Reference number: CB3B
Advice from: Craig Barker
Date of response: 5 September 2019

This advice is in response to request: Following the completion of expert evidence in your area of expertise, provide a brief final report to the IAC no later than five days before closing of the Hearing which complies with the PPV Practice Note – Expert Evidence and sets out:

a. any changes of opinion since your interim report (if any) and the reason for that change in opinion; and

b. your opinion on the latest version of the Proponent’s proposed approval documents (if any) and any other party’s suggested changes to the approval documents.

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List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AECOM</td>
<td>Consulting company</td>
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<tr>
<td>AHD</td>
<td>Australian Height Datum</td>
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<tr>
<td>ANZECC</td>
<td>Australian and New Zealand Environment and Conservation Council</td>
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<td>ARMCA NZ</td>
<td>Agriculture and Resource Management Council of Australia and New Zealand</td>
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<td>AS</td>
<td>Australian Standard</td>
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<tr>
<td>ASS</td>
<td>Acid sulfate soil</td>
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<td>BOM</td>
<td>Australian Bureau of Meteorology</td>
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<td>Coffey</td>
<td>Consulting company</td>
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<tr>
<td>DELWP</td>
<td>Victorian Department of Environment, Land, Water and Planning</td>
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<tr>
<td>ecoMarkets</td>
<td>GHD 2010, Port Philip CMA, Transient model development report, prepared for the Department of Sustainability and Environment, ecoMarkets project</td>
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<tr>
<td>EES</td>
<td>Environmental Effects Statement</td>
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<td>EPA</td>
<td>Environment Protection Authority - Victoria</td>
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<td>EPR</td>
<td>Environmental Performance Requirement</td>
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<tr>
<td>FE</td>
<td>Finite element (computer model)</td>
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<td>FEA</td>
<td>Finite element analysis model</td>
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<td>FH</td>
<td>Angle taken from the horizontal plane</td>
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<td>GDE</td>
<td>Groundwater Dependent Ecosystem</td>
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<tr>
<td>GHD</td>
<td>Consulting company</td>
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<tr>
<td>GIS</td>
<td>Geographical Information System</td>
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<td>GW</td>
<td>Groundwater</td>
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<tr>
<td>Haack</td>
<td>Water leakage class rating devised by Dr. A. Haack (1991)</td>
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<tr>
<td>HydroGeoLogic</td>
<td>Consulting firm</td>
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<tr>
<td>IREA</td>
<td>Independent Reviewer and Environmental Auditor</td>
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<td>IAC</td>
<td>Inquiry and Advisory Committee (for the North East Link Project)</td>
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<td>ISO</td>
<td>International Standards Organisation</td>
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<td>Kh</td>
<td>Hydraulic conductivity (horizontal plane)</td>
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<tr>
<td>km</td>
<td>Kilometres</td>
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<tr>
<td>Kv</td>
<td>Hydraulic conductivity (vertical plane)</td>
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<tr>
<td>L/sec</td>
<td>Litres per second</td>
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<tr>
<td>LIDAR</td>
<td>Light Detection and ranging - remote sensing method</td>
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<tr>
<td>m</td>
<td>Metres</td>
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<tr>
<td>m/day</td>
<td>Meters per day</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>m²</td>
<td>Squared metres</td>
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<tr>
<td>m³</td>
<td>Cubic metres</td>
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<tr>
<td>MODFLOW-USG</td>
<td>Unstructured Grid Version of MODFLOW</td>
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<tr>
<td>MMRT</td>
<td>Melbourne Metropolitan Rail Tunnel</td>
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<tr>
<td>MRI</td>
<td>Manningham Road Interchange</td>
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<tr>
<td>mya</td>
<td>Million years ago</td>
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<td>NELP</td>
<td>North East Link Project</td>
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<tr>
<td>NEPC</td>
<td>National Environment Protection Council</td>
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<td>NHMRC</td>
<td>National Health and Medical Research Council</td>
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<td>NZ</td>
<td>New Zealand</td>
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<tr>
<td>PASS</td>
<td>Potentially acid sulfate soils</td>
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<tr>
<td>PEST</td>
<td>Model-Independent Parameter Estimation &amp; Uncertainty Analysis</td>
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<tr>
<td>PFAS</td>
<td>Per- and poly-fluoroalkyl substances</td>
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<tr>
<td>SCM</td>
<td>Site Conceptual Model</td>
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<tr>
<td>SEM</td>
<td>Sequentially mined excavation</td>
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<tr>
<td>SEPP</td>
<td>State Environment Protection Policy</td>
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<tr>
<td>SON</td>
<td>State Observation Network</td>
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<tr>
<td>SRMS</td>
<td>Scaled Root Mean Squared</td>
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<tr>
<td>SWL</td>
<td>Standing water level (applies to both groundwater and surface water)</td>
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<tr>
<td>TDS</td>
<td>Total dissolved solids</td>
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<tr>
<td>TBM</td>
<td>Tunnel boring machine</td>
</tr>
<tr>
<td>VVG</td>
<td>Visualising Victoria’s Groundwater</td>
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</tbody>
</table>
1. Response to Practice Note Information

(i) Name of expert.
Craig Stephen Barker, 11 Glen View Close, Diamond Creek, Victoria, 3089

(ii) Expert's qualifications and experience.
B. Eng. (Honours), Civil Eng., M. Eng. Stud., Geotech. Eng., FIEAust CPEng NER APEC Engineer IntPE(Aus)) - Civil College, NER, No: 100466, RPEQ; and
Statutory Environmental Auditor (Contaminated Land) – Victoria (appointed pursuant to the Environment Protection Act, 1970).

(iii) The expert's area of expertise to make the report.
Currently work in my own private engineering consultancy firm, which conducts geotechnical investigations, groundwater investigations and contaminated land investigations.

As a current Statutory EPA Environmental Auditor within the State of Victoria and having been previously, a Statutory Environmental Auditor within the State of South Australia, I routinely deal with complicated groundwater and surface water interaction issues.

Worked on the Stockland Point Lonsdale Residential & Waterways Project, Victorian State Planning Panel Submission and Hearing, where I provided technical support to the key witness at Golder Associates, across issues of groundwater, surface water and land contamination.


I have a Masters of Geotechnical Engineering Studies from Sydney University.

I am a Fellow with the Institution of Engineers Australia and a Member of the Australian Geomechanics Society.

(iv) Any other significant contributors to the report and where necessary outlining their expertise.
There were no other contributors.

(v) All instructions that define the scope of the report (original and supplementary and whether in writing or oral).
IAC request to prepare this report on groundwater issues as per letter of 14 May 2019.
(vi) The identity of the person who carried out any tests or experiments upon which the expert has relied on and the qualifications of that person.

None.

(vii) The facts, matters and all assumptions upon which the report proceeds.

- The North East Link Project (NELP) Environment Effects Statement (EES);
- Expert Witness Reports;
- Written Submissions to the EES;
- Information meeting attendance with applicable NELP technical and planning staff in relation to cross-related Groundwater aspects held on 9 July 2019 at NELP Offices, Melbourne;
- Arranged bus tour of proposed Tunnel Alignment as arranged through NELP, dated 12 July 2019;
- Groundwater Conclave Attendance on 26 July 2019;
- Hearing Attendance across the following dates:
  - 21 June 2019 – Directions;
  - 25 July 2019 – Day 1;
  - 5 August 2019 – Day 8;
  - 8 August 2019 – Day 11; and

(viii) Reference to those documents and other materials the expert has been instructed to consider or take into account in preparing his or her report, and the literature or other material used in making the report.

- NELP EES Summary Report
- NELP EES Main Report Volumes – Chapters 1 to 28
- NELP EES Technical Report M – Ground Movement
- NELP EES Attachment III Risk Report
- NELP EES Attachment IV Stakeholder Consultation Report
- NELP EES Attachment V Planning Scheme Amendment
- NELP EES Attachment VI Works Approval
- NELP EES Map Book
- NELP Environmental Performance Requirements (EPRs) for the project
- Expert Witness Statements
• Mr. Hugh Middlemis (for NELP);
• Mr. Chris Smitt (for Manningham City Council);
• Mr. Peter Oxnam (for Carey Baptist Grammar School).

Public Submissions to the EES

Peer Reviews


• Relevant NELP issued Technical Notes.

References (refer to detailed list below).
(ix) A summary of the opinion or opinions of the expert.

In reviewing the EES documentation as outlined under Point (viii), I have formed the following opinions:

- The hydrogeological and numerical modelling (groundwater) assessment for the NELP generally meets Best Practice criteria for a Major Project such as this;

- The groundwater assessment is generally fit for purpose, in regard to achieving the EES scoping objectives, where it sets up a suitably detailed Site Conceptual Model for groundwater and surface water interactions across a suitably defined Study Area, which not only includes the project area, but a significant zone beyond;

- The groundwater assessment allows the NELP designers and Reference Project license issuers/reviewers to establish key environmental aspects for consideration across the project alignment, suitable EPRs for the protection of such aspects and the planning for future deployment of monitoring and management strategies linked to EPRs;

- The Regional Numerical Groundwater Model is extensive and well designed, working to the guidance provided across more recent Best Practice methods (which include use of sensitivity analysis, uncertainty analysis and the impacts from short and long term climate change effects on both the Study Area and the Reference Project’s impact to the Study Area;

- Quantitative impact estimates have been provided on the projects impact to the Study Area across both construction and operational stages, where groundwater system inflows into the tunnel void, changes to groundwater levels and stream flow to aquifer exchange flux has been estimated. Modelling predictions across these outputs has importantly considered modelling uncertainty, where matched probability of occurrence is provided for these parameters. This has allowed a suitable appraisal of project risk to the environment to then be conducted using well informed estimates of ‘likelihood’ of a risk event, where ‘consequence’ of a risk event can also be more accurately appraised from the modelling outputs;

- Ongoing groundwater monitoring and groundwater model refinement is required as project investigations continue to proceed with more detailed project design; and

- The EPRs as suggested are expected to suitably allow for the final design, construction and establishment of operational methods to minimise groundwater inflows into the tunnelling project and matched changes to groundwater levels and base flows to rivers/creeks and sensitive surface water features.
(x) A statement identifying any provisional opinions that are not fully researched for any reason (identifying the reason why such opinions have not been or cannot be fully researched).
None.

(xi) A statement setting out any questions falling outside the expert’s expertise, and whether the report is incomplete or inaccurate in any respect.
None.

(xii) Declaration
I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the IAC.
2 Key issues

(i) Question
Are there any changes of opinion since your interim report (if any) and the reason for that change in opinion?

(ii) Response
Following the issue of my Interim Report dated 24 July 2019, I have no changes of opinion that were outlined within my Interim Report. The list of outstanding requested items that were shown within “Table 1 – Summary of Outstanding Information Requests” from my previous Interim Statement have been provided and have been suitably reviewed and addressed, where my opinions have not altered.
3 Key Issues

(i) Question
What is your opinion on the latest version of the Proponent’s proposed approval documents (if any) and any other party’s suggested changes to the approval documents?

