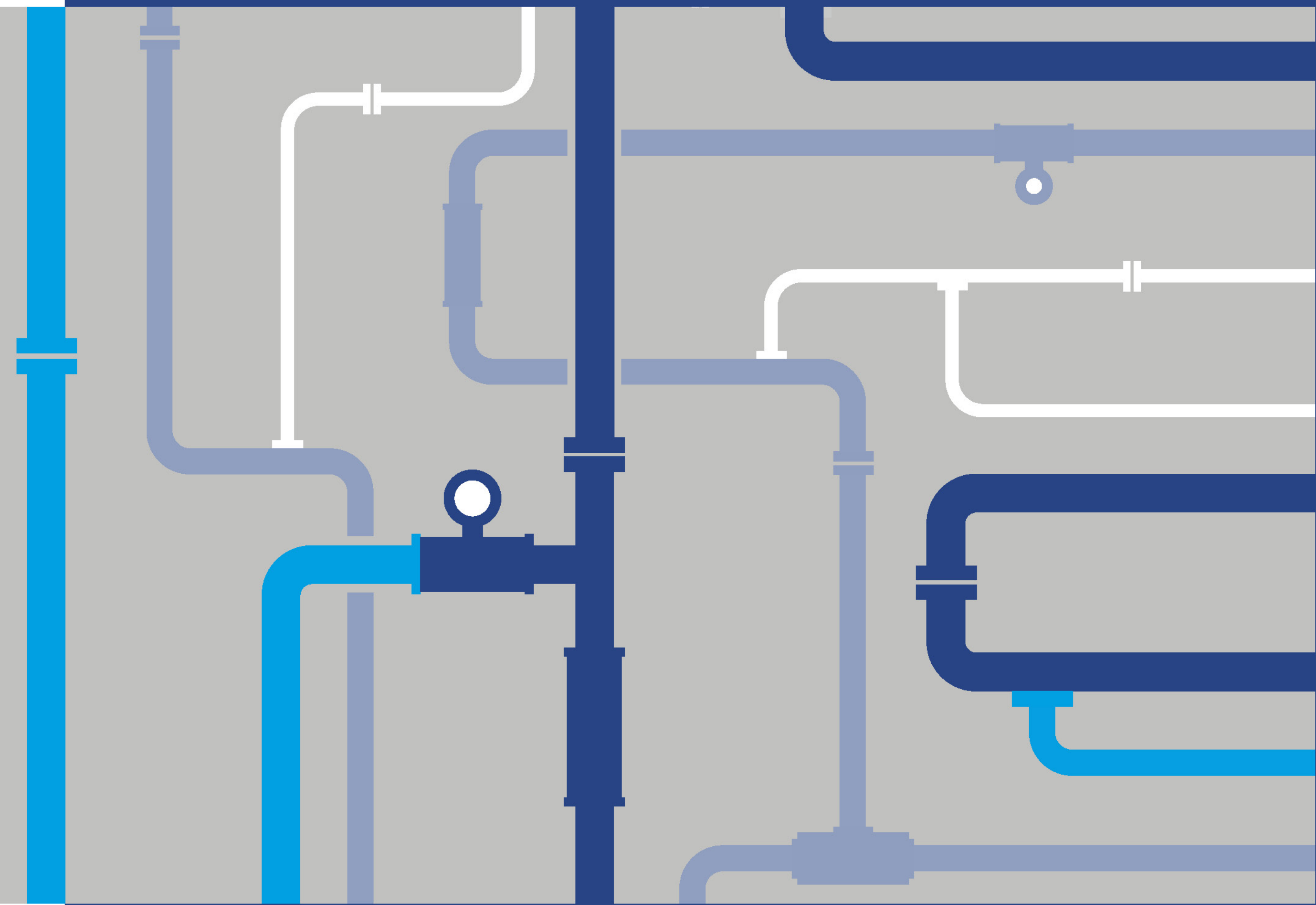
chapter 9

land stability and ground movement.



Environment Effects Statement | May 2021

western outer ring main

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Contents

Chapter 9

9.1 Introduction

This chapter provides an assessment of the land stability and ground movement impacts associated with the construction and operation of the Western Outer Ring Main (WORM) gas pipeline project (the Project). This chapter is based on the impact assessment presented in Technical report D *Land stability and ground movement.*

Land stability and ground movement includes the potential for ground movements that may arise during construction or operation of the Project. For this assessment, the term ground movement is used to refer to smaller scale movements around the pipeline due to open trench construction or trenchless activities. Land stability is used to refer to larger scale ground movements and the formation of unstable soil or rock masses through either human activity or natural processes. Land instability and ground movement can lead to damage to built infrastructure, vegetation, natural landforms and farmland and loss of land function. In the extreme, complete failure of a slope can result in significant and permanent changes to the landscape. It is therefore important to avoid or mitigate land stability or ground movement risks to safety, amenity, cultural or historical heritage, flora and fauna and hydrogeological processes.

The EES scoping requirements set out the following evaluation objectives in relation to land stability and ground movement:

- Avoid and minimise potential adverse effects on native vegetation, listed threatened and migratory species and ecological communities, and habitat for these species, as well as restore and offset residual environmental effects consistent with state and Commonwealth policies
- Maintain the functions and values of groundwater, surface water and floodplain environments and minimise effects on water quality and beneficial uses
- Minimise potential adverse social, economic, amenity and land use effects at local and regional scales.

To assess the potential effects on land stability and ground movement as a result of the Project, a land stability and ground movement impact assessment was undertaken to meet the following key issues identified in the EES scoping requirements:

- Potential erosion, sedimentation and landform stability effects during construction (scoping requirements Section 4.3)
- Potential for Project works and operations to affect business (including farming) operations or other existing or approved land uses through direct impacts of land loss or indirect impacts such as severance of land, erosion/sedimentation, reduced accessibility, or impacts on water supply and use (scoping requirements Section 4.5)
- Relocation or other impacts on existing or proposed infrastructure, including road/rail networks and power infrastructure (scoping requirements Section 4.5).

Other aspects closely related to the land stability and ground movement evaluation objectives are addressed in the following reports:

- Technical report A and chapter 7 *Biodiversity and habitats*
- Technical report B and chapter 8 *Surface water*
- Technical report C and chapter 8 *Groundwater*
- Technical report I and chapter 13 *Heritage.*

9.2 Method

The land stability and ground movement assessment comprised the following key tasks:

- Review of relevant legislation and policy at a national, state and local level.
- Establishment of a study area for land stability and ground movement. As land stability and ground movement effects are considered to be localised to the immediate area surrounding the pipeline, the study area for the assessment is the construction corridor.

> **What is the difference between ground movement and land stability?**
>
> **Ground movement** refers to smaller-scale soil or rock deformations induced by pipeline construction or operation activities. These deformations may subject nearby assets or features to unacceptable strains, as well as compromising local land stability.
>
> **Land stability** refers to larger scale movements due to the formation of unstable soil or rock masses. Effects on land stability may result in mass movement of soil bodies and disturbance to the natural landscape.

