proposed to be managed by further monitoring and modelling. However, it is unclear what action is proposed if the monitoring and modelling show a greater impact on surface water than is acceptable.
  - Contaminant transport impacts are proposed to be managed by groundwater monitoring, further modelling and unspecified mitigation/management measures to be implemented "*where feasible and reasonable*".
  - Ground settlement risk is proposed to be managed by detailed predictive settlement modelling, surveys of building condition, and establishing acceptable limits of settlement.

The proposed impact management and mitigation measures demonstrate consideration of the main potential impacts of the tunnel. The proposed measures highlight the need for further data collection and model updates before predictions can be used for proactive management of impacts. Due to the lag time of groundwater systems, unacceptable impacts may be impossible to avoid after groundwater monitoring thresholds have been reached (Currell, 2016), so it is often not possible to manage adverse groundwater impacts through monitoring alone . Proactive management based on quantification of uncertainty in predicted impacts and, collection of further data to constrain the uncertainty in predicted impacts would allow for risk-based decision making and design and represent best practice.

6. Gap Analysis

At this point, the EIS does not fully address the SEARs requirements to describe the hydrological regime for groundwater and assess the impact of project construction and operation on groundwater levels or quality to a standard of best practice. This gap analysis presents the additional work required to ensure the EIS fully meets SEARs requirements.

To fully address **SEARs requirements 9.1 and 9.2**, the following action is required:

- An update of the description of the existing hydrological regime is required to discuss the complexity of groundwater recharge in an urban environment.
- An update of the description of the uncertainty that the hydrogeological complexity in both recharge and unknown aspects of geology (such as dykes and faults) introduces into model calibration of water level observations and the subsequent model predictions.

To fully address **SEARs requirement 9.3**, the following action is required:

- An updated description of the project's groundwater impact during construction and operation is required to discuss the predicted impacts in the context of the uncertainty in model predictions. Ideally, this would be supported by a revised predictive uncertainty analysis that included:
    - Updating the model parameterization to reflect the highly heterogeneous conceptual model of hydraulic properties and recharge, using a highly parameterised model with pilot points or model grid scale parameterization.
    - Updating the bounds of the local hydraulic property values considered in the uncertainty analysis to reflect the full four orders of magnitude variability observed in the *prior* hydraulic testing (packer tests).
    - Generate alternative model parameter sets based on the *prior* information available from hydraulic testing.
    - Run predictive simulations using multiple alternative parameter sets to enable statistical analysis of predicted impacts.
    - Revise the statements of predicted impact and planned management action to be based upon statistical measures of potential impacts, such as most likely mean predicted impacts and conservative values such as 95th percentile predicted impacts.
- As discussed in section 4.4, it is this reviewer's opinion that the current groundwater observation dataset is unlikely to provide much constraint on model parameters and predictions. However, if a revised uncertainty analysis demonstrates that there is an unacceptable risk of impacts from the project cannot be discounted, then further groundwater testing with long duration pump tests that would inform model parameters and constrain the uncertainty in predicted impacts should be considered prior to construction.

To fully address **SEARs requirement 10.1 and 12.8**, the following action is required:

- Predicted drawdown at locations of known contaminant sites are presented in table 16-14 of the main EIS. However, there is no assessment of uncertainty in the drawdown predictions or discussion of the changes in rate and direction of groundwater flow that the drawdown will induce.
- An updated assessment of potential contaminant migration should at minimum discuss the predicted changes in water level (drawdown) and gradient (rate and direction of flow) at each location with

consideration of predictive uncertainty. Where adverse contaminant migration risk is greatest, potential contaminant transport risk should be further assessed using particle tracking or simulations of contaminant transport.

- Saline intrusion risk due to the project was simulated using a 2D cross sectional model of density dependent flow. While this is a reasonable simplification necessary to assess the computationally difficult simulation of density dependent flow, no uncertainty analysis was conducted in the assessment. An extension of the saline intrusion risk assessment that includes alternative model parameter values to better explore predictive uncertainty is recommended.