(ii) Response
The EES scoping requirement involved considering ‘Catchment Values’ – ‘To avoid or minimise adverse effects on the inter-connected surface waters, groundwater and flood plain environs’. The topic of groundwater is also closely linked-in with the topics of ‘Ground Movement’ and ‘Ecology’.

Key project-wide issues raised from the EES with respect to ‘Groundwater’ include:

- Undrained tunnel structures (such as the northern ‘Trench’ structure (within ‘Reach 2’), may only prove cost-effective, provided collected groundwater seepage inflow water can be suitably disposed of under a permitted action into the long-term (this is now a regular problem seen in Melbourne with the various Water Authorities). In some Councils and for some Water Authorities, a fully tanked solution is often required;

- For TBM tunnels a Haack Rating of 3 is proposed (the same class of water proofing proposed for the Melbourne Metropolitan Rail Tunnel (MMRT) from its EES. For areas of proposed trench or cut and cover construction (associated with the MMRT East and West portals and associated rail decline structures) and station boxes at: Domain, Parkville and Arden, excavations at these areas were to be tanked to a final Haack rating of 2. For the NELP, all areas of trench, cut and cover and cross passages are proposed to be rated Haack 3 (justification on this difference in water proofing class between the projects should be provided). Haack Class 2 is often specified for road tunnels, where the risk of frost forming may prove to be a road traffic hazard.
  
  o Has this risk been properly considered in specifying a Haack rating of 3 for the entire tunnel?
  
  o Once construction of these smaller cross/void structures is completed, they are planned to be suitably tanked to a proposed Haack rating of 3. The MMRT project (in its EES), proposed to construct similar cross passages to a Haack rating of 2. Justification is required on why these cross-passage structures should not be more effectively water-proofed to a Haack rating of 2 (where people may be required to pass through these cross passages for servicing and emergency evacuation).

- Mention is made of using mitigation measures such as grouting of the tunnel line (either from within the tunnel or from the ground surface). The IAC should seek further information on how this grouting is to be achieved; including what magnitude of investigations have been, or will be undertaken to determine:
Where grouting or ground freezing may be necessary, to mitigate against unacceptable groundwater inflows, and types of grouts planned;

The expected application pressures which will be acceptable to achieve effective grout placement and groundwater inflow mitigation;

The identification of conditions which might give rise to undesirable grout excursions and plans to monitor/detect against this event from occurring; and

The limiting grout pressures which may apply as consequence of surrounding sensitive buildings and infrastructure.

- There has been no attempt at modelling (i.e. through a sensitivity analysis) of the effects of significant anisotropy of the bedrock/basement (Silurian siltstone) away from the normal anisotropy considered between horizontal plan-direction and vertical direction (which has been considered by the current numerical modelling). Whilst the modelling of a significant difference between assumed horizontal hydraulic conductivity vs vertical hydraulic conductivity has been modelled (the order of 1,000 times less for vertical conductivity). The bedrock typically has a significant and consistent folding/faulting pattern when regional geology is considered.

  - Such (steeply dipping) rock bedding anisotropy is expected to have a significant effect on the distribution of aquifer drawdown, where for planning purposes for structures/buildings/services, such potential effects should be accounted for;

  - Rock layering and bedding will also in a similar manner, influence flow exchange and aquifer mounding; and

  - The MMRT project encountered significant effects from siltstone rock anisotropy (i.e. the St Pauls Cathedral aquifer pumping test). Whilst NELP have cross-referred to MMRT when quoting general ranges of hydraulic conductivity for siltstone / basement rock, such anisotropy effects as encountered with the Melbourne Formation siltstone have not been addressed in any significant detail in the NELP EES.

There is a lack of discussion of plans for improved / targeted drilling investigations to expose presently unobserved geological conditions, steep dipping fracture zones and structures likely to create anisotropic depressurisation patterns for the bedrock aquifer. Such plans need to work in with surface-based observations of geology and key features (surface inspections, rock and joint set/fault mapping, uses of historical geological plans, published reports, etc);

- For the Palaeozoic basement rocks (siltstone) in terms of the potential range for hydraulic conductivity, it’s estimated at over six orders of magnitude from the EES. There has now been considerable / upgraded groundwater response monitoring and modelling from large scale pumping with the MMRT – why cannot this response information and upgraded information for Melbourne Formation siltstone be brought immediately into the NELP project through state government cooperation?
• If the relocation of major utilities (such as the Bulleen Road Sewer) are to occur prior to major tunnelling works, how can the IAC be assured that suitable EPRs would be applied to this dewatering action if such works are completed under an ‘Early Works’ separate contract, where such EPRs may not apply (such a contractual situation occurred with the MMRT – critical service re-locations were conducted outside of the main Design and Construct Contract). Will the impacts from micro-tunnelling actions (such as what is proposed for the Bulleen Road Sewer) be groundwater modelled with future stages?

• Further justification and proving needs to be provided, as to why the Yarra Flood Plain Alluvium should only be modelled as one uniform layer (as it is under the current EES Regional Numerical Groundwater Model). When considering local project interaction effects with important surface water bodies (such as the Bolin Billabong) such broad assumptions are expected to have considerable influence possibly resulting in a ‘structural model uncertainty’;

• Calibrating the model with respect to monitored standing groundwater levels (SWLs) across the EES-based network of 69 monitoring bores has only been conducted to the April 2018 Groundwater Monitoring Event (GME):
  o The April 2018 GME is related to a significant climate ‘dry’ period’ (drought level);
  o Due to the lack of Study Area historical water bore information, calibration of the EES numerical model to higher rainfall periods and higher observed groundwater levels has not been undertaken (attempts to do so have involved historical water bores in other types of rock geology, located at significant distances from the Study Area);
  o Comparison of predicted standing water levels (SWLs) from the EES model to the April 2018 GME data often show a SWL difference of up to between 3 m to 5 m (seen by myself as significant) – The current model seems to be struggling to accurately model spatially on groundwater drawdowns through the geology;
  o Calibration of the model in terms of transient observed response has only been attempted across the three locations of constant rate extraction aquifer pumping tests (all in siltstone) located at:
    ▪ Borlase Reserve, Yallambie – siltstone geology;
    ▪ Kim Close; Bulleen - siltstone geology; and
    ▪ Bulleen – siltstone geology.
    Aquifer pumping tests have all been targeting the siltstone response, where response through the lower alluvium is not well understood;
  o There is a current / significant calibration gap with respect to suitable transient (time) related response for the current numerical model; and
• Higher regional groundwater levels will result in higher groundwater seepage rates to the tunnels and greater predicted drawdown areas – yet there is currently no suitable model calibration to a higher regional groundwater scenario.

• The numerical groundwater model should have catered for the impact of Melbourne Water’s Yarra Main East (i.e. permeable trench backfill), where it sits below the estimated upper aquifer system (in siltstone) – follows along the alignment of the Yarra River and Plenty River, but sits within Bulleen Road (mainly siltstone geology) and Templestowe Road (perhaps alluvium more so along Templestowe Road, so possibly not modelling here is a more justified action);

• Private water extraction bores located at:
  o Loyola College: WRK078524 drilled to 113 m below ground surface level (bgs) in 2015 (recent) – 125 mm diameter water bore in siltstone; and
  o WRK958500 – 25 m bgs deep bore drilled in 2007 (Marcellin College Sports Field).

  These bores are within siltstone and are likely to have a significant effect on drawdown response. They should be understood in terms of their physical setting and operation. More generally, a detailed bore survey (both registered and unregistered (by letter drop, unlicensed bore ‘amnesty’ offer and information door knock) is likely to yield better quality information on:
  o Water bore presence and groundwater yields;
  o Groundwater quality; and
  o Typical water extraction rate and use.

• There remains a limited understanding of the connectivity between both small creeks and major rivers (Yarra) and upper aquifer system, but for the general premise that groundwater feeds the lower reaches of the creeks and the Yarra River.

• Table 7-1 Groundwater Risks: Certain residual risks as currently rated seem to be rated too low:
  o Risk GW02: Construction – too low, given lack of quality data on surrounding groundwater users in the region;
  o Risk GW04: Construction - Dislocation of delineated contaminated groundwater plumes (there is also the risk of smearing existing contaminants vertically downwards, that can increase vapour risk levels;
  o Risk GW05: Construction, based on current discussions and viewed correspondence by the Author with EPA, Melbourne Water and Yarra Valley Water this risk may be downplayed for such a Major Project;
  o Risk GW07: Operation – too low, given lack of quality data on surrounding groundwater users in the region;
Risk GW09: Operation - Dislocation of delineated contaminated groundwater plumes (there is also the risk of smearing existing contaminants vertically downwards, that can increase vapour risk levels; and

Risk GW11: Operation, based on current discussions and viewed correspondence by the Reviewer with EPA, Melbourne Water and Yarra Valley Water, this risk may be set too low.

- In relation to assessing groundwater contamination within a fractured rock aquifer, which often has preferred flow pathways that are hard to identify, predict and model, the ‘normal’ types of hydrogeology ‘rules’ and theories when considering a homogeneous / uniform aquifer system do not normally apply. Enhanced groundwater contamination migration and movement in fractured rock is very likely to be a more topical issue (from my recent Melbourne CBD experience in relation to MMRT);

- The sustainability of some of the suggested mitigation strategies for the protection deep pools at the Bolin Bolin Billabong seem questionable. Suggested potential reduction in the contributing base flow to the Billabong here is up to 5.5 % construction, moving back to 3 % long term (Operations) – from current groundwater modelling prediction;

- Long-term groundwater monitoring beyond the two-year period from project post-construction is currently not proposed. This time period seems quite low given the tight geology (fractured rock) involved and anticipated long aquifer recovery times expected;

- The IAC should seek information on how and how quickly any inadequacies in achieving the Environmental Performance Requirements (EPRs) could be implemented during the Construction Phase, should needs arise despite applying the mitigation measures set out in the EES;

- General policing of the Groundwater EPRs is a key question.
  - Where is the requirement of an independent and suitably trained, experienced Environmental Auditor in the process, to assess and regulate EPR compliance?
  - Regulatory groups such as EPA or DELWP are unlikely to have the internal resources to police EPRs; and
  - There is also the aspect of making the final Design and Construct Consortium, strictly work under the guidance of a suitably competent and independent Auditor – For other recent Major Victorian Projects (MMRT, West Gate Tunnel), the requirement for a Statutory EWPA Approved Environmental Auditor to serve this role has not been called for.

The project would greatly benefit from this (use of a Statutory EPA- Appointed Environmental Auditor), if it were implemented (by way of the Auditor being truly independent in the process and directly answerable to EPA).
Further discussion across these above issues is covered in more detail across the following discussion topics:

- Geology / Hydrogeology;
- Planning to Answer EES Objectives;
- Risk Assessment Process;
- Site Conceptual Model – Water Balance;
- Regional Numerical Groundwater Model Design;
- Groundwater Model Calibration / Sensitivity;
- Groundwater Model Predictions;
- Modelling for Climate Change;
- Handling Uncertainty & Model Limitations;
- Modelling Peer Review;
- Project Risk Profiles; and
- EPR Discussion.

(iii) Question

In documents dated 18 June 2019 and 24 July 2019, you identified a number of issues which you considered to be the key issues arising from the proposed North East Link Project relevant to your expertise and falling within the scope of the IAC’s Terms of Reference.