- Desktop assessment and baseline data review of the ground and groundwater conditions along the construction corridor to identify ground movement hazards inherent in the existing built environment and natural landscape. Review of relevant planning scheme overlays.
  This assessment is also informed by Project-specific field investigations including a series of geotechnical and groundwater testing as a part of a number of supplementary reports (detailed in Technical report D).
- Characterisation of existing conditions along the alignment to gain an understanding of the risks that may be present at each location. This is defined as kilometre point (KP) numbers and also known as reaches. The Project KP numbers and reaches are shown on Figure 9-1. The existing conditions for each reach are described in more detail in Section 6.5 of Technical report D.
- A risk-based review of potential impacts to prioritise the focus of the impact assessment using land stability risk assessment criteria. The consequences of a ground movement or land stability hazard occurring were assigned using consequence categories from insignificant to severe based on the existing conditions and values in the study area. Refer to Section 5.6.1 Technical report D *Land stability and ground movement* for detail on the ground movement and damage thresholds used to clarify the consequence of damage on the affected asset based on the estimated ground movements. Refer to Section 5.6.2 Technical report D *Land stability and ground movement* for detail on the slope and trench stability risk assessment categories.
- Assessment of the potential land stability and ground movement impacts during construction and operation of the Project, prior to any mitigation measures. For ground movement, this was largely based on standard ground movement and damage thresholds used for Preliminary[1] and Second Stage[2] assessments. For land stability, the assessment on slope stability applied the guidelines outlined in the Australian Geoguide for Slope Management and Maintenance[3].

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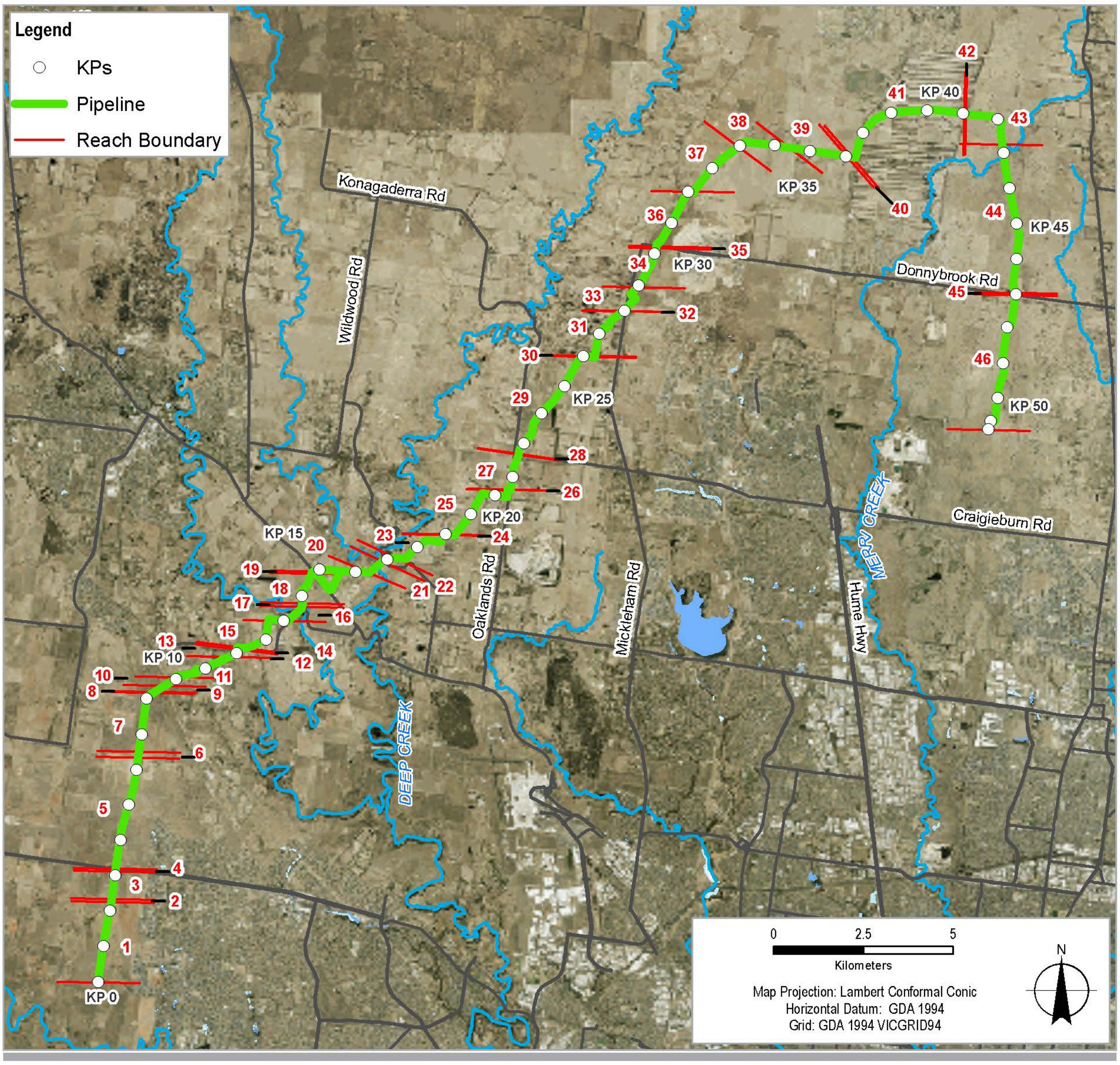
1 Rankin, W. J. (1988). Ground movements resulting from urban tunnelling: predictions and effects. In F. G. Bell, M. G. Culshaw, J. C. Cripps, & M. A. Lovell, Engineering Geology of Underground Movements (pp. 79-92). London: Geological Society Engineering Geology Special Publication No. 5.

2 Burland, J., Standing, J. R., & Jardine, F. M. (2001). Building response to tunnelling. Case studies from the Jubilee Line Extension. Thomas Telford Pub.

3 Australian Geomechanics Society. (2007). the Australian GeoGuides for Slope Management and Maintenance. Journal and News of the Australian Geomechanics Society, Volume 42, 159 - 182.

- Development of environmental management measures (EMMs) in response to the impact assessment to avoid and/or minimise impacts. Refer to Chapter 19 *Environmental management framework* for the full list of EMMs.
- Assessment of the residual impacts of the Project assuming implementation of the environmental management measures.
- Specifying the monitoring required to evaluate whether the Project meets the environmental management measures and detailing contingency measures as required.

Figure 9-1 Land stability and ground movement identified reaches



Data source: APA, 2020; GHD, 2020'; DELWP, Vicmap, 2020 Created by:jembury

9.3 Existing conditions

The following section outlines the existing conditions of the Project study area in relation to land stability and ground movement. To establish a baseline for the ground and groundwater conditions for the Project, and to identify any ground movement hazards inherent in the existing environmental and natural landscape, the following themes were investigated:

- Geology and geomorphology
- Hydrogeology
- Dispersive (sodic) soils
- Sites of geomorphological significance (SGGS)
- Local existing conditions.

9.3.1 Geology and geomorphology

The Project is located within the easternmost Western Plains geomorphic province of Victoria. The construction corridor is characterised by multiple Quaternary basalt volcanic eruption points that protrude above extensive lava plains produced by repeated volcanic episodes over long time periods. Within this predominantly volcanic setting, ranges of low hills protrude above the basalt plains, composed of pre-volcanic basement rocks and Neogene cover units.

The topography of the study area is generally flat to gently undulating, with the exception of significant low elevations at Jacksons Creek and Deep Creek where the valley sides are steep compared to the surrounding plains.