6.1 Requirements for Response to Submissions

To address these gaps on SEARs requirements the following inclusions are requested in the response to submissions document:

1) An updated description of the conceptual model of groundwater flow that addresses the complexity of groundwater recharge in urban settings with surface alterations and groundwater leakage to and from sewers and water supply infrastructure; the impediment that recharge complexity poses for model calibration to transient water level observations; and the limitations of the existing groundwater observation data set to constrain the uncertainty in model predictions.
2) An updated set of groundwater model predictions, based on a revised model parameterization that reflects the highly heterogeneous conceptual model of hydraulic properties and recharge, using a highly parameterised model with pilot points or model grid scale parameterization, and a range of model parameter values that spans the full four orders of magnitude observed in packer tests.
3) An updated predictive model that includes drain boundary flow rate constraints to represent the action of adaptively applying waterproofing measures to restrict local groundwater inflow rates to reasonable values. These could be based on the (Haack, 1992) Class 2 or 3 watertightness criteria as used in many other tunnelling projects in Australia. Combined with improved predictive uncertainty analysis this could provide more confidence in the proposed groundwater impact management plan.
4) An updated assessment of project groundwater risk based on a statistical analysis of alternative predictions made using an ensemble of parameter sets that reflect the local scale parameterization and range of plausible parameter values discussed in point 2 above.

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By Email:

Dear ,

Review Surface Water aspects of the Beaches Link and the Gore Hill Freeway Connection Environmental Impact Assessment

This document summarises my expert review of the surface water aspects of the above-mentioned Environmental Impact Statement (EIS) as engaged by the Department of Planning, Industry and Environment (DPIE).

I (Mr Brett Miller) have undertaken this review with particular attention paid to:

- Chapter 17 – Hydrodynamics and Water Quality
- Appendix O – Surface Water Quality and Hydrology
- Appendix P – Hydrodynamic and Dredge Plume Modelling
- Appendix Q – Marine Water Quality

In parallel, Dr Kevin Hayley of Groundwater Solutions was engaged as a subconsultant to WRL to provide DPIE with an expert review of groundwater aspects. This groundwater review is provided in a separate letter.

A previous WRL letter (3rd November 2020) provided a consistency review of groundwater and surface water aspects against the SEARS. This letter provides a review of the content in the EIS and provides recommendations.

The surface water and marine water aspects of the EIS that I have concerns about are summarised as:

1. Assessment and monitoring of potentially impacted waterways.
2. Potential changes to waterway baseflows resulting from groundwater changes.
3. Treatment plant and detention basin designs and overflows during larger rainfall events.
4. The depth of contaminated sediment to be dredged using the backhoe clamshell.
5. Monitoring of background conditions within Middle Harbour.
6. Assessment of Middle Harbour long term water quality changes.

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1. Assessment and monitoring of potentially impacted waterways.

Appendix O (Surface water quality and hydrology) has a summary statement that "The project construction is therefore likely to have a negligible impact on the water quality objectives (WQOs), which are currently not being met". While this statement may be accurate for some of the waterways, there is inadequate data to conclude that the WQO's are not currently being met for all waterways or to determine the relative impact during and after construction.

The EIS presents only six water quality monitoring samples in each of the waterways. Only one of these samples was during a wet weather event. All samples were undertaken over a five month period from October 2017 to February 2018. This is an inadequate sample set for determining the existing condition of each waterway. *A baseline water quality monitoring program should commence immediately upon approval to sample regularly, under a range of weather conditions and over an extended period of time including both summer and winter.*

The EIS makes reference to historical reports on water quality stating that various catchments are influenced by sewer overflows. Many of these reports are over ten years old. Sydney Water has spent much of this time undertaking an overflow reduction program and therefore it is uncertain whether these sewer overflows still exist. Council water quality monitoring has not been included in the water quality analysis (particularly relevant for Manly Dam). Reference is made to a 2004 UWS report stating that the Manly Dam catchment includes three sewer overflows and suffers from blue-green algae blooms. I am aware of catchment management improvements (including water management on the Wakehurst golf course) and I am not aware of an algae bloom in Manly Dam for at least a decade. *The assessment of water quality in each catchment should use all available historical data and include recent publications. Where possible assessment should include the long term improvements (or degradation) of water quality. The Response to Submissions Report is required to provide an updated assessment on existing water quality taking into consideration improvements implemented by Sydney Water and/or Council (i.e. as part of overflow reduction or other water quality programs).*