If your list above differs from the list previously provided, please provide a brief explanation for the change.

(iv) Response

There are no significant differences (see the discussion above).
4 Geology / Hydrogeology

The NELP is to be constructed through a range of natural geological strata. Basement rock (steeply dipping siltstone/sandstone) is of Middle Palaeozoic age, belonging to the Silurian and Devonian periods (354 to 441 million years ago (mya)). This is overlain at certain areas by Tertiary/Quaternary rock (2-65 mya). Anderson Creek Formation (early Silurian) rock outcrops in the north-east (around Warrandyte). Melbourne Formation (late Silurian (418 mya)) basement rock is found south of Warrandyte and within the Melbourne CBD. These Silurian and Devonian rocks were folded into a series of anticlines and synclines in the Middle Devonian (about 380 mya). Following this, the bedrock was intruded in places by plutonic rocks (granite family of Late Devonian age).

Following the end of the Devonian, there was a long period of weathering and erosion across 300 million years. Then, in early Tertiary times, large block-faults produced a wide shallow depression, known as the Port Phillip Sunkland. Port Phillip Bay and its immediate land surrounds are located within this feature, where this block is bounded to the east by the Selwyn Fault and across to the west by the Rowsley Fault. Overlying the Werribee Formation (Tertiary) is a thick sequence of Tertiary basaltic lava (Older Volcanics). These occur in the north from Bundoora to Greensborough. In many places these lavas are highly weathered. They are thought to have sourced from eruptions in Eocene and Oligocene Periods (30-55 mya) and may have been associated with the block faulting forming the Port Phillip Sunkland. Dykes, which are intrusions of igneous rocks filling wide fissures in rocks, thought to be associated with the Older Volcanics - are visible in places of the Eastern Freeway (penetrating through Silurian siltstone).

The ‘Nillumbik Terrain’ (across the north and east of Melbourne) as described by Neilson (ref. 9) is an erosional landform cut into the folded Silurian rock. This feature is overlain in some places by almost flat lying, ferruginous Tertiary sands (‘Brighton Group’) which cap hills in certain places (i.e., Kew, Camberwell and Heidelberg). The Yarra River, Gardiners Creek, Plenty River, Diamond Creek and their associated tributaries have deeply cut, old valleys through the Tertiary deposits, into Silurian bedrock (leaving only remnants of these Tertiary sands across isolated locations). The Yarra River emerges from Warrandyte Gorge to a mature, broad, alluvial valley at Templestowe and Heidelberg (wide alluvial flats, subject to flooding). These valleys have originated from downstream damming lava flows (Newer Volcanics), that had flowed down the ancient valleys of Merri Creek and Darebin Creek, into the ancient valley of the Yarra River.

Basement (Silurian) rock consists of a series of wave/folding (average wavelength of 1.2 km) where two key anticline features bound the general project area (Templestowe and Whittlesea). Major syncline features for the project area are the Bulleen and Greensborough Synclines. The general strike of these folds across most of Melbourne is suggested at North 20° to 25° East. Rock folding is accompanied by minor faults, where small reverse strike faults and transverse faults are common. The closest known major fault is the Selwyn Fault, which has a general North 20° East trend, which passes up the eastern side of Port Phillip Bay (from Dromana to Frankston). To the west of this fault, folding of basement rock is typically on a North 20° East strike. The Brushy Creek Fault (near Wonga
Park) runs sub-parallel to the Selwyn Fault and is thought to be a subsidiary movement to the Selwyn Fault.

The basement rocks consist of tightly folded siltstones and sandstones of low porosity, which generally have little potential as a water bearing media, but locally open joints and rock fractures can produce significant water volumes. Where these rocks outcrop, associated groundwater occurs in an unconfined state and where the rock is overlain by the Cainozoic layers it tends to be confined. Aquifer characteristics are not well known for basement ‘siltstones’:

- Pumping tests conducted within the Melbourne Formation at two sites located in Kings Domain, Melbourne, suggested for rock with fractures, a hydraulic conductivity (K) value of 0.56 m/day and for more intact rock (i.e., unfractured) a K value of 0.014 m/day (Robinson and Kenna, 1992). Hancock (1992) reported K values between 0.001 to 0.3 m/day along the Melbourne Warp feature. Hydraulic parameters vary according to the degree of fracturing and weathering;
- Water bore yields can be typically less than 0.6 L/sec, but higher bore yields are possible where the rock is highly fractured and/or deeply weathered;
- Groundwater salinities can widely vary out to total dissolved solids (TDS) of 11,000 mg/L, where the groundwater is sodium chloride dominant in shallower groundwater zones, but deeper into the aquifer, magnesium chloride often becomes the dominant salt;
- Weathering depth of this siltstone rock is highly variable and can range from only a few meters to greater than 50 m in depth; and
- Fresh siltstone (deeper into the formation) can also contain pyritic material.

The NELP Project geotechnical and hydrogeological investigations to-date show:

- Inter-bedded siltstone/sandstone, folded on a general north to north east trending axis (matched to the above geological observations), though to be associated with faulting and some intruded dyke zones:
  - Project drilling has shown that beneath the Yarra Valley sediments, there are a several potentially thick, high persistent faults, comprising crushed rock, sand and clay derived from parent siltstone;
  - No dyke intrusions through the siltstones (from current drilling investigations) have been encountered; and
  - The siltstones are deeply weathered, often to 30 m depth, but weathering and rock strength can be variable.
- Yarra Valley Alluvium may attain thickness of generally between 9 m to 15 m (at places up to 21 m thick) across river flats up to 1.6 km wide:
  - The lower beds of this alluvium are considered as lacustrine, deposited when the river was lake dammed by the downstream lava flows;
Higher flow energy lenticular river channels of sands and gravel may also occur through these alluviums;

- Near Manningham Road, there are a series of interpreted east to west draining, ancient alluvial ‘paleo-channels’, stranded from the continued down-cutting of the Yarra River. The channel in-fill material is believed to be Brighton Group clayey sands. To the south of Manningham Road (near Ilma Court) there are also in-filled drainage channels (Miocene alluvium) close to the proposed project tunnel ‘crown’.

(i) **Question**

Please include a brief summary of the key issues raised by submitters. If you refer to a particular submission please refer to the submission by number and not by the name of the submitter.

(ii) **Response**

Refer to the comments as raised in the other Sections.

(iii) **Question**

Where your opinion(s) materially differ from the relevant circulated evidence statements, please briefly outline the difference and reasons for it.

(iv) **Response**

No differences.

(v) **Question**

Please discuss the magnitude, likelihood and significance of adverse and beneficial environmental effects.

(vi) **Response**

I am of the opinion that, there is potential for unanticipated variance in the geological conditions along the Project alignment, which could result in the use of inappropriate tunnelling or excavation techniques. This may result in higher than expected groundwater inflows to excavations and respective groundwater drawdowns, construction delays, increased ground movements, or possibly all of these in combination. These risks are outlined under my ‘Key Issues’ listing.

(vii) **Question**

Please address the adequacy of the proposed environmental management framework, including the proposed environmental performance requirements and environmental management measures contained in the EES, with reference to applicable legislation and policy.
(viii) **Response**

I am of the opinion that, the proposed EMF and EPRs should suitably serve to understand and manage risk from the project.

(ix) **Question**

Please address the adequacy of the impact assessment and whether the proposed environmental performance requirements are capable of being met.

(x) **Response**

I am of the opinion that the impact assessment suitably understands and caters for the risk of geological / hydrogeological uncertainty and the matched EMF and EPRs can provide a means of suitably understanding this risk and managing it across both project construction and operation.

(xi) **Question**

Please address the question of feasible modifications to the design of the Project within or reasonably proximate to the project boundary that could offer demonstrably overall superior outcomes.

I am of the opinion that:

- Where the project profile is likely to encounter the upper aquifer system, the current ‘Trench’ design proposed with ‘Reach 2’ should also be subject to tanking (waterproofing) to a Haack Class of 3 (similar to other proposed initially ‘cut’ areas for the project). This would provide a superior outcome, in regard to reducing long-term denudation of the siltstone aquifer resource and provide better control in avoiding the enhanced migration of potential groundwater contamination plumes near ‘Reach 3’.
5 Planning to Answer EES Objectives

The following suitable sets of legislation and guidance are referred to by the EES in relation to groundwater:

Commonwealth Legislation
- National Environment Protection Council Act, 1994 (‘NEPC Act’); and
- Environment Protection and Biodiversity Conservations Act, 1999 (‘EPBC Act’).

Victorian Legislation
- Water Act, 1989;
- Environment Protection Act, 1970;
- Environment Protection Amendment Act, 2018;
- Yarra River Protection (Willip-gin Birrarun Murron) Act, 2017;
- Climate Change Act, 2017; and

Various Clauses across the Victorian State Planning Policy Framework have been referred to in relation to the environment (specifically water catchment protection and groundwater).

Key National Australian guidance has been referred to:
- Groundwater Modelling Guidelines, 2012;
- Minimum Construction Requirements for Water Bores in Australia, 2012;
- NHMRC, NRMMC, 2011, Australian Drinking water Guidelines;
- ANZECC / ARMCANZ, 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality;
- NHMRC, 2008, Guidelines for Managing Risks in Recreational Waters;
- MRMMC, EPHC, NHMRC, 2009, Australian Guidelines for Water Recycling: managed Aquifer Recharge; and

The key Victorian State Environment Protection Policies (SEPPs) have also been referred to across the Study:
- SEPP (Water), October 2018, which covers both surface waters and groundwater; and
- SEPP (Prevention and Management of Contaminated Land), 2002;

The following other key Victorian guidelines have also been referred to:
- Ministerial Guidelines for Groundwater Licencing and the Protection of High Value Groundwater Dependent Ecosystems, 2015;
- Environment Protection (Industrial Waste Resource) regulations, 2009;
- Water Industry Regulations, 2006;
- EPA Victoria, 2000, Groundwater Sampling Guidelines;
- EPA Victoria, 2006, Guidelines for Hydrogeological Assessments (Water Quality);
- EPA Victoria, 2014, The Clean-up and Management of Polluted Groundwater;
• EPA Victoria, 1991, Construction Techniques for sediment Pollution Control
• EPA Victoria, 1996, Environmental Guidelines for Major Construction Sites; and

Relevant Australian Standards/Codes of Practice have been referred to across the EES.

The following methodology has been undertaken to address the scoping requirement:
• Study Area identification and documentation of existing conditions;
• Identification of groundwater values (related to existing and potential beneficial uses);
• Conceptualisation of hydrogeological conditions and the potential beneficial uses for groundwater;
• Conduct of a Risk Assessment to identify key issues;
• Conduct of a detailed Regional Numerical Groundwater Model for the Study Area to better predict change response to groundwater associated with the project;
• Evaluation of potential impacts arising from predicted changes to groundwater; and
• Determination of residual risks and the identification of suitable EPRs to address both initial and assumed residual risks.

In defining the Study Area, this took in the entire alignment of the NELP Reference Design, where beyond this ‘Project Area’, the ‘Study Area’ was expanded by an approximate distance of 2 km, to cover a broader area than envisaged from the project’s impact.