Geological conditions along the alignment are dominated by the Newer Volcanics basaltic flows and stony rises. Alluvium is present in the Jacksons Creek and Deep Creek watercourses. Outcrops of the Silurian Deep Creek Siltstone and the Neogene Brighton Group are also present within the vicinity of Deep Creek. The proposed alignment also transverses the Siluro-Devonian Humevale Siltstone, Holocene colluvium and Quaternary alluvial terraces within the suburb of Mickleham.

Definitions of key geological units

Quaternary alluvium: Gravel, sand, silt: variably sorted and rounded; generally unconsolidated; includes deposits of low terraces; alluvial floodplain deposits.

Neogene Brighton Group: Gravel, sand, silt: variably calcareous to ferruginous sandstones and coquinas; marine to non-marine.

Devonian Humevale Siltstone: Siltstone: brown, laminated; minor very-fine to fine grained sandstone laminae and thin beds towards the top of the formation.

Silurian Deep Creek Siltstone: Siltstone (dark grey-green, thin to thick-bedded, mostly strongly bioturbated), and sandstone (regularly interbedded with siltstone; thin to very thin, commonly with ripple marks; rare conglomerate).

9.3.2 Hydrogeology

The depth to water table varies considerably across the study area but it is considered to be generally greater than five metres below ground level. This is with the exception of the following areas as identified during recent hydrogeological investigations:

- Bendigo Railway and the Tame Street Drain (KP 8.25 to 8.64)
- Jacksons Creek and surrounds (KP 13.68 to 13.79)
- Deep Creek and surrounds (KP 16.32 to 16.87)
- Donovans Lane and the North East Rail reserve (KP 41.05 to 41.10)
- Merri Creek and surrounds (KP 42.77 to 46.97)
- Donnybrook Road (east of Merrifield) (KP 46.97 to 47.03)
- North of the Wollert Compressor Station (KP 47.03 to end).

At these locations, it is anticipated that groundwater would be intercepted during excavation, and groundwater dewatering may be required to enable the trench excavations.

For further detail on the groundwater monitoring program and groundwater conditions, refer to Chapter 8 *Water* and Technical report C *Groundwater*.

9.3.3 Dispersive (sodic) soils

To determine the existing dispersivity of the soils along the Project alignment, a physical test (Emerson crumb test, AS 1289.3.8.1) was undertaken at select locations along the Project alignment. Given the available testing results, the presence of dispersive soils is known at Jacksons Creek, Deep Creek, Donnybrook Road (west), Merri Creek and Kalkallo Basin.

In addition to the locations tested, further testing is proposed to confirm other areas of the construction corridor where the potential for dispersive soils to be present is likely. In addition, regional mapping of sodic soils indicates that the Project is within an area described as containing 'dense, dispersive subsoils'[4] .

What are sodic soils?

When there is saline water in soils, there is potential for dispersive behaviour or 'sodicity' in fine grained residual soils.

This means that the exchangeable sodium amounts are higher, and thus the risk of dispersivity of the soil when exposed to fresh water may be greater, leading to ground movement and land stability impacts.

Dispersivity or dispersion describes the behaviour of soil particles separating from one another. Dispersion can cause soil aggregates to breakdown resulting in structural decline and erosion.

Further testing of the construction corridor prior to construction would enable targeted management of the risks associated with dispersive soils appropriate to the identified dispersive hazard in different locations along the alignment (refer to EMM GM7 for further detail).

[4] Victorian Resources Online. (2014). Victorian Soils Map. Retrieved from Agriculture Victoria: http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/victorian_soils_map_2014

9.3.4 Sites of geomorphological or geological significance (SGGS)

SGGS are identified on the basis that they either represent a specific characteristic of the region, or that they include an outstanding, rare, or possibly unique geological or geomorphological feature[5]. Sites are generally selected as commissioned by the Victorian Environmental Assessment Council in accordance with the Victorian *Environmental Assessment Council Act 2001*. A Project-specific investigation on this matter has not been requested under the *Victorian Environmental Assessment Council Act 2001*, however, existing SGGS of relevance to the Project can be identified[6].

The following have been identified within the study area as a site of 'Regional Significance':

- Merri Creek Channel (Victorian Resources Online (VRO) site 35 – near KP 42.8): landscape and vegetation is relatively untouched since pre-European settlement
- Hayes Hill Eruption Point (VRO site 38 – near KP 46): although not a major eruption centre, Hayes Hill is approximately 700 metres north of 1140 Donnybrook Road, and is a significant site as the likely source of lava that determined long-term landform development along the Merri and Darebin Creeks and the Yarra River
- Jacksons Creek High Level Cut-off (VRO site Ko6 – near KP 13.7): is approximately 1 kilometre north-east of the Project, and presents the best example of a high level cut-off in the area (geological term for a site of geomorphological or geological significance)
- Deep Creek Outcrop (VRO site Ko5 – 200 metres north of Deep Creek pipeline crossing): the confluence of Deep Creek and Emu Creek
- Bald Hill Eruption Cone (VRO site 36 – at its closest point is approximately 650 metres from the pipeline near approximately KP 39 to KP 41): composite volcanic cone emplaced between the Miocene and Holocene epochs.

Based on the assessment of the existing SGGS sites, the land stability and ground movement report concludes that the sites are not expected to be affected by the design or construction methodology for the Project.

9.3.5 Local existing conditions

The descriptions of existing conditions along the alignment has been undertaken based on 46 land stability and ground movement reaches. The reaches were determined to delineate changes in geology and/or construction methodology and to indicate where land stability and ground movement risks may arise. The location of the reaches is illustrated in Figure 9-1.

For a detailed description of the local existing conditions at each of the reaches along the alignment including the construction methodology, geology, hydrogeology and existing assets, refer to Section 6.5 of Technical report D *Land stability and ground movement.*

[5] Victorian Resources Online. (2018). Sites of Geological or Geomorphological Significance. Retrieved from Agriculture Victoria: http://vro.agriculture.vic.gov.au/dpi/vro/portregn.nsf/pages/port_lf_ppsites_sig.

[6] Rosengren, N. J. (1986). Sites of Geological and Geomorphological Significance in the Western Region of Melbourne. Melbourne: The University of Melbourne.

The following locations were identified as being subject to greater ground movement risk from boring due to their location within granular soil. For further detail on the impact assessment of these crossings, refer to Section 9.5.2.

- **Holden Road (KP 6.34 to 6.50):** horizontal boring is proposed beneath Holden Road, which contains the following sensitive receptors:
  - Deer Park to Sunbury APA gas transmission pipeline parallel to WORM, a steel pipe of 0.15 metres diameter. Lateral offset between the two pipelines is approximately 7.5 metres at the crossing
  - VHI listed cobbled stone road (VHI number H7822–2283)
  - Optical fibre cable owned by NextGen runs parallel to WORM with a lateral offset of 6 metres.
- **Bulla-Diggers Rest Road (KP 11.11 to 11.18):** horizontal boring is proposed beneath Bulla-Diggers Rest Road, which contains the following sensitive receptors:
  - Direct buried copper communication wire owned by Telstra at a depth of 1.2 metres below ground level
  - 100 mm diameter PVC water pipeline owned by Western Water at a depth of 1.2 metres below ground surface
  - Direct buried copper communication wire owned by Telstra at a depth of 0.2 metres below ground level
  - Concrete drainage culvert underneath the private driveway on the north side of the road.
- **Mickleham Road (KP 27.95 to 28.06):** horizontal boring is proposed beneath Mickleham Road, which contains the following sensitive receptors:
  - Concrete drainage culvert approximately 12 metres north of the crossing
  - Communication wire owned by Telstra within a 50 millimetre diameter PVC casing at a depth of 0.55 metres below ground surface
  - Direct buried communication wire owned by Telstra at a depth of 1.2 metres below ground surface
  - Direct buried optical fibre cable owned by Optus at a depth of 1.2 metres below ground surface
  - High voltage overhead power line with nearest power pole approximately 12 metres north of the crossing owned by Jemena.