The EIS does not discuss or analyse any impacts directly to Bantry Bay that may result from discharges to the westward flowing steep creeks draining from Wakehurst Parkway. This should be included in the analysis. It is also unclear if these creeks have been included as sensitive environments. *Bantry Bay and these above mentioned creeks should be included in the waterway assessment. Further information to address this deficiency is required to be provided in the Response to Submissions Report.*

Appendix O lists the groundwater water quality sampling. However the table only presents median values, does not specify the range and does not provide the number of samples. *Additional information on the groundwater water quality monitoring should be provided.*

Construction wastewater treatment plants are proposed to reduce the discharge quality to ANZG 2018 standards. In most instances this should protect waterway health. *However, should the longer term monitoring program identify that a waterway presently has quality significantly better than ANZG, then treatment to a higher level will be required.*

Uncertainty exists in the contaminants, concentrations and volumes of groundwater flow and the treatment methods proposed. No discussion as to the technology, space, capacity or energy use of the water treatment plants could be identified in the EIS. *Information on the treatment plant technology and how these treatment methods could be expanded if so required is required to be provided in the Response to Submissions Report.*

2. Potential changes to waterway baseflows resulting from groundwater changes.

Catchment runoff will potentially decrease due to groundwater infiltration, which will in-turn effect the hydrology (in particular base flows) of the catchment streams. This is particularly important for the more natural catchments. The EIS provides inadequate estimates of reduced baseflow based on the groundwater model's prediction of groundwater drawdown.

The EIS does not provide predictions of baseflow reductions during extended dry periods or drought. *For the sensitive, natural waterways, predictions of baseflow reduction should be based on extended timeseries modelling so that flow frequency curves pre and post construction can be assessed on an ecological impact basis for all of the relevant flow facets. Further information on potential impacts from baseflow reductions during periods of extended dry weather or drought conditions are required to be provided in the Response to Submissions Report.*

Statements such "reductions in flow are unlikely to results in a complete loss of aquatic habitat" (for Burnt Bridge Creek) are unacceptable and further modelling and assessment is required.

The groundwater model states that it provides a conservative estimate of groundwater drawdown, however as discussed in the report by Dr Kevin Hayley fractured Sydney Sandstone can result in local areas of higher drawdown. The proponent has committed to limiting groundwater drawdown by constructing the tunnel lining to meet a 1 L/s/km inflow rate. Should this specification be averaged over the full length (or sections) of the tunnel, groundwater drawdown, and hence reduction in surface water baseflows, could be greater than predicted in localised areas. *The 1 L/s/km criteria should be conditioned as being for any point along the tunnel.*

Water balances are provided during the construction stages. However only average daily values have been presented. *The detailed groundwater and surface water balance should address the range of ratios of usage, harbour discharge and groundwater extraction through both dry weather and wet weather periods, with particular emphasis on dry weather and baseflow conditions.*

3. Treatment plant and detention basin designs and overflows during larger rainfall events.

Treatment plants and detention basins will have a particular rainfall frequency or annual exceedance probability (AEP) that will generate inflows beyond the capability of the treatment plants or sediment detention basins to effectively treat or contain. The EIS does not state this AEP nor does it contain any analysis of the water quality impacts of discharges or bypasses during these larger events.

The Response to Submissions should state the design AEP of the treatment plants and the detention basins. The predicted quality of bypass flows should be provided. Any environmental impacts of bypass flows should be assessed.

In many instances, construction and operational discharges during larger events do not have a significant impact because of the additional dilution with other catchment runoff. This may not be the case with Manly Dam where the total mass of sediments and constituents is captured within the dam.

Modelling should be undertaken to assess the cumulative water quality impacts including regular conditions and larger AEP wet weather events.

Sediment detention basins and treatment plants should be designed and operated so that previously captured materials cannot be released or scoured during these wet weather events. *The Response to Submissions Report is required to explicitly state that this will be the case.*

4. The depth of contaminated sediment to be dredged using the backhoe clamshell.

The backhoe dredge with environmental clamshell for removal of the top contaminated sediment will minimise the movement and escape of contaminated materials.