• Specific geotechnical and hydrogeological intrusive investigations were however, limited to either within or close to the project area; and
• The broader Study Area used data as obtained generally from ‘desk-top’ research.

Stakeholder engagement leading into the establishment of the Regional Numerical Groundwater Model involved the following parties:
• Consultation was made with Melbourne Water in establishing a suitable 60-year predictive model life (post construction) when establishing the temporal steps for future transient predictions for groundwater response to the project. Discussions included across the Bolin Bolin Billabong and elsewhere across the Yarra River floodplain; and
• The Wurundjeri Council and Board were consulted regarding Bolin Bolin Billabong.

The project objectives for the groundwater assessment are considered to have been suitably addressed, where the related groundwater modelling objectives were also addressed. The Regional Numerical Groundwater Model contributes to the achievement of meeting the stated project objectives by:
• Providing predictive groundwater and surface water body effects output that integrates well into the adopted risk-based environmental impact assessment framework of the EES;
• The assessment considered existing and future conditions, likely project impact pathways, matched to a suitable SCM and linked risk management measures;
• The groundwater model was suitable and used Best Practice methods, including the use and reporting of both sensitivity analysis and uncertainty analysis;
• The Regional Numerical Groundwater Model considered across long-term climate change effects with prediction; and
• The model reported quantified predictions, both spatially and across time for alterations of groundwater levels and related river/creek flows for the Study Area; and
• Reporting of consequence and likelihood in relation to expected groundwater impacts were clearly and suitably presented, to allow the nomination of EPRs for the future monitoring, minimisation and management of adverse groundwater-related environmental effects (to suitably address project uncertainty and currently identified groundwater model limitations).

(i) Issues Raised by Submitters

Please include a brief summary of the key issues raised by submitters. If you refer to a particular submission, please refer to the submission by number and not by the name of the submitter.

(ii) Response

See previous discussion.

(iii) Question

Where your opinion(s) materially differ from the relevant circulated evidence statements, please briefly outline the difference and reasons for it.

(iv) Response

No significant differences apart from:
• My as-previous discussed opinion on the controlling effects of anisotropy when it comes to bedded and fractured rock;
• My opinion that alternate groundwater models should have also been considered in parallel to the Regional Numerical Groundwater Model, when considering localised effects of the project of sensitive waterways and other localised project interactions with groundwater.

(v) Question

Please discuss the magnitude, likelihood and significance of adverse and beneficial environmental effects.

(vi) Response

I am of the opinion that:
• Project risks related to groundwater and other associated study disciplines (Ground Movement, Ecology, Contamination) can be suitably identified and managed into the long-term through use of the EMF and linked EPRs;
• The current risk appraisal process is considered too low on certain aspects (refer to my response in Section 3).

(vii) Question
Please address the adequacy of the proposed environmental management framework, including the proposed environmental performance requirements and environmental management measures contained in the EES, with reference to applicable legislation and policy.

(viii) Response
Refer to my provided opinions in the other Sections.

(ix) Question
Please address the adequacy of the impact assessment and whether the proposed environmental performance requirements are capable of being met.

(x) Response
Refer to my provided opinions in the other Sections.

(xi) Question
Please address the question of feasible modifications to the design of the Project within or reasonably proximate to the project boundary that could offer demonstrably overall superior outcomes.

Not relevant to this section.
6 Risk Assessment Process

The risk assessment process aims to address the EES scoping requirements and the Ministerial Guidelines for Assessment of the Environmental Effects under the Environment Effects Act, 1978.

- It appraises both project construction effects and long-term operation effects;
- It systematically identifies the interactions between the project-build elements and activities using the project numerical groundwater model;
- It allows for scaling and differentiation of those higher risks from other lower risk aspects for suitable management and attention;
- It allows for development of the Reference Design, such that it can identify, avoid, mitigate and management environmental risks; and
- It helps to direct and inform EPRs for the management and implementation of project risk controls.

The risk assessment process generally followed that described within AS/NZ ISO 31000:2009, where a combination of risk ‘likelihood’ rating was matched with ‘consequence’ of the risk being studied.

- The risk assessment assigned five key risk rankings related to groundwater risk (‘Negligible’, ‘Minor’, ‘Moderate’, ‘Major’ and ‘Severe’); and
- Consequence criteria considered the extent of impact, its severity and the duration of the impact.

The risk assessment suitably considered geological conditions and preliminary, but quite detailed Regional Numerical Groundwater Modelling predictions were made which some degree of conservatism when considering groundwater effects. EPRs were then established to suitably mitigate identified higher risk aspects back to a suitable residual risk value (then deemed by the NELP designers as appropriate). Multiple iterations were made through the risk identification and appraisal process, as the technical understanding of the Project developed.

The impact assessment process suitably recognised required evaluation objectives and set out a suitable understanding of existing conditions. It looked to suitably identify the values associated with groundwater (who and what is utilising an environmental aspect in the Study Area?). A suitable and through hydrogeological conceptualisation of the Study Area was completed. The process suitably considered the proposed Reference Design built elements and how these will interact with the Water Cycle for the Study Area:

- Groundwater level changes (drawdowns or water mounding increases due to ‘aquifer damming’ effects);
- Exposure of potentially acid sulfate soil (PASS)/ or acid siltstone rock from groundwater dewatering;
- The impact of change to effective ground stresses from dewatering and its associated effects on soil and overlying buildings/structures (process of sediment consolidation);
With changes to the hydraulic gradient of the aquifer, the disruption to existing land contamination areas along the project alignment (groundwater contamination and mobilisation of soil vapour contamination); and

Changes to groundwater quality from alterations to the groundwater regime.

In considering ‘consequence’, suitable recognition of groundwater/water abstraction benefit, base flow to waterways/creeks/swamps, water use by deep-rooted vegetation, the impacts from aquifer depressurisation/consolidation of sediments and disruption to contaminated land sites or acid sulfate soil (ASS) / PASS areas has been made:

- In considering aquifer drawdown impacts, the guidance from the Rural Water Corporation 1993, has been referred to. For a poorly defined aquifer system (such as the main two aquifer systems in the Study Area) an upper limit for aquifer drawdown of 10 % reduction of the available drawdown length in a well (to pump intake level under the non-pumping condition) is used;

- For GDE’s the DELWP, 2015 Ministerial Guidelines are referred to, which rates the consequence of licensed groundwater impact using a three-tiered approach from ‘Minor’ to ‘Significant’. For non-licensed groundwater extraction (such as what would occur with this project’s groundwater influence into the long-term (beyond construction), reference has been called across to the Ecology portion of the EES Study;

- For the consideration of streamflow impact the DELWP, 2015 Ministerial Guidelines are referred to, which rates using a three-tiered approach from ‘Minor’ to ‘Significant’ across flow reductions (for licensed extraction). For non-licensed water extraction (such as what would occur with this project’s groundwater influence into the long-term (beyond construction), reference has been called across to the Ecology portion of the EES Study; and

- Impacts from sediment depressurisation and consolidation, contamination migration and PASS/ASS mobilisation are suitably discussed elsewhere in the EES documentation.

(i) **Issues Raised by Submitters**

Please include a brief summary of the key issues raised by submitters. If you refer to a particular submission, please refer to the submission by number and not by the name of the submitter.

(ii) **Response**

Refer to my provided opinions in the other Sections.

(iii) **Question**

Where your opinion(s) materially differ from the relevant circulated evidence statements, please briefly outline the difference and reasons for it.
(iv) **Response**  
No notable differences.

(v) **Question**  
Please discuss the magnitude, likelihood and significance of adverse and beneficial environmental effects.

(vi) **Response**  
Refer to my provided opinions in the other Sections.

(vii) **Question**  
Please address the adequacy of the proposed environmental management framework, including the proposed environmental performance requirements and environmental management measures contained in the EES, with reference to applicable legislation and policy.

(viii) **Response**  
Refer to my provided opinions in the other Sections.

(ix) **Question**  
Please address the adequacy of the impact assessment and whether the proposed environmental performance requirements are capable of being met.

(x) **Response**  
Refer to my responses in other Sections.

(xi) **Question**  
Please address the question of feasible modifications to the design of the Project within or reasonably proximate to the project boundary that could offer demonstrably overall superior outcomes.

(xii) **Response**  
Refer to my responses in other Sections.
7 Site Conceptual Model – Water Balance

The report discusses the Groundwater Cycle, covering key topics across aquifer: recharge, storage, transmission and discharge back into the open environment. The relationship to Groundwater Dependent Ecosystems (GDEs) and groundwater is suitably outlined, where the Proponent points out that the specific composition and natural ecological processes occurring within a specific GDE are greatly influenced by groundwater. Groundwater can contribute baseflow to a wetland or creek/river system, and/or have water taken up through the process of evapotranspiration. Its correctly noted that the degree of dependence may vary temporally (by the seasons) or opportunistically. Groundwater dependence can also be spatially variable within a relatively short distance and will depend on topography, depth to the water table, vegetation rooting depth, soil types and groundwater quality.

The EES outlines how topography can influence groundwater flow regimes and related GDEs:

- Local groundwater flow regimes are associated with local variances in groundwater flow direction matched to local changes in topography (such as emergent springs, or upper wetland areas). These regimes can be very dynamic and change rapidly across the seasons matched to groundwater recharge and local rainfalls; and

- Regional groundwater flow regimes are driven from regional differences in topography and contributing regional recharge and discharge zones. Groundwater under these areas may flow for several kilometres, where the regional groundwater flow regimes are typically deeper, with longer flow paths (and hence less responsive to seasonal variation to groundwater recharge).

In defining existing conditions across the Study Area, the SCM aimed to use all available and relevant data:


- From the NELP Geotechnical Investigation, available data up to the point of the EES write-up covering: core drilling/sampling, soil sampling and laboratory testing, geophysical assessment, downhole packer testing of investigation drill holes, groundwater monitoring well construction and development records, aquifer testing (rising or falling ‘slug’ tests and large scale pumping tests), groundwater level gauging and groundwater sampling and laboratory analysis. Up to the end of June 2018 and mainly along the NELP project area/alignment the following key works had been completed feeding into the hydrogeological study:
  - 110 geotechnical investigation boreholes;
  - 70 groundwater monitoring wells;
  - 30 bores subject to aquifer slug tests;
  - 62 bores had been subject to downhole packer testing; and
  - 33 groundwater monitoring wells had been field sampled and laboratory test
The developed SCM for the Regional Numerical Groundwater Model was based on all available data as collected by the proponent up to the end reporting period of the EES (31 July 2018). It is viewed by the Author as consistent with the study objectives and stated target confidence level classification. The described SCM is considered generally consistent when considering modelling objectives and required target model confidence level classification for EES use.

A reasonable approach to spatial variability of as-measured aquifer response parameters was made across:
- Hydraulic conductivity (horizontal and vertical);
- Yield / Storage; and
- Stream bed conductance.