9.4 Risk assessment

The risk assessment identified the risks associated with land stability and ground movement as a result of the Project's construction and operation in accordance with the method described in Chapter 5 *Evaluation and assessment framework*.

To determine the key risks associated with land stability and ground movement, the key sources of movement including trenchless crossings, open trench excavations and construction drawdown, were assessed alongside the potential land stability risks including slope stability, trench stability and erosion. Table 9-1 presents a summary of the nine construction risks and two operation risks identified and assessed as part of the land stability and ground movement assessment. These risks provide a framework for the impact assessment discussed in Sections 9.5 and 9.6.

Table 9-1 Risk assessment for land stability and ground movement

Risk ID	Works area	Risk pathway	Initial mitigation measures	Initial risk rating	Additional mitigation measures	Residual risk rating
Construction						
GM1	Pipeline	Open trench excavations in unstable ground (granular material) causing instability and wall collapse resulting in disturbance to nearby land and native vegetation.	EMM GM1 – All third party services would be identified and proved prior to construction and asset owners' vertical and horizontal clearance requirements will be agreed. EMM GM2 – Design and construction to be informed by geotechnical and hydrogeological conditions. EMM SW3 – Develop appropriate site rehabilitation measures as part of the final CEMP for disturbance caused by open trench construction. EMM SW4 – Develop appropriate control measures as part of the final CEMP for open trench construction	Medium	EMM GM3 – Management of trench stability: support and duration. EMM GM7 – Preparation and implementation of sodic soil management measures	Negligible
GM2	Pipeline	Open trench excavations in stable ground (cohesive material) causing ground movements subjecting nearby sensitive receptors to unacceptable strains.	EMM GM1 – All third party services would be identified and proved prior to construction and asset owners' vertical and horizontal clearance requirements will be agreed. EMM GM2 – Design and construction to be informed by geotechnical and hydrogeological conditions	Negligible	No additional mitigation required	Negligible
GM3	Pipeline	Construction dewatering in compressible soils causing consolidation settlement, subjecting nearby assets and features to unacceptable strains.	EMM GM1 – All third party services would be identified and proved prior to construction and asset owners' vertical and horizontal clearance requirements will be agreed. EMM GM2 – Design and construction to be informed by geotechnical and hydrogeological conditions	Negligible	No additional mitigation required	Negligible

Risk ID	Works area	Risk pathway	Initial mitigation measures	Initial risk rating	Additional mitigation measures	Residual risk rating
GM4	Pipeline	Construction dewatering in dispersive soils causing erosion and land disturbance.	EMM GM1 – All third party services would be identified and proved prior to construction and asset owners' vertical and horizontal clearance requirements will be agreed. EMM GM2 – Design and construction to be informed by geotechnical and hydrogeological conditions. EMM GM4 – Management of trench erosion, consolidation and swelling.	Negligible	No additional mitigation required.	Negligible
GM5	Pipeline	Volume loss associated with trenchless pipe installation in soil causing unacceptable strains to nearby assets and features.	EMM GM1 – All third party services would be identified and proved prior to construction and asset owners' vertical and horizontal clearance requirements will be agreed. EMM GM2 – Design and construction to be informed by geotechnical and hydrogeological conditions. EMM GM5 – Trenchless bore management.	Low	No additional mitigation required.	Low
GM6	Pipeline	Trenchless pipe installation encountering unexpected poor ground conditions at crossings with insufficient geotechnical data causing unanticipated asset damage or horizontal directional drilling (HDD) 'blow out' during construction.	EMM GM1 – All third party services would be identified and proved prior to construction and asset owners' vertical and horizontal clearance requirements will be agreed. EMM GM5 – Trenchless bore management.	Medium	EMM GM6 – Confirmation of ground risk.	Low
GM7	Pipeline	Pipeline construction in proximity to existing slopes causing ground movements, erosion and potential slope instability.	EMM GM4 – Management of trench erosion, consolidation and swelling.	Medium	EMM GM3 – Management of trench stability: support and duration. EMM GM7 – Preparation and implementation of sodic soil management measures.	Low

Risk ID	Works area	Risk pathway	Initial mitigation measures	Initial risk rating	Additional mitigation measures	Residual risk rating
GM8	Pipeline	Trench excavations through waterways and wetland areas resulting in land disturbance as a result of increased erosion effects.	EMM GM1 – All third party services would be identified and proved prior to construction and asset owners' vertical and horizontal clearance requirements will be agreed. EMM GM2 – Design and construction to be informed by geotechnical and hydrogeological conditions. EMM GM4 – Management of trench erosion, consolidation and swelling.	Low	No additional mitigation required.	Low
GM9	Pipeline	Pipeline construction near sites of Special Geological or Geomorphological Significance causing ground movement and land disturbance.	EMM GM2 – Design and construction to be informed by geotechnical and hydrogeological conditions. EMM GM4 – Management of trench erosion, consolidation and swelling.	Negligible	No additional mitigation required.	Negligible
Operation						
GM10	Pipeline	Pipeline acts as a long term drain in compressible soils causing consolidation subjecting proximal assets and features to unacceptable ground strains.	EMM GM4 – Management of trench erosion, consolidation and swelling.	Negligible	No additional mitigation required.	Negligible
GM11	Pipeline	Permanent ground and surface water flow changes as a result of excavations causing ongoing erosion.	EMM GM4 – Management of trench erosion, consolidation and swelling.	Medium	EMM GM7 – Preparation and implementation of sodic soil management measures.	Low

Note: refer to Table 9-3 for the full list of environmental management measures.

9.5 Construction impact assessment

This section presents a discussion of the construction impacts associated with the Project in relation to land stability and ground movement and are grouped according to four main themes drawn from the higher risk pathways:

- Open trench excavations in unstable ground
- Volume loss arising from trenchless crossings in soil
- Trenchless pipe installation encountering poor ground conditions
- Pipeline installation in proximity to existing slopes.

The potential for impacts associated with these main themes are discussed in the following sections.

9.5.1 Open trench excavations in unstable ground

Excavation of deep trenches during construction can result in wall instability. Without any mitigation measures, wall collapse could result in a large amount of land disturbance to a localised area near the trench. The degree of disturbance could have considerable effects on nearby sensitive receptors including natural landforms and native flora and fauna as well as compromising agricultural functionality and potential impacts on areas of cultural sensitivity.

With a typical excavation depth of approximately 2 metres, the trench excavations required for the Project are slightly deeper than what would traditionally be classified as a shallow trench (less than 1.2 metres). If the trench is not supported through trench shields, struts or anchors, the trench stability will depend on the strength of the material through which the trench is excavated.

