Identification of critical issues

- Range of volume loss from Tunnel Boring Machine (TBM) tunnelling has been assumed to range from between 0.4 % to 0.8 %:
  - Lower Plenty Road to Banyule Flats (‘Reach 4’): 0.8 % volume loss;
  - Banyule Flats to Manningham Road Interchange (‘Reach 5’): 0.4 to 0.8 % volume loss; and
  - Avon Street to Rocklea Road (‘Reach 7’): 0.3 % volume loss.
- Primarily most of the tunnelling is targeted through Silurian siltstone (fractured soft rock).
- As a comparative guide, for the Melbourne Metropolitan Rail Tunnel (MMRT) project, estimated volume losses through Melbourne Formation siltstone (at generally similar depths of tunnelling) were as follows:
  - TBM in siltstone rock: 0.5 % volume loss.
  - Sequential Excavation Method (SEM) in siltstone rock: 0.5 % volume loss.
  - Use of TBM with closed face in soft ground: 1 % volume loss.

The values as assumed seem comparable. The NELP EES suggests a volume loss using SEM of 0.3 % which may prove optimistic.

Aspects related to ground movement of liquefaction (often associated with soft ground and earthquake events), vibration settlements, thermal effects and...
reactive soil movements (expansive clays) all considered of lesser importance – not considered.

- Reach 5: Banyule Homestead (Influence on Siltstone Bedding – Stability)
  - One instance of slope stability assessed;
  - In-situ rock bedding at this location dipping into the slope at ~ 65°, with planar jointing approximately orthogonal to bedding (dipping out of slope) forming a blocky rock mass.
  - There is evidence the current slope angle is controlled by this jointing.
  - The observed slope face angle of 26° to 36° closely matches the jointing that dips out of the face at “25” to “30”.

TBM influence was estimated from finite element analysis (FEA) to cause minimal strain impact under this area – not considered further.

- There are some issues with prediction inaccuracy and applicability of using the Gaussian Bell Curve Method (which has been applied for this Project to estimate both total settlements, the extent of settlement troughs and change in slope on ground) for the estimation of tunnelling settlement trough predictions when dealing with a fractured rock mass, particularly when movements and strains are more associated with discrete fractures or defects in the rock and you start to move away from ‘soft rock’ behaviour:
  - Volume of the settlement trough is taken as equal to the volume loss associated with tunnelling;
  - Volume loss is defined as a ratio of the over-excavated material to the theoretical excavation volume;
  - Trough width is taken as equivalent to one standard deviation of the Gaussian Bell Curve shape for its positioning.

Its proposed with more detailed assessment to confirm the general risk assessment approach for ground movement prediction by conducting more detailed and complex numerical methods that better simulate the behaviour of fractures and faults/features in the rock. This future check modelling and monitoring of rock behaviour under stress change will need to be built into a suitable EPR.

- Anisotropy effects of fractured rock systems and its importance: Conductivity of the ground (fractured siltstone rock) to groundwater flow is often substantially higher in the horizontal direction than the vertical. In rock, groundwater will often preferentially flow through an interconnected fracture network leading to a widespread zone of influence that may prove difficult to predict (you can get a wider zone of influence than was expected).

- The order of 5 mm is proposed as a predicted vertical movement was used as the threshold for further appraisal of buildings and structures.

- First stage risk assessment process – if a ‘slight’ risk to damage or distress (buildings/aboveground infrastructure) or greater by:
  - Predicted 5 mm vertical total movement from the Project influence;
  - Predicted strain at 1:500 (0.2 %).

- For underground utilities slightly different appraisal system adopted based on relative stiffness of service to surrounding soil:
  - Consider is there is any ‘rigid’ pipe – joint rotation or joint pull-out risk; or
Are there critical bending and extensional strains expected on the service line if its acting more like a flexible member (allowable strains depend on the material type).

- Second stage risk assessment to buildings and structures considered:
  - Specifics of geometry and relative stiffness of the structure;
  - Elastic modelling (beam movement adopted on Gaussian subgrade shape);
  - Tensile strain pushes out to ‘moderate’ risk as strain approaches 0.15 % to 0.3 %, then onto Detailed Evaluation (Stage 3).