The modellers provide some limited amount of justification to the simplification of suspected anisotropy effects for groundwater flow and storage within both the alluvium layer and siltstone rock layers, however this is more directed to the basis of a regional water balance understanding for the Study Area. The Author has concerns that the current model may not suitably account for anisotropy effects when considering more localised impacts from the project (either in relation to certain surface water bodies, or when considering aquifer drawdown prediction).

Discussions with the modellers suggested that they did consider alternative SCMs and investigated the merits of these options early in the EES study, but it was considered at that time, the Regional Numerical Groundwater Model could handle predictive use, both across the Study Area in general (when considering impacts to the Yarra River) and more local impacts (such as for Bolin Bolin Billabong). The Author notes some of the ‘Limitations’ as stated by the modellers in the report regarding this (where the dual usage may appear to be questionable).

Description of Project Segments

It is useful to divide the project alignment into what the EES describes as 11 nominated study ‘Reaches’ of the project (from the ‘Ground Movement’ Technical Appendix M):

Reach 1: M80 Ring Road to Watsonia Railway Station

Involves mainly surface works at the M80 Ring Road/Greensborough Bypass intersection with Greensborough Highway, where road carriageways start their cut into the ground surface near Watsonia Railway Station. Site geology consists of thin residual clays over highly weathered Silurian siltstone, with a deeply weathered profile down to 15 m to 25 m bgs.

Reach 2: Watsonia Railway Station to Northern Tunnel Portal

Involves general open cut trenching, which will extend to a maximum depth of 13 m bgs. Several cross-connecting viaduct or bridge-type overhead structures are also proposed. Site geology consists of extremely to highly weathered Silurian siltstone/sandstone.
Reach 3: Northern Tunnel Portal to Lower Plenty Road

Involves 1.4 km of cut and cover construction, to extend to a maximum depth of 35 m bgs at the tunnel portal. Site geology consists of extremely to highly weathered siltstone. It is likely that there is a steeply dipping fault zone, just north of Lower Plenty Road.

Reach 4: Lower Plenty Road to Banyule Flats

Involves placement of twin TBM cut tunnels (each at 15.7 m diameter, spaced at 16 m wall to wall) which will extend (tunnel invert) to a maximum depth of 42 m bgs. Smaller mined cross-tunnels will inter-connect the main tunnels every 120 m (for emergency evacuation of persons). Site geology consists of slightly weathered to fresh siltstone/sandstone with minor dyke ingress and fault zones.

Reach 5: Banyule Flats, Banksia Park, Yarra River

Involves placement of twin TBMs, driven to the north from a temporary portal at Banksia Street. Site geology consists of slightly weathered to fresh siltstone however some moderately weathered siltstone is present near the tunnel crown at certain locations. Near the adjoining Manningham Road Interchange (MRI) which is to be of cut and cover construction, there is the possibility that the tunnel crown may intersect the base of ancient alluvium. There are thick alluvial sediments (15 m thick) overlying the TBM tunnels, which could respond with consolidation settlement if significant dewatering occurs from tunnelling activity. There are also several suspected faults present (variable conditions likely to be encountered).

Reach 6: Manningham Road Interchange, Bulleen

Involves cut and cover across an existing industrial and commercial land use area, to place a large interchange ‘box’ structure to a maximum placement depth of 22 m bgs. Site geological studies suggest that the Yarra River has eroded the toe of east facing siltstone plateau (some 10 high, where the edge slope is approximately 20° from horizontal (FH)). Siltstone is generally moderately to extremely weathered and is overlain in certain areas by old east to west ‘fingers’ of Pleistocene paleochannels (holding Brighton Group sands).

Reach 7: Avon Street to Rocklea Road (SEM Tunnels)

Involves the SEM caverns (road ramps near Golden Way) and sequentially mined excavations forming the twin tunnels across this relatively short intermediate tunnel section. Maximum surface cover depth is of the order of 35 m bgs, where the SEM tunnels are to be of general individual dimension: 14 m wide by 12.5 m high. Site geology at the area of Ilma Court (overlying low-rise residential) shows extremely to highly weathered siltstone, but with infilled paleochannels (Brighton Group sands) near the tunnel crown level that may result in changes to expected mining conditions. Associated alluvium nearby is also up to 8 m thick.

There are faults in the area and weathered dyke features. Key risk features are:

- These openings are expected to have more issues encountered, related to requirements for tunnelling supports and related ground movements; and
- These openings will be constructed as a drained tunnel initially, followed by placements of primary and secondary reinforced concrete tunnel wall seals. As such
more significant aquifer depressurisation will occur at these areas, causing higher consolidation settlement;

Reach 8: Rocklea Road to Bulleen Oval
Involved placement of a cut and cover tunnel to ramp-connect to Bulleen Road. Site geology shows a deeper (21 m thick) alluvium layer and significant faulting within the underlying siltstone (typically slightly weathered to fresh).

Reach 9: Eastern Freeway to Bulleen Road
Involves mainly surface works, with lane widening and construction of a viaduct ramp, where the Bulleen Swim Centre and Boroondara Tennis Centre are to be acquired for construction. Site geology involves river alluvium over thin residual clay and then highly weathered siltstone.

The required relocation of the Bulleen Road Sewer was not accounted for with the Regional Numerical Groundwater Model. This involves the placement of a nine 9 diameter access caisson/shaft, to allow pipe jacking and trenching for the new sewer alignment. It is assumed that this exercise will be undertaken as ‘Early Works’ leading into the main tunnel build.

Reach 10: Eastern Freeway-West
The area is underlain by undifferentiated river alluvium, transitioning across to basalt rock (Quaternary Newer Volcanics) when moving to the west along the Freeway.

Reach 11: Eastern Freeway-East
Involves some significant road widening of the Freeway. Site geology transitions from younger siltstone bedrock into older Anderson Creek Formation siltstone. There is some amount of minor river alluvium associated with Koonung Creek which crosses under the Freeway.

Alternative Design Options Being Considered to the Reference Design
Several alternative design options are mentioned within the EES:

- MRI: Involving lowering of the alignment of the TBM tunnels and the MRI by a further 2 m;
- Northern TBM Launch Option;
- Banksia Park TBM Retrieval Shafts:
  - There is an alternative proposal for two, separate TBM retrieval shafts to be located on the north side of Bridge Street, Banksia Park;
  - These shafts (which would be constructed before the MRI construction) are estimated to be of approximate plan size: 25 m wide x 50 m long and will be between 30 m to 34 m bgs; and
  - The EES considered consolidation effects from soft soils at this area from the shaft dewatering operations (dewatering expected to occur 9 months before nearby MRI dewatering commences).
Project Dewatering Risk - Construction

Key dewatering risk aspects are mainly related with the project’s construction include:

- Placement of the road tunnels (through TBM methods and more-traditional SEM tunnelling). TBM tunnelling is proposed across Reaches 4, 5 and 7;
- Placement of the TBM launch and retrieval portals (Lower Plenty Road (Reach 3) and Banksia Street/Manningham Road (Reach 6). These involve the use of cut and cover drained excavation/tunnelling methods. Whilst certain associated ground support mechanisms with cut and cover construction (such as diaphragm walls, continuous secant concrete or steel supported piles and wall toe grouting methods) can help to limit groundwater inflows to the excavation, due to the time-scale of construction, these excavations essentially act as a ‘drained’ tunnel across construction, until more complete water-proofed lining (tank) is added towards the end of construction; and
- Cut and cover or normal trench excavation methods across Reaches: 2, 3, 6 and 8. Again these reaches would effectively act as a drained excavation across construction, until final tanking controls are in place (The trench which is expected to intersect upper groundwater at Reach 2 is currently not proposed to be tanked into the long-term).

The magnitude, location and extent of dewatering impact to the aquifers are mainly influenced by the following construction factors:

- **Tunnel Design and Water Tightness.** Tanking of the structures prevents significant water ingress, thereby minimising surrounding changes to groundwater levels. For the project, a targeted water-tightness criteria for the Reference Design of Haack Class 3 (after Haack, 1991) is proposed, which allows the following typical permissible leakage rate over two differing measures:
  - 0.2 L/m² within a 10 m reference length of structure; or
  - 0.1 L/m² within a 100 m reference length of structure.

Haack Class 3 is normally applicable for route sections of traffic tunnels for which a water tightness of Haack Class 2 is not required (such as at transit hold points or walkways, where persons are more openly exposed to the tunnel area). Haack Class 3 requires ‘The patches of moisture reveal that the wall all of the lining must be so tight, that only isolated, locally restricted patches of moisture occur. Restricted patches of moisture reveal that the wall is wet, leading to a discolouration of a piece of blotting paper or newspaper if placed upon it – but no trickling water is evident.’

The EES documentation does not call up the use of Haack Class 2 water-tightness in any of the Reference design. Haack Class 2 requires ‘The wall of the tunnel lining must be so tight that only slight, isolated patches of moisture can be detected on the inside (e.g., observed as discolouration). After touching such slightly moist patches with a dry hand, no traces of water should be detectable on it. If a piece of blotting paper or newspaper is placed upon a patch, it must on no account become discoloured as a result of moisture absorption’. This higher degree of water-proofing is normally called up for frost-endangered sections of traffic tunnels (the Haack rating comes out of Europe) and station tunnels. It is noted that with the proposed East-
West Link Tunnels, a generally similar level of water-tightness for the road tunnels was proposed (at < 0.1 L/m² through the tunnel surface (ref. 13). The Author notes that the Haack rating system is a relatively old approach, developed before the more-widespread use of sophisticated lining, sealing and membrane systems for tunnels and should be only treated as a guideline;

- **Tunnel Construction Method:** The use of ‘closed face’ TBMs which utilise earth pressure balance / slurry face tunnelling methods help to reducing groundwater inflow and progressive tunnel material unravelling/cave-in in poor ground. Closed face TBMs utilise a front-end bulkhead behind the cutting tool, which forms a pressurised chamber that may be varied to match inwards ground pressures. As the TBM passes through, behind the main cutting head, pre-cast concrete segmented lining systems with HDPE or similar chemical resistant edge water seals are systematically and rapidly placed by robot arm into place, where the annulus between the rock/soil and the segments are then immediately pressure-sealed with cement grout. This type of tunnelling approach provides for an essentially immediate and efficient seal to prevent groundwater ingress to the tunnel. Numerical modelling assumed that TBM tunnelling would deploy this type of ‘closed face’ tunnelling approach as compared to ‘open face’ TBM tunnelling.

With the use of SEM tunnelling methods for tunnelling (such as the use of road header excavation on a working tunnel face), groundwater is far less controlled, requiring pumping out to effectively form a fully ‘drained’ excavation. The use of progressive grouting ahead of the tunnelling face can only normally assist with reducing groundwater inflow to some degree. The numerical modelling assumed that these SEM tunnel sections would be fully drained across most of the construction, until final invert base slabs could be installed and fully grouted to effectively water-tighten the tunnel to Haack Class 3.

Cut and Cover and Trench tunnel sections assumed the use of diaphragm side walls will effectively form a toe cut-off to lateral groundwater ingress into the tunnel cuts to an estimated distance of 5 from below the final tunnel invert level, but that vertical upwards groundwater ingress through the base of these excavations would continue, until the final base slabs of the tunnel are constructed and grout sealed (leading into final tunnel operation).