The particle size distribution testing undertaken as part of the existing conditions assessment indicates the following in relation to the strength of the materials across the alignment:

- **Fine grained (cohesive) soil:** approximately 90 percent of the soil samples tested comprise fine grained, cohesive materials as the primary component. The majority of the open trench construction is expected to be excavated through clays or silts of residual basalt, which may remain temporarily stable up to a limiting height depending on the undrained shear strength of the soil.
- **Granular material:** the remaining 10 percent of the soil samples tested comprise granular material as the primary component. Vertical cuts cannot be sustained in granular soils (ie sand or gravel) under drained conditions, as a drained-cohesionless soil will always fail when the slope angle is greater than the angle of friction of the soil (soil strength parameter). Failure could occur even if only a portion of the trench depth is excavated through these unfavourable conditions.

In addition to strength of the materials, internal erosion effects for granular soils or adverse reactions associated with dispersive behaviour in fine grained (cohesive) soils may reduce the stability of the trench wall. The rate at which this instability may occur may be increased during periods of elevated antecedent rainfall due to saturated conditions. Erosion and reduction in trench wall stability over time may lead to wall instability if the trench is left open for significant periods.

Although the majority of trench excavation through fine grained clays or silts are expected to be stable, the potential for unfavourable conditions, such as encountering granular soils, requires management to reduce potential impacts on nearby land. There is insufficient geotechnical information to determine specific locations where granular soils may be encountered along the alignment. It is considered that there is potential for granular soils to be encountered at any location along the alignment.

Land stability and ground movement management measures are described in EMM GM3, GM4 and GM7 and would broadly include the following requirements for all trench excavations:

- Trench excavation works would be conducted in accordance with the requirements of the Safe Work Australia Code of Practice: Excavation Work (2018) and WorkSafe Victoria Compliance Code: Excavation (2019) to minimise the risk of trench wall collapse
- The time that trenches and bell holes remain open would be minimised as far as reasonably practicable
- Implementation of erosion and sediment control measures including the use of trench breakers installed at regular intervals along the trench excavation
- Compaction of the trench backfill as per APA's performance requirement and/or contractor's construction requirements
- Inclusion of sodic soil management measures within the final CEMP
- Routine inspection and monitoring of the construction corridor in accordance with International Erosion Control Associated (IECA) Best Practice Erosion and Sediment Control (2008).

The above EMMs seek to achieve avoidance of the impact according to the mitigation hierarchy by reducing the likelihood of residual impacts associated with wall collapse. If avoidance is achieved, the residual impact is not anticipated to occur. In a worst-case scenario, if wall collapse is to occur, contingency response measures will be required to minimise the duration and intensity of the impacts. These are to be detailed in the final CEMP and may include for example, requirements for temporary shoring (eg wall support) and the removal, replacement, and rehabilitation of the disturbed soil.

9.5.2 Volume loss arising from trenchless crossings in soil

For the Project, ground conditions are expected to vary at the depth of the bore between three main ground condition types, which have different implications on ground movement (or volume loss) without mitigation, as described in Table 9-2.

It is noted that the use of drilling support fluid (for example bentonite) as a form of temporary bore support during drilling can significantly reduce the potential for high volume losses, however, movements are still possible.

What is volume loss?

The process of boring causes ground movements ahead of the bore face. This means that a volume of ground slightly greater than that of the theoretical volume of the tunnel will be excavated. This is called volume loss and usually occurs around bores excavated in soft ground such as firm to stiff cohesive soils or within granular soils. The volume loss translates into surface settlement, with the maximum settlement occurring directly above the bore centreline.

Table 9-2 Trenchless crossing ground conditions and potential pre-mitigation volume loss

Ground conditions at bore depth	Volume loss impacts	Location along the alignment
Rock	Though only minor movements are expected in the bore through basalt, liaison with asset owners may require the implementation of settlement monitoring and contingency plans. No further assessment is required.	• Reach 4 (KP 3.10 to 3.18): Melton Highway • Reach 8 (KP 8.25 to 8.30): Bendigo Rail Line • Reach 10 (KP 8.64 to 9.06): Calder Freeway, Dillon Court and agricultural land • Reach 19 (KP 14.73 to 14.80): Sunbury Road • Reach 40 (KP 37.03 to 37.18): Gunns Gully Road/Hume Freeway • Reach 42 (KP 41.01 to 41.10): North Eastern Rail Line • Reach 45 (KP 46.97 to 47.03): Donnybrook Road (East)
Cohesive soil (clay or silt)	The stiff soils expected would arch, minimising movements. For the anticipated bore diameters and assumed volume loss of 3%, associated maximum settlements and trough gradients are expected to be within the minor or insignificant damage category for affected assets. No further assessment is required.	• Reach 21 and 22 (KP 16.32 to 16.87 and KP 16.87 to 17.23): Deep Creek and Wildwood Road • Reach 28 (KP 22.65 to 22.67): Craigieburn Road
Granular soil (sand or gravel)	Dense granular soils would be expected to dilate upon excavation, resulting in low to negligible movements. Boring through loose soils may lead to partial bore collapse if the ground is temporarily unsupported. The granular soils are generally expected to be of sufficient density to exhibit some dilation, meaning that ground movement is not expected to be significant. However, there is the possibility of localised brittle failure of the soil resulting in greater movements. A volume loss of 5% is considered suitable for these ground conditions. Each crossing is examined in confirming specific construction methodology to minimise volume loss in the sections below.	• Reach 6 (KP 6.34 to 6.50): Holden Road • Reach 14 (KP 11.11 to 11.18): Bulla-Diggers Rest Road • Reach 32 (KP 27.95 to 28.06): Mickleham Road

Additional assessment of each of the trenchless crossings within granular soil is described in Section 8.2.1 of Technical report D *Land stability and ground movement*.

To determine potential impacts on sensitive receptors, a ground movement assessment has been conducted on the higher risk crossings, described in Section 9.3.5, deemed to be at higher risk of ground movement due to the presence of potentially unstable granular material at the depth of the bore. This includes a preliminary assessment and a second stage assessment. These higher risk crossings include Holden Road, Bulla-Diggers Rest Road and Mickleham Road.

The preliminary assessment considered each crossing against a simple damage risk criteria[7]. This determined that two of the three crossings (Bulla-Diggers Rest Road and Mickleham Road), required second stage assessment, primarily due to the relatively high ground slope estimated.

The second stage assessment considered the horizontal and vertical ground strains at the affected utility depth, utility materials and pipe-soil relative stiffness effects at the three high risk crossings. Tensile and compressive strains are estimated along the length of the pipeline and are compared to the assumed acceptable strain limits at each point. In lieu of acceptable strain limits provided by the asset owners, the tensile and compressive strain limits assumed for the utility damage risk assessments have been based on lower bound thresholds within the expected range of values[8].

This assessment determined that based on the strain limits and maximum strains, the impact is minor for both of the crossings. Refer to Table 8-3 in Section 8.2.3 of Technical report D *Land stability and ground movement* for further detail on the strain assessment results.

The following land stability and ground movement management measures are described in EMM GM1, GM2 and GM5 and would broadly include the following requirements for all trenchless crossings:

- Third party asset management
- Detailed design and construction to be informed by geotechnical and hydrogeological conditions
- Trenchless bore management to temporarily support the bore during trenchless activities
- To manage support fluid pressures, a volumetric drilling fluid tracking program is to be implemented with defined threshold levels for fluid loss, stop works and further investigation.