Any structures of heritage value or community significance went straight to Stage 2 Risk Appraisal.

**Concept of ‘Confinement – Convergence Method (CCM)’**
- For rock, ground movement effects may be determined using the CCM, where the tunnelling excavation process is simulated in 2D by a ‘relaxation factor’ and the movements cease when the lining is ‘installed’ after an appropriate degree of rock stress relaxation has occurred;
- The degree of stress relaxation of the rock which can occur is the key parameter (depends largely on the delay required to install the final tunnel lining and to make meaningful contact with the rock and final liner (to take up load);
- The rock may also yield to some extent in this stress relaxation process, so estimating rock yield potential becomes important (use of the Geological Strength Index (GSI) after Hoek, 1999);
- Volume loss (VL) for a circular tunnel can be estimated based on the predicted radial convergence around the tunnel and tunnel starting diameter (VL % = 4 * (δ/D)*100).

With respect of retaining walls, given the stated typical types for the reference design, most of these walls are expected to have a high relative stiffness where variation in ground condition and style of anchoring or propping of the excavation then become the major influencers to ground movements.
- For stiffer ground conditions (such as is the general case for this Project) use the trough estimation process by Clough & O’Rourke (1990).
- Case of Bulleen Road North Portal – stiff clay alluvium involved (softer soil) – use of GABA empirical curve fitting method 2017 or CIRIA C760 report methods considered more appropriate.

All residential properties will be subject to a condition survey (pre-works) which lie within the estimated zone of influence from the trough modelling.

Key assumption (considered to be conservative) when dealing with alluvial deposits – Yarra River (i.e. relatively unconsolidated) – thickness of the soft/compressible layer to be taken as the total estimated thickness of the alluvium layer, less its starting unsaturated thickness from the top of this alluvium layer.

Siltstone/sandstone inter-bedded is interpreted to be folded on a general north to north east trending axis, 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...
**Issue**

- rock, sand and clay derived from the ‘parent’ rock, which are interpreted to behave as a soft soil material (a reasonable assumption);  
  - No dykes (as yet) have been encountered with vertical drilling methods – their occurrence could complicate tunnelling methods;  
  - The siltstones are deeply weathered—often down to 30 m depth, but weathering and general rock strength can also be variable;

- **Around Manningham Road, there are a series of interpreted east to west draining ancient alluvial ‘paleo-channels’, which were subsequently stranded by the continued down-cutting of the Yarra River. The in-fill material here is believed to be Brighton Group marine sandy clays. To the south of Manningham Road (near Ilma Court) there are also in-filled drainage channels (Miocene alluvium) close to the proposed tunnelling ‘crown’.

- The alluvial aquifer and the underlying siltstone bedrock aquifer are expected to be inter-connected. Seasonal variability in groundwater contribution to the surface water features (creeks, rivers, wetlands) is not well understood where a groundwater monitoring program is underway.

A total of 11 geotechnical/geological study ‘reaches’ have been nominated:

- **Reach 1: M80 Ring Road to Watsonia Station (Surface Works)**
  - Silurian bedrock ranging from highly weathered to fresh to slightly weathered from 15 to 25 m bgs (thin residual clay soils overly);
  - Minimal ground movements are anticipated, just minor movements from additional placed embankment loads with lane widening.
  - A former in-filled quarry site near M80 intersection with Greensborough Highway (solid inert waste up to 7 m deep) placed around mid-1950’s;
  - AK Lines Oval – former landfill site from 1950’s; and
  - Also part of the Maroondah Aqueduct / Dandenong West Melbourne Ring Water Supply Main - (concrete lined steel pipeline, 2.16 m in diameter – built 1970s) under M80 Western Ring Road, near Chappell Drive (6 to 19 lanes with new build) – deemed a ‘slight risk’ for Preliminary Analysis (16 mm maximum vertical settlement predicted, where this pipeline should act in a flexible manner) – recommendation to model and monitor as further action. Currently EPRs: GM1/GM2 recommended.