- **Tunnelling Pre-treatments:** When required, the use of probing and pre-grouting methods can be undertaken in advance of tunnelling (such as lancing, tube canopies, etc.). Ground freezing and the use of compressed air are also tunnel stabilisation methods that can be undertaken, to exclude groundwater and to stabilise soil and rock conditions. The Regional Numerical Groundwater Model did not assume that any of these methods would be deployed across the Reaches.

**Project Dewatering Risk – Tunnel Operation**

The Regional Numerical Groundwater Model considered the following groundwater and related surface water impacts from long-term tunnel operations:
• Long-term dewatering assuming Haack Class 3 rating for the submerged tunnel elements (Reaches 3 to 8);
• Predicted impact of Climate Change out to 2065 and
• The impact of aquifer damming across the water table (for both the basement siltstones and alluvial sediments). This effect can cause both a localised drawdown on the downstream side of aquifer flow (i.e. behind the structure) by the resultant hydraulic effect, and importantly, a rise-up in groundwater levels (mounding) on the up-gradient side of the tunnel structure (where if this starts to egress to the top 2 m of the soil profile from ground surface, it may cause significant water-logging impacts to soil and soil salinisation from the higher TDS in this groundwater).

(i) Issues Raised by Submitters
Please include a brief summary of the key issues raised by submitters. If you refer to a particular submission please refer to the submission by number and not by the name of the submitter.

(ii) Response
Refer to my provided opinions in the other Sections.

(iii) Question
Where your opinion(s) materially differ from the relevant circulated evidence statements, please briefly outline the difference and reasons for it.

(iv) Response
No substantial differences.

(v) Question
Please discuss the magnitude, likelihood and significance of adverse and beneficial environmental effects.

(vi) Response
Refer to my provided opinions in the other Sections.

(vii) Question
Please address the adequacy of the proposed environmental management framework, including the proposed environmental performance requirements and environmental management measures contained in the EES, with reference to applicable legislation and policy.

(viii) Response
Refer to my provided opinions in the other Sections.
(ix) **Question**
Please address the adequacy of the impact assessment and whether the proposed environmental performance requirements are capable of being met.

(x) **Response**
Refer to my provided opinions in the other Sections.

(xi) **Question**
Please address the question of feasible modifications to the design of the Project within or reasonably proximate to the project boundary that could offer demonstrably overall superior outcomes.

(xii) **Response**
Refer to my provided opinions in the other Sections.
8 Regional Numerical Groundwater Model Design

The NELP Regional Numerical Groundwater Model generally matches in its concept, the approach used for other major recent Victorian Major Projects: CityLink Tunnels, West Gate Tunnel Project, MMRT and Level Crossings Project (Bonbeach and Edithvale Stations).

The model is consistent with the guidelines established by Barnett et al, 2012, where effort has been made to represent the outlined SCM for the Study Area. This has occurred through an iterative process, with phases of geotechnical and hydrogeological information. An initial target confidence level of ‘Class 1’ as described by Barnett (et al, 2012) was proposed, with some aspects of the model also pushing into ‘Class 2’ for a moderately complex groundwater model. This model class is considered suitable by the Author, given the state of the current Reference Design, the intended model use and the current availability of project data.

The model MODFLOW-USG was deployed, which is an unstructured grid version of the industry standard MODFLOW computer modelling code. This software (by the unstructured grid), allows for the ability to closely represent the project geometry with reasonable accuracy, whilst still allowing for an outward regional scale model. The model is based around:

- Regional topography (assumed groundwater divides) and surface water courses forming logical boundary conditions;
- A model layering approach that attempts to mimic the effects of topography and layering of basement siltstones, whilst at the same time modelling the alluvium layer, following the main water courses as one uniform layer only (a notable model limitation for alluvium when considering localised groundwater effects);
- The results of the regional desk-top study and project area drilling investigations were input to a proprietary Geographical Information System (GIS)- based ‘wireline’ data-management model (‘Leapfrog’). This was used in combination with available regional LIDAR survey topographic data for accurate model cell constructing; and
- Model cell sizes are reduced at tunnel and trench structures to accurately represent these key control features. The horizontal discretisation of the model finite element (FE) mesh is considered suitable for its intended modelling application.

The choice of the spatial domain, numerical and discretisation method is deemed by the Author as generally suitable for a numerical regional model, which can at the same time, attempt to assist in predicting localised groundwater interactions from the project.

- It is a full regional scale three-dimension model, which allows for both vertical and horizontal flows across all FE cell faces;
- The lateral extent of the model is suitably matched to known/set boundary conditions;
- With respect to layer geometry, one weakness of the current model, is that it treats the alluvium as one effective layer. Whilst aquifer physical properties can be altered (albeit laboriously) by individually defining properties for individual FE blocks and the program can more easily deal with basic horizontal to vertical anisotropy effects through its coding, the model is limited, particularly when attempting to model more...
significant alluvium sand layering or ‘stringer’ effects in the vertical direction. It is noted that more recent NELP investigations have in some of the Reach studies, found more significant and persistent gravel banding within the main alluvium profile. Future model refinement may require additional layering of the alluvium mesh to better cater for the representation of such vertical layering/strings; and

- Vertical layering is also somewhat limiting to the assumed depth for placed diaphragm cut-off walls when modelling cut and cover or open trench construction (where currently the 5 m depth of toe embedment for such walls is the only option for realistic construction modelling).

Generally, the Regional Numerical Groundwater Model mesh set-up is considered well-suited to match the SCM and model target confidence level class required for EES use. The aquifer system/s are reasonable described and established across:

- Hydrostratigraphy – aquifer type: The model layering is generally considered appropriate for use;
- Aquifer geometry including layer elevations and thicknesses matches closely to project construction staging; and
- Confined or unconfined flow conditions are suitably addressed and can suitably vary with changes in topography, model element properties and time.

The Author considers that the current model has some limitations in accurately modelling across:

- Modelling of significant internal features such as basement rock faults and regional folds in the siltstone aquifer (particularly when applying the model to localised project effects, as opposed to regional response effects); and
- General modelling of river plain alluvium as one layer is also considered to be a major potential limitation, again in particular to modelling localised project effects to sensitive water bodies or predicting aquifer depressurisation and related consolidation effects.

There is a clear description of the SCM and a matched model graphical presentation that is easy to visualise within the EES report.

The power and usefulness of this FEA model comes with its ability to model transient groundwater response (head levels and flow response between FE cells) and to change-up mesh material types, to closely mimic the construction staging of the project into long-term tunnel operation:

- With the placement of diaphragm walls, where the toe of these walls would extend below the design tunnel invert level (floor level), matched to model layer 5) to extend to the base of model layer 6, to mimic the sealing-off of the alluvial sediments (MRI and southern portal cut and cover structure). The installation of the diaphragm walls is simulated through time-stepping the material property hydraulic conductivity to a very low value, compared to the surrounding aquifer domain materials. Excavation of the ground within the cut and cover spaces is simulated as a drain at relevant FE nodes;
• The base slab of the northern portal cut and cover (just north of Lower Plenty Road) was assumed to eventually be tanked. Base slab placement (final tanking) is simulated at the completion of excavation, through time-stepped reduction of vertical conductivity for these base cells. Further to the north of this section, currently the Reference Design assumes the placement of a free-draining section (the ‘Trench’) which is assumed to drain groundwater freely (both horizontally and vertically, where the assumed final floor of this trench area penetrates the groundwater table; and

• TBM tunnels model their limited leakage effect (to an equivalent assumed Haack 3 Class maximum leakage rating), where this leakage is modelled by use of a well/sink boundary condition, taking up groundwater at these FE nodes.

Use of the temporal modelling domain (time stepping for transient response) has been well planned and described, where the applied regional numerical model time steps are appropriate:

• Up to 16 temporal steps were included within the current model;
• Both to steady-state and transient modelling is facilitated, where the model can deal with many aspects of complexity (to model the proposed build) and its construction staging;
• The model can build in the various aquifer stress steps as can be best predicted via the Reference Design staging as mentioned in the EES; and
• The regional numerical model boundary conditions seem plausible and are generally well matched with the SCM and suitably described in the report. The Author notes in regard to checking that chosen boundary conditions are not unduly influencing key model outcomes, that no parallel testing using alternate two-dimensional models or other available analytical solutions, based on the consideration of strategic ‘slices’ through the three-dimensional model has been conducted (even though the guidance from Barnett, 2012 recommends this action). The current justification from the incumbent groundwater modeller, is that from considerable groundwater modelling experience attained with this same MODFLOW-USG model across coal seam gas domain and effect modelling in Queensland, the modeller has a sufficient ‘feel’ for the effect of layer thickness and mesh size on model outcomes (which is why such alternate modelling or analytical solution checks have not been considered at this stage).

Parameter assumptions for diffuse recharge selection are considered as appropriate and well thought out.

Conceptualisation of the surface-water groundwater interaction (i.e., the SCM) by the model is in general accordance with modelling objectives and is considered appropriate. It is noted that there is no direct coupling of the Regional Numerical Groundwater Model to a dynamic surface water model for the Yarra River and its related tributaries within the modelling domain.
Available past Yarra catchment flow observations were considered as somewhat unreliable and varied across available past models as researched; and

- No significant spring discharges have been observed across the Study Area.

Researched surface water gauge station starting water levels and observed base flows from another larger Yarra and tributaries surface water modelling study (ecoMarkets Port Phillip model) were input to the groundwater model. These available river and creek observations were temporally matched to surrounding steady state head observations from the groundwater monitoring wells along the Project Area. Model output therefore, in relation to assessing river and creek base flows can only be used to assess change in water flux across river and creek modelled elements (not total base flows for these surface water features).

It is considered that the setting of initial modelling conditions to the only observed one main event of well head levels was an appropriate action. The Author notes that some further attempts at model calibration comparison and adjustment was also made to a lesser set of groundwater monitoring level data for the project conducted later into 2019. The effect of initial modelling conditions on key model outcomes was not appraised, where this is understandable given the current lack of high-quality groundwater level temporal data for the project.

The modeller suitably describes the numerical solution of the regional groundwater model in the EES reporting, where it was considered by the modeller to be adequate:

- For both the steady state and transient groundwater models, required head convergence was set to 0.001 m. It was indicated that the model converges well, with an acceptably small error;
- The model was indicated as being numerically stable across the calibration and uncertainty analysis processes; and
- Mass balance error was observed to be less than 0.05 per cent for steady state calibration and for all time steps across transient calibration.

(i) **Issues Raised by Submitters**

Please include a brief summary of the key issues raised by submitters. If you refer to a particular submission please refer to the submission by number and not by the name of the submitter.

(ii) **Response**

See other Sections.

(iii) **Question**

Where your opinion(s) materially differ from the relevant circulated evidence statements, please briefly outline the difference and reasons for it.

(iv) **Response**

No differences.
• The use of smaller scale / parallel use of other groundwater models (particularly of two-dimensional type) is strongly recommended into the next phase of project investigation, particularly to examine for potential aquifer anisotropy effects and the degree of connection between ‘stream’ and alluvial aquifer.