The application of the above management measures is considered to minimise the residual impact at the two higher risk crossings, which is already considered to be minor, and is unlikely to affect the serviceability of the utilities assessed. Complete avoidance of the impact is not considered to be practicably achievable for the trenchless activities and ground conditions assumed.

9.5.3 Trenchless pipe installation encountering poor ground

The construction methodology for the Project proposes horizontal boring or HDD trenchless methods at a number of locations where there is insufficient geotechnical information currently available to assess the specific level of ground movement potential impact at each site.

To manage this uncertainty, where sensitive utilities are located, the contractor would determine the potential damage to utilities when ground information is made available. This may be obtained by geotechnical investigations prior to construction. The key locations and associated sensitive receptors identified for specific investigation include:

- Beatty's Road: 100 millimetre diameter glass reinforced plastic (GRP) drainage pipe, 100 millimetre diameter PVC casing pipe, 400 millimetre diameter water pipeline (identified through surface features only and other minor utilities)

[7] Rankin, W. J. (1988). Ground movements resulting from urban tunnelling: predictions and effects. In F. G. Bell, M. G. Culshaw, J. C. Cripps, & M. A. Lovell, Engineering Geology of Underground Movements (pp. 79-92). London: Geological Society Engineering Geology Special Publication No. 5.

[8] AS2566.1: 1998 Buried Flexible Pipelines, Attewell & Woodman, 1982, Polymer Properties Database, 2019.

- Morefield Court: 100 millimetre diameter PVC water pipeline and other minor utilities
- Sunbury Road: 150 millimetre diameter, 375 millimetre diameter and 450 millimetre diameter water main, DN100 casing and other minor utilities
- St Johns Road: 100 millimetre diameter water main and other minor utilities
- Oaklands Road: minor utilities only
- Mt. Ridley Road/Parkland Crescent: minor utilities only
- Donnybrook Road (west): Communication wire conduit with 100 millimetre diameter PVC casing with two Optus cables and one Telstra cable, 225 millimetre diameter high density polyethylene (HDPE) water pipeline owned by Yarra Valley Water with 1.4 metres of ground cover in good condition, 225 millimetre diameter PVC drainage pipeline, two electricity cables owned by Jemena within a 150 millimetre diameter PVC casing and other minor utilities.

Another potential impact associated with HDD trenchless methods is the use of temporary drilling support fluid, which can result in blow-out (or fracking). Based on the available geotechnical information[9], this is considered to be a rare circumstance for the majority of the HDD or pipe-jack trenchless crossings expected for construction of the pipeline. If these unexpected conditions arise, the constructor would be required to have appropriate procedures in place to manage any blow-out including the implementation of volumetric fluid tracking program. Successful implementation of this is considered to reduce the risk of blow-out to low, therefore no further impact assessment is deemed necessary.

What is blow out or fracking?

The use of temporary drilling support fluid (such as bentonite) during trenchless HDD or pipe-jacking operations can result in blow-out (or fracking), where the drilling fluid leaks through the bore into the surrounding soil, potentially at high pressures, resulting in loss of strength of the affected soil.

Blow-out is typically associated with the over-pressurisation of bore support fluid in loose, cohesionless granular soils.

Land stability and ground movement management measures are described in EMM GM1, GM5 and GM6 and would broadly include the following requirements for all crossings where there are currently unconfirmed ground conditions:

- Third party asset management
- Trenchless bore management to temporarily support the bore during trenchless activities
- For sites where there is insufficient or no geotechnical information, confirm the viability of proposed temporary works (ie choice of trenchless method) by completing additional geotechnical investigations.

Successful application of the above EMMs is considered to result in only negligible to minor residual impacts on existing utilities. A possible residual impact could include some minor strains felt by the utility, however, loss of serviceability would not occur. Given uncertainties surrounding geotechnical risk for any form of trenchless activity, complete avoidance of residual impacts is considered unlikely.

9 Construction Sciences. (2020). Pipeline ROW, Water Crossing and HDD Crossing Geotechnical Report.

9.5.4 Pipeline installation in proximity to existing slopes

As a part of the Project construction, there is potential for the trench excavations to reduce existing slope stability, potentially leading to slope failure.

Pre-mitigation, this is expected to be most prevalent during open trench construction through the valley north of the Jacksons Creek crossing. The steep slope East of Wildwood Road may also be subject to some slope instability risk, however, given that the trench would be excavated up the slope gradient, different and less critical failure mechanisms would apply.

To assess the potential likelihood of slope failure for the Project, the assessment considered three scenarios of variable ground conditions that may exist during unsupported open trench construction near the slopes. This assessment assumes no trench support.

What is slope failure?

How does slope failure occur?

Excavation of a trench near a slope may act as a destabilising notch near the base of a slope, reducing the natural resistance of the slope to sliding failures. Further minor destabilizing effects induced by the construction works may also contribute to the overall stability of the slope, including surface erosion.

What are the consequences?

Slope failure would result in significant and potentially widespread impact to sensitive receptors such as natural landforms, farmland and flora and fauna.

Following this assessment, the scenarios were determined to have the following likelihood of slope failure:

- Scenario 1: Trench through cohesive material – remote likelihood of slope failure
- Scenario 2: Trench through cohesive material, trench is left open for extended periods (including rainfall events), includes consideration of weather events and saturated soils – almost certain likelihood of slope failure
- Scenario 3: Trench through granular material – almost certain likelihood of slope failure.

Land stability and ground movement management measures are described in EMM GM3, GM4 and GM6 and would broadly include the following requirements to reduce the likelihood of slope failure near Jacksons Creek:

- Trench excavation works would be conducted in accordance with the requirements of the Safe Work Australia Code of Practice: Excavation Work (2018) and WorkSafe Victoria Compliance Code: Excavation (2019) to minimise the risk of trench wall collapse
- The time that trenches and bell holes remain open would be minimised as far as reasonably practicable
- Implementation of erosion and sediment control measures including the use of trench breakers installed at regular intervals along the trench excavation
- Compaction of the trench backfill as per APA's performance requirement and/or contractor's construction requirements
- Inclusion of sodic soil management measures within the final CEMP
- Routine inspection and monitoring of the construction corridor in accordance with International Erosion Control Associated (IECA) Best Practice Erosion and Sediment Control (2008).

These EMMs seek to avoid the potential for trench excavations to reduce existing slope stability, potentially leading to slope failure. Application of these EMMs will effectively reduce the likelihoods of Scenario 2 and Scenario 3 to rare, indicating negligible residual impacts. If avoidance is achieved, wall instability is not anticipated to occur. In a worst-case scenario, if wall instability and slope failure is to occur, contingency response measures would be detailed in the final CEMP.