The EIS states that the top 0.5m is contaminated. It is unlikely that testing of materials would be taking place during dredging, so it is imperative that the depths of contaminated materials are accurately known before work commences. *The Response to Submissions Report should clarify what factor of safety would be used for the dredge depth. If the existing knowledge is insufficient, additional bed sediment sampling must be undertaken.*

Continuous real-time turbidity monitoring outside the "moon pool" should be undertaken for the entire period of contaminated material backhoe dredging. Cease-to-dredge operational rules based on this real-time data should be prescribed in advance.

5. Monitoring of background conditions within Middle Harbour.

The EIS is lacking adequate monitoring of the background water quality and physio-chemical conditions within Middle Harbour.

The EIS states that there is limited data for turbidity during wet weather events in Middle Harbour. Collection of this background data should commence immediately for inclusion into operational limit rules.

The physio-chemical conditions of Middle Harbour were only observed twice. This is inadequate for determining the stratification and oxygen levels within the estuary. *I recommend that a minimum one continuously profiling data logging buoy be deployed at the crossing site to monitor temperature, salinity and dissolved oxygen throughout the water column for a period of at least twelve months before any construction commences. This dataset should be combined with additional monthly transects of the estuary similar to those presented in the EIS.*

6. Assessment of Middle Harbour long term water quality changes.

The potential ongoing impact on marine waters in Middle Harbour resulting from the introduction of a sill at the tunnel crossing has not been adequately assessed. Numerical modelling presented in the EIS has shown that the flushing time increases in the bottom of the estuary upstream of the sill and periods of low dissolved oxygen (DO) are extended. The EIS concludes that this increase in minor, however there has been inadequate data to calibrate or verify the model for this condition.

The original current metering program appears to have been designed for calibration and verification of dredge plume modelling. Only later were two water quality transects undertaken to gather information on the potential stratification and flushing. Numerical modelling of mixing in slow moving, stratified water bodies requires appropriate verification data and (due to the inherent uncertainties) should be accompanied by modelling sensitivity analysis. The modelling presented in the EIS has not provided this verification or sensitivity analysis.

The EIS states that flows in Middle Harbour are constricted by the shallow, narrow channel at the Spit Bridge. The argument is made that since Middle Harbour is already constricted, the addition of the sill will not have an impact on flows. However, the tidal range upstream of the Spit Bridge is the same as the tidal range downstream indicating that there is no constraint to flows into and out of Middle Harbour. It is the size of the tidal prism within Middle Harbour relative to the water depths which result in slow water velocities. As such, accurate modelling of slow moving velocities and internal mixing processes is important.

The EIS does not provide any information on the vertical mixing and turbulence methods used in the numerical modelling of Middle Harbour. *This information should be provided for review. Additional sensitivity analysis of vertical mixing and turbulence parameters should be modelled and included in the Response to Submissions Report.*

The EIS states that low DO can occur at the bed while vertical mixing maintains high DO throughout the water column. The presence of any stratification of temperature or salinity will inhibit this vertical mixing of oxygen from the surface towards the bed. Subtle changes in flow patterns may change the amount of energy available to de-stratify the water column, which in turn may result in extended periods of reduced DO near the bed.

The EIS states that based on average rainfall patterns the DO depletion near the bed of middle harbour occurs “a few times per year”. However, adequate monitoring of DO within Middle Harbour has not been undertaken to support this statement. The EIS states that this would be rapidly vertically mixed but no measurements of this mixing rate have been made and numerical model sensitivity analysis on the mixing parameters has not been provided. Further the EIS has not addressed potential changes in lowest DO concentrations and duration of periods when DO levels are below particular thresholds.

The EIS has not adequately addressed the potential for the tunnel sill to change flow conditions to the detriment of water quality in Middle Harbour. Monitoring (discussed at Section 5) should commence immediately upon approval and data used for additional model calibration and verification. Model predictions should include both wet weather and dry weather conditions and uncertainty analysis.

The recommended baseline data of the physio-chemical conditions in Middle Harbour will be suitable for both verification of predictive models and comparison with post construction monitoring. Should either the predictive modelling or the post construction observations indicate deteriorated water quality, *the proponent may need to consider artificial mixing devices (for example mechanical propellors or bubble plumes) to overcome the influence of the sill.* The extended baseline data and the verified numerical modelling would be crucial in the design and optimisation of such a device.

Should any of the points made in this review require clarification, please contact me on
on .

Yours sincerelv*.*

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