- **Reach 2: Watsonia Rail Station to Northern Portal (Open Cut)**
  - Cut depth up to 13 m bgs.
  - Silurian bedrock ranging from extremely weathered to highly weathered;
  - Nearby Hurstbridge Metro Rail Line (not considered at risk from ground movement);  
  - Passes through western boundary of Simpson Barracks (some impacts to L-shaped Building (not at risk, but recommended to apply EPRs: GM1/GM2 and GM3) and related Outbuilding (deemed ‘slight risk’) due to proximity of proposed cutting and its construction type – masonry wall) - recommended to apply EPRs: GM1/GM2 and GM3;  
  - Elder Street Gas Main (near Watsonia Station), runs along Greensborough Road – 450 mm diameter, high pressure, steel
welded circular pipe set at 10 m bgs within a 60 mm diameter outer conduit, subject to 4 m deep trench excavation at Greensborough Road (18 mm maximum vertical settlement predicted).
Recommendation to model and monitor applies for this: Current recommendation for EPRs: GM1/GM2.

○ **Reach 3: Northern Portal to Lower Plenty Road (Cut & Cover)**
  - Cut depth up to 35 m bgs.
  - Silurian bedrock ranging from extremely weathered to highly weathered;
  - Steeply dipping fault zone expected just north of Lower Plenty Road;
  - Combined settlement effects from deep cut and cover and TBM may prove significant (bedding plane strains and fault line);
  - Former small landfill at Borlase Reserve 1966-1972, fill to 5 m bgs;
  - > 5 mm vertical settlement zone can extend laterally from cut by up to 45 m (most influence near northern portal).
  - Greensborough Road water main (0.6 m diameter concrete lined welded steel pipe) at west side of excavation (max vertical pipe displacement of 7 mm, with no change in ground slope) – not at risk.
  - Lower Plenty Road Water Main (required re-alignment of 3 x concrete lined steel welded pipes (largest diameter is 1.35 m) – up to 76 mm of maximum vertical movement at this area. Requires Stage 2 Assessment (not yet done). Current EPR recommendation: GM1/GM2 and GM4 (pipeline re-alignment).

○ **Reach 4: Lower Plenty Road to Banyule Flats (TBM)**
  - Tunnelling depth up to 42 m bgs.
  - Silurian bedrock ranging from slightly weathered to fresh with minor dykes and significant fault zones;
  - Zone of > 5 mm vertical influence extends out some 25 m from tunnels centreline.
  - Many one to two storey residential premises above warranted Stage 2 Assessment:
    - ‘Lower Plenty Road 2 (LPR2)’: Low rise residential near Lower Plenty Road Portal cut and cover & TBM interface (between 5 to 29 mm vertical structural movement – ‘slight’ damage rating – deploy EPRs: GM1/GM2/GM3);
    - ‘Banyule Creek 1 (BC1)’: Low rise across TBM alignment includes Viewbank Aged Care (all around 10 to 12 mm vertical movement) - ‘negligible’ damage rating – but still deploy EPRs: GM1/GM2/GM3);
    - ‘Banyule Creek 2 (BC2)’: Low rise residential cross TBM alignment, including a Kindergarten (all around 10 to 12 mm vertical movement) - ‘negligible’ damage rating – but still deploy EPRs: GM1/GM2/GM3);
  - Banyule Creek Sewer passes above TBM alignment at Banyule Flats (up to 36 mm max vertical movement predicted with northbound tunnel) – warranted a Stage 2 Assessment.
    - 0.45 m diameter vitreous clay pipe with shallow founding (stiff/brittle construction) – pipe joint rotations and pull-out governs;
Model predictions indicated that further assessment not warranted, but enact EPRs: GM1 and GM2.