• The current single alluvial layer in the model should be divided up in terms of the vertical direction to attempt to provide a closer representation when known, more substantial permeable sand and gravel lenses are detected in the alluvium.

(v) Question
Please discuss the magnitude, likelihood and significance of adverse and beneficial environmental effects.

(vi) Response
Refer to my provided opinions in the other Sections.

(vii) Question
Please address the adequacy of the proposed environmental management framework, including the proposed environmental performance requirements and environmental management measures contained in the EES, with reference to applicable legislation and policy.

(viii) Response
Refer to my provided opinions in the other Sections.

(ix) Question
Please address the adequacy of the impact assessment and whether the proposed environmental performance requirements are capable of being met.

(x) Response
Refer to my provided opinions in the other Sections.

(xi) Question
Please address the question of feasible modifications to the design of the Project within or reasonably proximate to the project boundary that could offer demonstrably overall superior outcomes.

(xii) Response
Refer to my provided opinions in the other Sections.
9  Groundwater Model Calibration / Sensitivity

The model calibration methodology generally confirms to best practice. Calibration used an iterative process, to estimate important / estimated influencing model input parameters to describe hydrogeological conditions and domain boundary conditions, for model matching to available observed aquifer and river/stream observations. The calibration process has been accurately (from what data is available) and transparently reported. Key historical observations data used for model calibration only could include:

- Groundwater levels as measured by NELP in April 2018 across 69 groundwater monitoring bores (to provide an essentially synchronous data set for steady-state hydraulic head matching; and
- Aquifer drawdown response to three constant rate, single stage aquifer pumping tests, conducted within essentially siltstone, to calibrate the model to a short-term transient response from extraction stress (water removal from the aquifer).

All suitable types of available historical observations were attempted to be used for model calibration. A current self-identified weakness with the Regional Numerical Groundwater Model, is that there is no current long-term groundwater monitoring data available for either the siltstone or alluvium domains. This disallows an effective long-term transient response calibration to the model. Recharge within the model domains is only calibrated to a steady-state response, through the approximation of an average recharge rate. The model therefore is not appropriately calibrated to enable accurate replication to seasonal groundwater and surface water dynamics with any confidence. This means that if the Regional Numerical Groundwater Model is to be utilised for the prediction of project-related impacts to the shallow groundwater system, the model mimics a seasonally averaged response. Groundwater levels within the siltstone aquifer can fluctuate across significant levels (by up to at least 1 to 2 m), which warrants care with any deductions made from the model (particularly when dealing with groundwater level response issues). Further model verification using additional groundwater and stream data collected across the next 12 months will assist in further reducing this uncertainty.

Graphs showing modelled and observed groundwater monitoring well hydrographs were provided with reporting at an appropriate scale for comparison, however, as described above, apart from the three short-term aquifer pumping test data, only one point in time was available for comparison across the model domain.

The model was calibrated to the following objective criteria:

- A pre-defined Scaled Root Mean Squared (SRMS) error of less than 10 per cent with respect to hydraulic heads (a SRMS error of < 5 to 10 % may be considered well calibrated for a regional-scale groundwater model); and
- A pre-defined mass balance error of less than 1 % (after Barnett et al., 2012).

The steady state model indicated the following SRMS performance across key parameters:

- Predicted groundwater levels: 3.2 %; and
- Predicted groundwater drawdowns: 5.9 %.
The report indicated that the model was predicting key outputs, consistent with the SCM and related expectations for the Study Area:

- Outputs for piezometric surface and groundwater flow direction were consistent with regional topography and those inferred from other studies (ecoMarkets Port Phillip model); and
- Piezometric head influence to pumping from the three aquifer tests were broadly as-observed for the relatively short time scale, single-stage pumping tests at the predictive nodes/wells.

Modelling for model parameter sensitivity deployed the ‘PEST’ model routine, where various parameters are ranked on their influence on model outputs. This appraised across key outputs: groundwater level, drawdown and creek to aquifer exchange flux. High model sensitivity was noted across parameters: recharge, hydraulic conductivity, evapotranspiration, specific storage and river bed conductance. The sensitivity results from PEST modelling provided guidance for the conduct of the ‘Null Space Monte Carlo’ uncertainty appraisal.

Model sensitivity checks to initial starting conditions set for the model were conducted when conducting Climate Change appraisals. Sensitivity checks to lower aquifer stresses when compared to higher aquifer stress were also conducted:

- Model calibration comparison to the three aquifer pumping tests may be considered a lower aquifer stress application, when compared to likely stresses to be provided by the future Reference Design; and
- Project construction (higher aquifer stress) was modelled in comparison to the long-term operation of the Reference Design (a lower stress).
- Sensitivity checks across modelled boundary conditions were not conducted.

The as-calibrated parameter ranges are considered as generally plausible, although the Author notes the following:

- There is some illogical plan location to the assigned variations in hydraulic conductivity (refer to Figure 15 of the Modelling Report); and
- Over one half of the assigned parameters for hydraulic conductivity as established by the groundwater model through its allocation of parameter values are starting to fall right on the pre-defined values (refer to Figure 14 of the Modelling Report). That is, the assigned values from the Model are starting to fall outside or close to the plausible range.

(i) **Issues Raised by Submitters**

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(ii) **Response**

Refer to my provided discussion in the other Sections.
(iii) Question
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(iv) Response
No differences.

(v) Question
Please discuss the magnitude, likelihood and significance of adverse and beneficial environmental effects.

(vi) Response
Refer to my provided opinions in the other Sections.

(vii) Question
Please address the adequacy of the proposed environmental management framework, including the proposed environmental performance requirements and environmental management measures contained in the EES, with reference to applicable legislation and policy.

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Refer to my provided opinions in the other Sections.

(ix) Question
Please address the adequacy of the impact assessment and whether the proposed environmental performance requirements are capable of being met.

(x) Response
Refer to my provided opinions in the other Sections.

(xi) Question
Please address the question of feasible modifications to the design of the Project within or reasonably proximate to the project boundary that could offer demonstrably overall superior outcomes.

(xii) Response
Not applicable.
10 Groundwater Model Predictions

The calibrated model was based around the Reference Design for construction works timing and post-construction operation (long-term). Clearly presented model predictions allowed the study objectives to be achieved for: groundwater inflows to tunnelling works, groundwater drawdown and mounding, depth to groundwater and groundwater exchange with rivers, creeks and billabongs. Outputs related to mass balance were considered as being realistic for the water body types and expected cross-connections. A groundwater model confidence level of ‘Class 1 to 2’ (after Barnett et al, 20102) has been suggested by the report and the Peer Reviewer, which meets the study objective. The model uncertainty analysis and prediction spanned across a wide range of model input parameters. It showed:

- With construction, groundwater levels will lower towards the base of cut and cover excavations and SEM tunnels. This is expected to cause up to a 25 m aquifer drawdown at these immediate areas to the excavation. The planned use of supporting diaphragm walls for cut and cover will mitigate this drawdown impact further away from the cut and cover excavations;
- At the southern portion of the tunnel alignment, aquifer damming (groundwater mounding) is predicted at the eastern side of the Banksia cut and cover;
- With permanent tunnel linings in place, groundwater levels will slowly recover, following an initial ‘lag’, where the initial groundwater drawdown/mound ‘cone of effect’ continues to spread laterally away from the project for up to several months. Following an estimated period of between five to 10 years, the groundwater system will start to approach a new dynamic equilibrium around the expected changed conditions from the project into the longer-term;
  - The fully tanked cut and cover section at Lower Plenty Road is predicted to have an immediately surrounding long term groundwater drawdown of < 0.5 m;
  - The fully tanked portion of cut and cover sections at Banksia is predicted to have an immediately surrounding long term groundwater drawdown of < 1 m. Mounding of the water table on the up-gradient side for the Banksia cut and cover is not expected to result in a depth to groundwater from surface of < 5 m bgs;
  - The fully tanked portion of cut and cover sections at Bulleen is predicted to have an immediately surrounding long term groundwater drawdown of < 0.2 m;
  - At the northern alignment portion, the currently proposed free-draining trench zone (within Reach 2) will cause a permanent groundwater drawdown of between 0.5 m to 1.0 m (where the proposed un-tanked trench floor penetrates the upper water table). There is minimal predicted permanent drawdown nearby, around the fully tanked section of the Lower Plenty Road cut and cover to the south (< 0.5 m);
• In the southern portion of the alignment, permanent drawdown of < 1 m to <0.2 m respectively is simulated on the down-gradient side of the Banksia and Southern (Bulleen) cut and covers respectively. Mounding of the water table on the up-gradient side of the Banksia cut and cover is not predicted to result in a depth to groundwater to surface of less than five metres bgs; and
• Drawdown of up to 2 m is predicted above the TBM tunnels in the northern portion of the alignment, where recharge and groundwater through-flow within the bedrock are insufficient to completely offset seepage into the TBM tunnels. Significant aquifer drawdown is not predicted to occur where the TBM tunnels would be located below alluvium, as the aquifer would be maintained by a higher recharge and aquifer through-flow.

• With construction for the project’s various sections of cut and cover excavations, a predicted average groundwater inflow between 70 m$^3$ per day to 106 m$^3$ per day applies (flow is controlled by the diaphragm walling). These flow predictions may be subject to rock anisotropy effects, if dominant rock bedding angles in these areas are steep;
• A low percentage impact from the project to contributing groundwater fluxes to the Yarra River, when considering the DELWP (2015) Ministerial guidelines (5.5 % at end of construction, stabilising out to 3 % into the longer-term). As a measure, a 5 % reduction in base flow flux to the Yarra is equivalent to a 0.01 % reduction in its total open river flow rate through that river stretch;
• Modelling predicts a low percentage impact from the project to contributing groundwater inflows to the Bolin Bolin Billabong, when considering the DELWP (2015) Ministerial guidelines. For the deep pool, a base flow volume reduction of 3 % to 5 % is predicted, with matched groundwater drawdown for the area of approximately 0.1 m (this has potential to cause pool level reductions across the dry seasons);
• Modelling predicts a small leakage rate increase from TBM tunnelling (loss) from Banyule Swamp (estimated at < 0.3 %) and a loss from the Banyule Billabong of < 0.6 %, where estimated alluvium aquifer drawdown effect for both these features would be approximately 0.1 m; and
• Most of the anticipated modelling uncertainty is related to the prediction of groundwater drawdown and mounding effects from the construction of the cut and cover tunnels and SEM tunnels. Moving into the longer-term for modelling prediction, estimated uncertainty reduces (e.g., for groundwater drawdown the uncertainty range is less than 1 m).

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(ii) **Response**
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(iii) **Question**
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(iv) **Response**
No differences.

(v) **Question**
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(vi) **Response**
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(vii) **Question**
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(viii) **Response**
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(x) **Response**
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(xi) **Question**
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(xii) **Response**
Not relevant.
11 Modelling for Climate Change

Climate change scenario - stress assessments were based on suitable technical references for model inputs, where uncertainty analysis and general model output showed a low risk of sensitivity of change to the model predictions across water level changes, or baseflow changes, when compared to current day (null scenario) model calibration and prediction.