9.5.5 Construction residual impacts summary

With the implementation of mitigation measures, residual impacts on land stability and ground movement during construction include:

- If avoidance of wall instability during excavation of deep trenches is achieved, the residual impact is not anticipated to occur. In a worst-case scenario, if wall instability is to occur, contingency response measures will be required to minimise the duration and intensity of the impacts. These are to be detailed in the final CEMP and may include, for example, requirements for temporary shoring (eg wall support) and the removal, replacement, and rehabilitation of the disturbed soil
- The potential residual impact associated with volume loss at trenchless crossings is considered to be minor and is unlikely to affect the serviceability of the utilities assessed
- Potential residual impacts associated with trenchless pipe installation encountering poor ground could include some minor strains felt by the utility, however, loss of serviceability would not occur
- Potential residual impacts associated with pipeline installation in proximity to existing slopes is considered to be minimal if avoidance is achieved, as wall collapse is not anticipated to occur. In a worst-case scenario, if wall collapse and slope failure is to occur, contingency response measures would be detailed in the final CEMP.

9.6 Operation impact assessment

This section presents a discussion of the operational impacts associated with the Project in relation to the following land stability and ground movement theme:

- Permanent groundwater and surface water flow changes as a result of excavations.

The potential for impacts associated with this main theme is discussed in the following section.

9.6.1 Permanent groundwater and surface water flow changes as a result of excavations

Without mitigation, open trench construction can create potential for long term (operational phase) erosion of the disturbed soils/backfill by altered groundwater seepage and surface water flows. This effect may be exacerbated by the presence of dispersive (sodic) soils, particularly where steep slope gradients exist.

Appropriate construction mitigations would contribute to minimising long term (operational phase) impacts. In accordance with EMM GM4, mitigations will include the use of trench breakers, as well as compaction of the trench fill as per APA's performance requirement and/or contractor's construction requirements. The degree of compaction would take into account design load limits on the pipe.

In addition, EMM GM7 requires preparation and implementation of sodic soil management measures within the Construction Environment Management Plan (CEMP) to mitigate adverse long term dispersive reactions.

Routine inspection and monitoring of the operational easement area will be undertaken throughout operation as per the VTS OEMP to identify any issues such as ongoing erosion or other changes to the ground surface. Identification and management of issues identified would be in accordance with IECA Best Practice Erosion and Sediment Control (2008).

These EMMs are to be applied to each location where trench excavations are to occur. Application of these EMMs is considered to minimise residual impacts such as ongoing minor dispersive behaviour that would require monitoring as described in the VTS OEMP. Avoidance is not considered practically achievable given the anticipated extent of dispersive soils throughout the Project area and the variability inherent in geotechnical conditions.

9.6.2 Operation residual impacts summary

With the implementation of mitigation measures, potential residual impacts on land stability and ground movement during operation, such as land degradation and slope creep, would be minimised. This residual impact is caused by changed groundwater and surface water flows, and exacerbated by the presence of dispersive (sodic) soils. If there are any signs of ongoing erosion, land degradation or slope creep resulting from construction, that is visible during operation, this will be managed by identifying it through inspections and undertaking rectification works in consultation with landowners. The mitigation is described in the VTS OEMP, and EMMs GM4 – Management of trench erosion, consolidation and swelling, and GM7 – Preparation and implementation of sodic soil management measures.

9.7 Cumulative impact assessment

The following planned projects may induce land stability and ground movement effects cumulatively with the Project:

- **Outer Metropolitan Ring Transport Corridor Project:** Cumulative land stability and ground movement effects may arise as a result of the excavation activities required for the construction of the OMR road embankments or from excess ground settlement due to increased surface loading. Generally, these effects are only expected to occur where the two projects intersect. In these instances, for the design of the OMR project may need to consider the existing WORM pipeline as well as any existing or ongoing effects caused by the WORM Project. The key cumulative impacts between the WORM pipeline and future OMR will be minimised through ongoing coordination between APA and the Department of Transport, in relation to the WORM pipeline design (depth, location, etc), construction methodology (backfill, compaction, etc) and future accessibility requirements. The WORM will need to be designed and constructed in a way that will minimise any impact to the OMR. APA will enter into a Coordination Deed with DoT to ensure its requirements are met.
- **Sunbury Road Upgrade:** Cumulative land stability and ground movement effects may arise as a result of the excavation activities required for the construction of the road embankments or from settlement of the ground due to increased surface loading. In the location where the Sunbury Road Upgrade would intersect with the WORM pipeline, the WORM pipeline would be installed using trenchless HDD techniques. The ground conditions at the depth of the bore are inferred to be basalt bedrock. This implies that there would be minor to negligible changes to the ground surface or subsurface when compared to elsewhere along Sunbury Road, and cumulative impacts would be minimal.

- **Bald Hill to Yan-Yean Pipeline:** The proposed pipeline alignment may cross underneath the North Eastern Railway in the vicinity of the WORM crossing. However, it is considered that if the bore is to also be within rock, the cumulative ground movement risk will be relatively unchanged. Liaison with the relevant railway authority would confirm any mitigation or contingency requirements when the ground movement risk is known for the Bald Hill to Yan-Yean project, such as the implementation of a settlement monitoring and contingency plan.

With the application of the WORM EMMs, it is considered that the cumulative impact of these projects is minor to unchanged.

9.8 Environmental management

9.8.1 Environmental management measures

Table 9-3 lists the environmental management measures (EMMs) relevant to land stability and ground movement. In general, these EMMs have been developed in accordance with the International Erosion Control Association Best Practice Erosion and Sediment Control, Appendix P – Land Based Pipeline Construction (IECA, 2008).

In developing the EMMs, the land stability and ground movement report adhered to the mitigation hierarchy that is, an obligation to first avoid, minimise, restore and only after exhausting those measures, offset the remaining residual impacts. For the land stability and ground movement assessment, the first step of the mitigation hierarchy, avoidance, was preferred to manage identified environmental impacts. Where avoidance could not be achieved, due to the nature of the Project, the existing conditions and/or the type of impacts, minimisation, was the next level in the proposed mitigation hierarchy. Application of the mitigation hierarchy for each EMM is identified in the mitigation hierarchy column in Table 9-3.

Table 9-3 Land stability and ground movement environmental management measures

EMM #	Environmental Management Measure	Stage	Mitigation hierarchy
GM1	**Third party asset management** Identify and prove all third party services prior to construction and agree vertical and horizontal clearance requirements with asset owners. Liaise with asset owners for any asset within the construction easement to confirm asset clearance and other mitigation, protection or contingency requirements, including possible settlement monitoring at the railway crossings. Where utility crossings occur during open trench construction, the asset protection must be agreed with the provider and adhered to.	Design	Minimisation

EMM #	Environmental Management Measure	Stage	Mitigation hierarchy
GM2	**Design and construction to be informed by geotechnical and hydrogeological conditions** Existing and planned geotechnical and hydrogeological investigations must form the basis of design and inform expected ground and water conditions during construction so that due consideration is given toward the existing ground key issues (such as those identified in Technical report D *Land stability and ground movement*). This information is to: • Provide information on the soil and rock expected to be encountered during all excavations • Provide information on the presence of reactive soils • Provide information on the presence of dispersive ("sodic") soils • Provide information on the locations and extent of groundwater drawdown requirements.	Design	Minimisation
GM3	**Management of trench stability: support and duration** Carry out trench excavation works in accordance with the requirements of the Safe Work Australia Code of Practice: Excavation Work (2018) and WorkSafe Victoria Compliance Code: Excavation (2019). Measures are also to be considered where potentially unstable ground may compromise the stability of the trench as assessed by a suitably qualified geotechnical engineer. In addition, the time that trenches and bell holes remain open will be minimised as far as reasonably practicable. As a general rule, trenches should not remain open for longer than 3 months and should comply with SafeWork Australia (2018). For some excavations (for example for main line valves, hydrostatic test sections and tie-in locations) this time period may be exceeded and trench wall support is to be provided in accordance with SafeWork Australia (2018). Should failure occur, contingency response actions may include, for example, methods for temporary shoring and the removal, replacement, and rehabilitation of the disturbed soil.	Construction	Avoidance