Reach 5: Banyule Flats – Banksia Park – The Yarra (TBM)
- TBMs to be driven from a temporary portal on Banksia Street;
- MRI constructed by cut & cover;
- Mainly through slightly weathered to fresh siltstone for TBM;
- There are several faults present through this area;
- Manningham Road – there is the possibility that the tunnel crown could intersect the base of ancient alluvial sediments (requirement for open to closed face TBM operation could exacerbate settlements).
- Zone of > 5 mm vertical zone of influence (ZOI) extends out some 38 m from tunnels centreline.
- Sensitive receptors above include:
  - Banyule Homestead (outside ZOI);
  - Banyule Flats North Slope (siltstone with 65° rock bedding dip into the slope – warranted FEA review – only minor impact predicted);
  - Banyule Swamp (7 Ha pond near TBM alignment – up to 35 mm vertical movement predicted – requires Stage 2 Assessment on associated water outfall structure sensitivity) – Currently GM1/GM2/GM3/GM4 all recommended – links across to Ecological Risk Study;
  - Heide Museum of Modern Art & related sculpture park (‘Crescent House’ (18 mm max vertical movement) and ‘Theoretical Matter’ (24 mm max vertical movement) – main sculptures at risk – both these went to Stage 2 Assessment). Outcome deploy EPRs: GM1/GM2/GM3 for both sculptures.
  - ‘Helmet’ large steel framed sculpture (up to 93 mm max vertical movement) – significant risk – some mention of a possible relocation early in the Chapter. Detailed assessment recommendation to deploy EPRs: GM1/GM2/GM3/GM4 following conduct of detailed structural analysis around ground movement predictions.
  - Journey’s End (outside the ZOI);
  - House near Bridge Street (near Journey’s End) – requires Stage 2 Assessment.

Reach 6: Manningham Road Interchange - Bulleen (Cut & Cover)
- Large interchange ‘box’ to be constructed to 22 m bgs;
- Pleistocene alluvials (Manningham Road) over siltstone which is moderately weathered to extremely weathered;
- Soft soils at Yarra Flats;
- ‘MRI Slope Stability – where Yarra River is within 35 m of closest cut and cover activity. This slope has a maximum slope angle of 20° and is 10 m high. Slope stability analysis suggested not an issue – EPR recommendation GM1 applies.
- MRI retention structures expected to result in groundwater mounding (up to 6 m height increase to east of MRI box structure) –
### Issue

could result in some increased ground heave with reactive clays (old alluvium) – EPR recommendation GM1 applies.

- **Reach 7: Avon Street to Rockleigh Road (SEM Tunnels)**
  - Extremely weathered to highly weathered siltstone;
  - Ima Court has infilled paleochannels – mining change difficulty;
  - Maximum depth is 35 m bgs (tunnels 14 m x 12.5 m cross sectional area each);
  - Includes cavern mining for road ramps near Golden Way;
  - Initial ‘drained’ tunnel construction followed by full tanking via secondary liner;
  - ZOI up to 25 m from tunnel centreline;
  - Bulleen Road Residential areas within;
  - Bulleen Residential (‘BR’) (associated with MRI and SEM tunnelling) Initial ZOI estimates: up to 26 mm maximum vertical settlement – required Stage 2 Assessment – includes: St Andrews Crescent, Golden Way, Claremont Ave, Rocklea Road, Killara Mews – mainly low rise residential, but SEM tunnelling results in between 7 to 26 mm maximum vertical settlement (critical locations are on the east and west side of the tunnel alignment). Damage rating expectation is ‘very slight’ – but enact EPRs: GM1/GM2/GM3.
  - Former in-filled clay brick quarry area (Yarraleen Reserve) deep foundations expected to support residents here – deemed not at risk.

- **Reach 8: Rockleigh Road to Bulleen Oval (Cut & Cover)**
  - Associated groundwater drawdowns are expected to cause more noticeable settlements here;
  - Deep layer of alluvium (to 21 m bgs) – soft to stiff clays and loose to medium dense sands;
  - Significant faulting across slightly weathered to fresh siltstone;
  - Bulleen Road West Sewer (will need to be relocated via trenching and pipe-jacking) – under what contract controls (Early Works – will EPRs still apply – currently EPRs: GM1/GM2/GM3 required)?
  - Generally, up to 80 m ZOI from alignment centreline, but Bulleen Road Sewer increases this zone out to 110 m;
  - Bulleen Oval has significant deposits of uncontrolled fill (with asbestos risk mixed in waste);
  - Bolin Bolin Billabong and nearby Integrated Water Facility – not considered at risk.
  - Trinity Grammar School & Marcelin College Playing Ovals – minor drainage risk perhaps from some minor settlement.