Modelling used a time span between 1965 to 2018 as the climate baseline (incorporating hydrological variability), to best the model a match to April 2018 groundwater level data. The operational scenario for the project was then considered and compared to a long-term scenario without the projects affect. The impact of short-term climate variability affecting across the project construction period was also considered, by adopting both a lead-in dry sequence of input data from the known 65-year climate baseline, as well as a lead-in wet sequence of input data.

- The model suggests that climate change impacts will not greatly impact upon either changes to groundwater levels or groundwater fluxes;
- Climate change impact is expected to be associated with a lead-in ‘dry’ scenario, where groundwater lowering from reduced regional recharge is predicted to cause a reduced groundwater drawdown at the free-draining trench area (Reach 2) and reduced mounding influence (up-gradient of the Banksia cut and cover);
- Across TBM influenced areas, a lead-in dry condition will result in an increased aquifer drawdown (from less available surrounding recharge contribution);
- In considering a lead-in ‘wet’ scenario, modelling prediction for the Banksia cut and cover showed depth to the standing water table from ground surface may temporarily be less than 5 m bgs when uncertainty effects are factored in for the input parameters. The modellers suggest the likelihood of such an occurrence is low.

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(x) Response
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(xi) Question
Please address the question of feasible modifications to the design of the Project within or reasonably proximate to the project boundary that could offer demonstrably overall superior outcomes.

(xii) Response
Not relevant.
12 Handling Uncertainty & Model Limitations

The proponent suitably points out most of the limitations of its numerical regional groundwater model within the EES documentation. They recognise the modelling work is based solely on a ‘Reference Design’, where final implemented changes to the tunnel design by the selected Design and Construct Consortia may have implications on predicting groundwater impacts.

Sources of modelling uncertainty were suitably discussed within the report (i.e., measurement of observation and input parameters, structural model uncertainty, limited calibration data). Modelling conducted a suitable multi-parameter sensitivity analysis to appraise for uncertainty effects, using the Null-Space Monte Carlo method. The model produced useful, easy to interpret, spatial outputs across the key criteria (groundwater level response (total head and change in head) and stream to aquifer flux exchange), where matched probability of occurrence was reported from this model analysis (either 95th percentile or 5th percentile results, depending on the type of parameter being appraised).

As recognised by the EES modellers, the limited transient behaviour calibration of the Regional Numerical Groundwater Model heightens the risk of producing a non-unique groundwater response prediction.

- Attempts to overcome this limitation/predictive risk are planned to be addressed through ongoing monthly monitoring of the NELP groundwater monitoring well network (some wells have now been monitored up to 31 July 2018, for at least across six months, to start to provide a high-quality temporal data set). In the context of suitable proving/calibrating of model transient response to climatic variance, this time-frame of well groundwater level monitoring is still relatively too-short, but its recognised, that as time and monitoring continues, the ability of the re-calibrated groundwater model to accurately predict on project effects to groundwater increases;

- Groundwater monitoring well installation and monitoring locations currently swarm around the project alignment, with very little recognition of groundwater response monitoring for the broader domain away from the project alignment. Given the type of siltstone aquifer, reliance cannot be made on surrounding published data bases for groundwater response (i.e., the lack of State Observation Bores); and

- Some of the currently installed project groundwater monitoring wells do not have well slotted screen immediately placed across the first identified aquifer intersection (where well screens may be set deeper for project definition/investigation requirements).

Risk of a non-unique predictive solution could also be further examined and tested, using alternate groundwater models or solutions to the particular response problem are still being considered for the groundwater system and its project interaction. At this stage such testing checks on the regional response model have not been conducted by the proponent. The proponent plans instead, to further calibrate/confirm the Regional Numerical Groundwater
Model predictions through future groundwater monitoring programs under EPRs GW1 and GW2.

The proponent points out correctly, that whilst minimum water level contour outputs of resolution at 0.1 m have been reported with modelling prediction, given the current state of the groundwater model and its calibration, a regional predictive model of this kind should not be capable of accurately predicting water level responses at certain areas within the model to within a tolerance band of less than 0.5 m. This can have implications when dealing with groundwater response predictions linked with shallow and sensitive surface water bodies.

It is possible in the future, that groundwater responses may be significantly influenced by ‘known unknowns’, which may include the dewatering response of other nearby construction projects, or operation of either existing or newly installed groundwater extraction or injection bores on other nearby lands. Nearby examples may include:

- An operational commercial car wash within the suburb of Kew, Victoria, is known to only operate a licenced deep groundwater extraction bore within Silurian siltstone across the summer months, to supplement its on-site water supply. This dewatering is known to have a very large impact on the unconfined fractured siltstone aquifer that surrounds this bore (up to one kilometre of bore influence). Whilst this bore is outside of the Study Area, it is a good example of a known unknown; and

- Water recycling and re-use schemes, such as that owned / operated by Manningham Council, located near the Bolin Bolin Billabong may not only replace water to shallow aquifer systems under gravity influence (where details of water recharge should be clearly investigated and understood).

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(vi) **Response**
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(ix) **Question**
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(xi) **Question**
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(xii) **Response**
Not relevant.
13 Modelling Peer Review

Principal Hydrogeologist and groundwater Modeller: Mr. Hugh Middlemiss (HydroGeologic) conducted an independent review of the Regional Numerical Groundwater Model and groundwater assessment for the EES. Key outcomes of this review included:

- The NELP groundwater modelling assessment was conducted with a ‘high degree of professionalism and meets best practice criteria’;
- The assessment was fit for its intended objectives and integrated well into the risk-based environmental impact assessment framework;
- The assessment considered existing and future conditions, likely project impact pathways and linked management measures;
- The groundwater model was suitable and used best practice methods, which included the use of sensitivity analysis and uncertainty analysis;
- The groundwater model considered long-term climate change effects;
- The groundwater model provided quantified predictions in terms of both spatial and time across groundwater level alteration and alteration to the related river/creek flow system for the domain; and
- The reporting of consequence and likelihood information was clearly and suitably presented, to allow the nomination of EPRs to monitor, minimise and manage adverse groundwater-related environmental effects.

(i) Issues Raised by Submitters

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(ii) Response

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(x) **Response**
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(xi) **Question**
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(xii) **Response**
Not applicable.
14 EPR Review

Suggested EPRs as listed in Section 9 of the Groundwater EES Report are discussed below:

- ‘GW1’ relates to informing the Design and Construct team about the SCM (Assessment):
  - Continue to review and improve the numerical model for the Study Area;
  - Further field investigation to better calibrate the model;
  - Considers both changes to groundwater level and quality;
  - Help to develop more promising mitigation strategies; and
  - Matching the numerical groundwater model to actual construction techniques to be used.

- ‘GW2’ relates to Groundwater Monitoring:
  - Pre-construction baseline and construction influence;
  - Return calibration to the numerical groundwater model;
  - Assessing for adequacy of design and construction performance;
  - Covers groundwater levels, flows and water quality;
  - Links in with EPR FF6 – GDE Monitoring and other identified beneficial uses for groundwater;
  - Confirms the suitability/effectiveness of applied mitigation measures;
  - Post construction monitoring for at least 2 years, or until an acceptable groundwater restoration is confirmed; and
  - EPA being actively involved.

- ‘GW3’ relates to Design & Construction Measures to Mitigate:
  - Short and long-term groundwater seepage disposal/management;
  - The important aspect of mobilising contaminated groundwaters – a proven risk for this type of project;
  - Impacts with respect to ASS/PASS;
  - Impacts to waterways and GDEs and terrestrial ecosystems (trees);
  - Subsidence (ground movement) impacts related to depressurisation/consolidation;
  - Applies to all aspects of the alignment construction;
  - Manage, minimise, mitigate (Waste Management Hierarchy); and
  - Water Authority Agreements/Licences – an important/current issue.

- ‘GW4’ relates to Groundwater Management Plan (covers both construction and operation – to 2 years into project operation):
  - Consult with EPA;
  - Link with numerical groundwater model;
  - Establish guidance on chemical and material usage – construction materials;
  - Establish suitable guidance in respect of Managed Aquifer Recharge (MAR) - chemical quality and hydraulic influences (if required);
  - Long term tunnel material compatibility with groundwater;
• Maintaining long-term drainage infrastructure to suitability of use (control of anti-clogging chemicals);
• Measure for, appraise and treat intercepted contaminated groundwaters (construction);
• Controls for remedial grouting with construction (or operation fixes);
• Confirming the status of surrounding operational water bores in the agreed Study Zone; and
• Link in with Southern Rural Water.

• ‘GW5’ relates to Managing Groundwater Across Operation
  • Manage/Monitor/Re-use of groundwater seepage inflows;
  • Licences and Guidelines to apply; and
  • Emergency response plan for unexpected groundwater inflows.

• There are also clear linkages across to the following other discipline EPRs:
  • Ground Movement ‘GM1’ – Assessment;
    • Surface Waters:
      ▪ ‘SW2’: Spill Containment;
      ▪ ‘SW3’: Approvals for Wastewater Discharges; and
      ▪ ‘SW11: Water Sensitive Urban Design’
  • Contaminated Land:
    ▪ ‘CL1’: Spoil Management Plan;
    ▪ ‘CL2’: Impacts from ASS;
    ▪ ‘CL3’ Impacts from Odour;
    ▪ ‘CL4’ Impacts from vapour & Ground Gases; and
    ▪ ‘CL5’ Managing Chemicals, Fuels & Hazardous Materials
  • Flora & Fauna:
    ▪ ‘FF6’: GDE Monitoring & Mitigation Planning;
  • SCC4:
    ▪ ‘SCC4’: Minimise & manage waste (other than spoil).
(i) **Issues Raised by Submitters**
Please include a brief summary of the key issues raised by submitters. If you refer to a particular submission please refer to the submission by number and not by the name of the submitter.

(ii) **Response**
Refer to my provided discussion across the other Sections.

(iii) **Question**
Where your opinion(s) materially differ from the relevant circulated evidence statements, please briefly outline the difference and reasons for it.

(iv) **Response**
No differences.

(v) **Question**
Please discuss the magnitude, likelihood and significance of adverse and beneficial environmental effects.

(vi) **Response**
Refer to my provided opinions in the other Sections.

(vii) **Question**
Please address the adequacy of the proposed environmental management framework, including the proposed environmental performance requirements and environmental management measures contained in the EES, with reference to applicable legislation and policy.

(viii) **Response**
Refer to my provided opinions in the other Sections.

(ix) **Question**
Please address the adequacy of the impact assessment and whether the proposed environmental performance requirements are capable of being met.

(x) **Response**
Refer to my provided opinions in the other Sections.

(xi) **Question**
Please address the question of feasible modifications to the design of the Project within or reasonably proximate to the project boundary that could offer demonstrably overall superior outcomes.
(xii) Response

Refer to my provided opinions in the other Sections.
15 Approval Documents

(i) Question

Please list any recommended changes to the approval documents.

(ii) Response

This section summarises areas of suggested change across the EPRs:

- Tank the Open Trench sector that will intersect upper groundwater within Reach 2;
- Deploy a Statutory EPA Appointed Independent Environmental Auditor; and
- Consider the use of parallel groundwater predictive models in combination with the Regional Numerical Groundwater Model.