EMM #	Environmental Management Measure	Stage	Mitigation hierarchy
GM4	**Management of trench erosion, consolidation and swelling** Implement measures to manage soil dispersion, erosion, consolidation and swelling risks including: • Implementation of erosion and sediment control measures in accordance with EPA 1834 guidelines (2020) and is to be informed by the International Erosion Control Association (IECA) Best Practice Erosion and Sediment Control, Appendix P – Land Based Pipeline Construction (2008). This includes the use of trench breakers installed at regular intervals along the trench excavation where necessary (for example, near to existing slopes and where shallow groundwater tables exist) to minimise ongoing erosion caused by altered water flow regimes as a result of trench construction. • Compaction of the trench backfill as per APA's performance requirement and/or contractor's construction requirements. Degree of compaction and design of backfill to take into account design load limits on the pipe and density and permeability of surrounding soil. • Routine inspection and monitoring of the construction area (easement patrols) must be undertaken throughout operation as per the VTS OEMP to identify any issues such as ongoing erosion, ground movement, slope creep or other adverse effects on land use. Management, monitoring and identification of issues may be in accordance with IECA Best Practice Erosion and Sediment Control (2008). Additional erosion control measures in proximity to waterways are contained in EMM SW4. Additional measures for rehabilitation and monitoring of trenched waterways are contained in EMM SW3.	Construction/ operation	Avoidance of trench wall collapse (Section 9.5.1) and slope stability failure (Section 9.5.4). Minimisation of potential impacts on groundwater and surface water flows (Section 9.6.1).
GM5	**HDD trenchless bore management** Use trenchless bore support (such as a suitable drilling mud or bentonite) to temporarily support the bore during the trenchless activities in accordance with the guidelines for horizontal directional drilling, microtunnelling and pipe jacking (ASTT, 2009). Prior to construction, undertake a detailed hydrofracture risk assessment where appropriate to confirm that the risk of blow-out is low. Prepare and implement a volumetric drilling fluid tracking program with defined threshold levels for fluid loss, stop works and further investigation. Monitor and manage support fluid to effectively minimise ground deformations and risk of bore collapse in unstable ground to reduce the risk of damage to nearby sensitive receptors as well as the potential for frac-out.	Construction	Minimisation

EMM #	Environmental Management Measure	Stage	Mitigation hierarchy
GM6	**Confirmation of ground risk** For sites where there is insufficient or no geotechnical information, confirm the viability of proposed temporary works (ie choice of trenchless method) by completing additional geotechnical investigations. Additional investigations may include shallow surface geophysical methods, trial pitting or drilling as appropriate (subject to environmental or access constraints). Take into account any new geotechnical information at all relevant sites and develop and implement measures for trenchless construction to mitigate the risk of adverse environmental impacts (for example excessive settlement, damage to assets). Relevant sites include Beatty's Road, Morefield Court, Sunbury Road, Oaklands Road, Donnybrook Road (West). Carry out further utility proving works where information is not currently available at the crossing location (including at the Donnybrook Road (West) crossing).	Design/ Construction	Minimisation
GM7	**Preparation and implementation of sodic soil management measures** Complete additional site investigations to further identify areas of higher dispersion risk along the alignment (in addition to those listed in Technical report D *Land stability and ground movement* Section 6.3). Develop, document within the CEMP and implement minimum requirements to be put in place to manage dispersive/sodic soils during construction and operation. Management measures may be proportional to the level of risk identified by the additional site investigations and in general accordance with the guidelines contained within Best Practice Erosion and Sediment Control, Appendix P (IECA, 2008) where applicable. A management plan must be developed prior to construction and implemented detailing how sodic soil hazards will be managed during construction. Application of EMM GM4 is also considered to assist in the management of dispersive soils.	Design/ construction/ operation	Avoidance of trench wall collapse (Section 9.5.1) and slope stability failure (Section 9.5.4). Minimisation of potential impacts on groundwater and surface water flows (Section 9.6.1).

9.8.2 Monitoring

To manage and monitor performance in accordance with the environmental management measures described above, performance criteria and monitoring would be applied. The objective of the monitoring requirements is to minimise the risk of trench collapse or slope failure, using the indicators of ground movement, settlement and sensitivity of adjacent assets. Monitoring requirements include:

- Ground movement: Application of EMM GM1 requires the construction contractor to identify and prove all third party services potentially impacted, prior to construction and liaise with asset owners to confirm asset clearance and other mitigation, protection or contingency requirements, including possible settlement monitoring at the railway crossings.
- Land stability:
  - Construction: The contractor would be required to meet the performance criteria in the contractor's CEMP for the installation of trench support based on the prevailing conditions during construction (EMM GM3) as well as meeting the Safe Work Australia (2018) requirements for trench excavation. Performance criteria would require the contractor to successfully install support where necessary so that the impact associated with trench instability or slope failure is avoided. The contractor's CEMP is also to include methods for contingency response in the case of trench or slope failure that may include, for example, requirements for temporary shoring (eg wall support) and rehabilitation of the disturbed soil (EMM GM3).
  - Additionally, the preparation and implementation of sodic soil management measures (EMM GM7) would include requirements for management of issues surrounding dispersive soils during construction and that meet the requirements outlined in APA's CEMP at a minimum.
  - Operation: The VTS OEMP includes requirements for routine inspections and maintenance of the easement area (easement patrols) during operation (EMM GM4). Performance criteria for inspections and monitoring would require APA operational staff to inspect the construction easement so that any ongoing or immediate issues are identified accurately and timely, and associated impacts are minimised. Relevant impacts may be associated with ongoing erosion, ground movement, slope creep or adverse effects on local land use. Management, monitoring and identification of issues may be in accordance with IECA Best Practice Erosion and Sediment Control (2008).

9.9 Conclusion

This chapter has identified and assessed existing conditions, impacts and mitigation measures for land stability and ground movement for the Project.

Based on the review of existing conditions and the Project description, the key issues assessed in the report relate to trenchless crossing ground movement, slope stability and trench stability.

The key findings of the assessment are:

- Trenchless crossings in soil conditions may result in a minor (only aesthetic) level of asset damage as a result of ground strains
- Encountering cohesionless granular material in trench construction could result in trench wall collapse and result in localised impact on nearby land. There is potential for impact on slope stability in the valley north of the Jacksons Creek crossing.

Application of the Project EMMs would minimise impacts associated with land stability and ground movement. The seven proposed EMMs include requirements for fluid application for bore support during trenchless crossings, adherence to third party asset clearances, development and implementation of a sodic soils management plan, and provision of trench support or battering to reduce the potential for slope or trench wall failure and associated impacts.

Following implementation of the Project EMMs the potential residual impacts associated with land stability and ground movement are not considered to be significant. In response to the EES evaluation objective described at the beginning of this chapter, effects of the Project on land stability and ground movement have been assessed and EMMs have been identified to avoid or minimise residual impacts on land stability and ground movement.