- **Reach 9: Eastern Freeway – Bulleen Road to Freeway (Surface Works)**
  - Traffic lane widening and viaduct ramp;
  - Swim Centre and Tennis Centre land to be acquired;
- Alluvium over highly weathered siltstone;
- Required relocation of East Yarra Sewer Main – planned shaft excavations for pipe jacking;
- Only sensitive receptor is Bulleen Road West Sewer (2.25 m diameter reinforced concrete pipe asset of Melbourne Water):
  - Sits on alluvial clay;
  - Subject to increased loads from the surface ramps and nearby settlement influence from the shaft excavation to relocate the East Yarra Sewer Main (maximum ground displacement 27 mm vertical) – taken to Stage 2 Assessment;
  - Assessment looked at rigid pipe model (joint rotations and pull-out risk) – outcome not at risk but deploy GW1/GM2/GM3.

- Reach 10: Eastern Freeway – West (Surface Works)
  - Undisturbed alluvium transitions from underlying siltstone to Newer Volcanics basalt to west;
  - Former landfill (Camberwell Municipal Landfill – 1966 to 1977) – Musca Reserve & Freeway Golf;
  - Not many sensitive receptors here.

- Reach 11: Eastern Freeway – East (Surface Works)
  - Significant road widening is required;
  - Mainly siltstone geology, with minor alluvium at Koonung Creek crossing under Eastern Freeway;
  - Former landfill near intersection of Doncaster Road & Freeway – Banyule North (1970’s in-filled);
  - Koonung Creek Conduit (existing ‘BEBO arch’ construction – not to be further assessed as it will be treated with a concrete cover slab to structurally bridge over) – but deploy EPRs: GM1/GM2/GM3 on arch as fail-safe;
  - Kenneth Street Water Main, Bulleen (1.1 m diameter steel pipeline – owned by Melbourne Water) sits atop clay alluvium up to 18 m deep with a 3.2 m ground cover to works – additional assessment showed no significant risk (only to 7 mm maximum vertical settlement).

- Alternative Design Options Being Considered From Reference Design

Some discussed alternative design options in the EES:

- Manningham Road Interchange: Involves lowering the alignment of the TBM tunnels and the MRI by a further 2 m:
  - Will result in a 3 m increase in the predicted settlement trough width;
  - Maximum vertical settlements may increase by a further 3 mm; and
  - Structural damage ratings should not alter to surrounding receptors.

- Northern TBM Launch:
  - Will not cause a large change to the excavated tunnel geometry.

- Banksia Park TBM Retrieval Shafts:
  - Alternative proposes 2 x separate TBM retrieval shafts on the north side of Bridge Street at Banksia Park;
These shafts are 25 m wide x 50 m long and will be between 30 to 34 m bgs;
- The shafts will be constructed before the MRI construction;
- Designers considered consolidation effects with soft soils at this area from dewatering operations with these shafts (dewatering to occur 9 months before MRI dewatering commences);
- Additional impact from this action takes up one additional residence within the ZOI (on Bridge Street) – assigned a ‘slight’ risk ranking.
- Subsequent Stage 2 Assessment on this timber framed/weatherboard residence showed up a ‘negligible’ risk ranking, but it was recommended to deploy EPRs: GM1/GM2/GM3.

The outlined tunnel design approach when it comes to predicting settlement and strain response if to deploy the Gaussian Bell-Curve Model (empirical curve fitting method). For non-homogeneous rock (such as what is potentially the case for this project with the siltstones), ground movements may be driven more by specific displacements along discrete bedding, fracture lines or joint lines. If tunnel monitoring shows up a discrepancy such as this type of movement the approach to counter this is to add further tunnelling support at such areas to limit these more-specific movements.

Trough width parameter (i) is a ratio of the tunnel depth – generally (i) was taken as 0.5 * Zo (for clay type soils), where Zo is the depth to the tunnel crown from the ground surface. For sands the EES suggests a value of (i) of 0.3 *Zo and for fractured rocks the EES suggests a value of (i) of 0.7 *Zo.

When these suggested numbers are compared to what was submitted in the MMRT – EES they compare favourably – see MMRT suggestions below:

- Soil (All Types) (i) = 0.4 *Zo
- Rock (i) = 0.6 *Zo
- Alluvials (i) = 0.3 *Zo

One key issue is that the EES information seems lacking around the investigation and understanding of regional rock stress fields for the Project.

- The current design information seems to be assuming that horizontal and vertical stresses are in a hydrostatic type of equilibrium / balance.
- There is no obvious calling off or reporting of the measurements of stress ratios estimated in the field for these basement rocks (siltstones) from the Geotechnical Investigations.
- Varying stress ratio and rock bedding anisotropy will have an influence of predicted ground movement zones and magnitude of settlement/strain.

Generally these EPRs seem quite sound and well-constructed.
‘GM1’ relates to the Site Conceptual Model and understanding of the ground movement mechanism (Assessment);

‘GM2’ relates to measuring a ground movement ‘baseline’ and then conducting careful monitoring checks across the Project life into Operation (Plan for Movement Monitoring);

‘GM3’ relates to establishing a baseline of building and infrastructure asset condition before construction, followed post-construction surveys and consultation with the stakeholders of these assets;

‘GM4’ relates to rectifying damage to buildings and infrastructure. It’s noted that the Councils are currently not listed in GM4 (where some assets may be listed as a heritage item by the Council).

General policing of the Ground Movement EPRs is a key question – where is the presence of an independent Auditor in the process, which may occur before any independent mediation is called up as a requirement?

Requests for information from the proponent

<table>
<thead>
<tr>
<th>Information required</th>
<th>Reference (by page number in Technical Report M Folder)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Provide some more definition around the concept of ‘good workmanship’ in the context of this tunnel build.</td>
<td>Page 2, Section 1.2</td>
</tr>
<tr>
<td>• Have any ‘small utilities’ thus far been identified by NELP that warrant a particular assessment?</td>
<td>Page 16, Section 5.2</td>
</tr>
<tr>
<td>• Provide the output evidence of the FEA related to the Banyule Homestead slope stability appraisal.</td>
<td>Page 54, Section 8.2.5</td>
</tr>
<tr>
<td>• Confirm the value for ‘Symax’ for risk screening as part of the Stage 1 Risk Assessment. Is it 5 mm as indicated on Page 22, or 10 mm as indicated on Figure 5-3, Page 26.</td>
<td>Page 22, Section 5.6.1</td>
</tr>
<tr>
<td>• Provide some further detail on how the structural appraisal of the Banyule Creek Sewer was assessed.</td>
<td>Page 39/54</td>
</tr>
<tr>
<td>• In regard to the Helmet sculpture (Banksia Park) owned by Manningham Council, the early part of the EES Chapter suggests this sculpture will be relocated, yet the Detailed Assessment at the end of the Chapter provides EPR recommendations GM1/GM2/GM3/GM4 – please confirm the agreed plans for this.</td>
<td>Section 8.4.1</td>
</tr>
<tr>
<td>• The ‘Out Building’ at the Simpson Barracks appear to have a mis-match in its assigned risk ranking, when the conclusions of the Chapter are read (indicated as beyond a slight risk).</td>
<td>Page 1, Appendix A and Page 81</td>
</tr>
<tr>
<td>• Provide the actual Geotechnical Investigation Reports for the Project</td>
<td>Not Formally Referenced</td>
</tr>
<tr>
<td>• Provide the forming calculations that were the basis for Table 1</td>
<td>Appendix D1 – Numerical Validation</td>
</tr>
</tbody>
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