7. Mitigation and Management Measures

7.1 Summary of Potential Impacts to Groundwater

The potential impacts of the pipeline on groundwater have been summarised in Table 12, which groups impacts into those occurring during construction, and those that may be on-going or permanent.

7.2 Constraints on Pipeline Corridors

Based on the identified potential impacts to groundwater arising from construction of the pipeline, and using the available knowledge of groundwater occurrence in the pipeline option corridors, an assessment of the potential constraints that these may have on the pipeline alignment was made.

It is considered that most of the identified groundwater impacts arising from the pipeline can be addressed through implementation of appropriate management activities. The impacts are not expected to constitute constraints on the location of the selection of the final pipeline alignment.

A discussion on the potential constraints along the pipeline option corridors has been presented in Table 13, which is based solely on minimising groundwater impacts. It does not account for other factors such as geotechnical issues or constructability.

7.3 Recommended Investigation Program

A field investigation program has been prepared to resolve data gaps. It is expected that groundwater (and environmental) investigations will be undertaken as part of the geotechnical drilling program. The program will involve the:

- Establishment of groundwater monitoring bores to define depths to water table in key areas, including:
  - Obtaining bore construction licences
  - Construction of bores consistent with National guidelines (LWBC, 2003)
- Lithological logging of geological profiles
- Collection of time-series water level monitoring data
- Review of depth to water table mapping
- Geophysical survey to define the geometry of the bedrock underlying alluvium, and the thickness and physical characteristics (grain size) of the alluvial sediments
- Assessment of hydraulic gradients to confirm interaction with surface water systems
- Baseline monitoring to establish seasonal water level responses and background water chemistry prior to construction

Table 12 - Identification of Potential Impacts to Groundwater from a Pipeline

Potential Impact Timing	Potential Impact	Description	Mitigation Measures
Construction	Dewatering	Dewatering effort for construction purposes may be required. Dewatering effort is unknown at this time, however it is expected that greater dewatering effort would be required in the alluvial aquifers than the bedrock and perched regolith aquifers. The influence of dewatering is unknown at this time; however it has the potential to have a number of impacts, as noted below. ▪ Other groundwater users; ▪ GDE; ▪ Surface water flows; ▪ Subsidence of unconsolidated sediments; ▪ Disposal of recovered groundwater.	The severity of any impact is largely based on the duration of dewatering. There are a number of potential mitigation measures which include: ▪ Supply of alternate water sources to groundwater users or maximise distance of pipeline from user. ▪ Reduce dewatering pumping times / increase pipe laying or construction effort; ▪ Re-injection of pumped waters; ▪ Altering dewatering methodology (e.g. use of sheet piling).
	Quality	Groundwater quality may be adversely impacted by construction activities (e.g. spillage of stored fuels, dewatering, and application of dust suppressants). These aspects are considered elsewhere in this document Phase 1 Environmental Assessment of the pipeline option corridors.	These impacts can be mitigated or prevented by implementing appropriate environmental management actions as part of the works.
		Groundwater quality, specifically high salinity, also has the potential to impact on pipeline materials including concrete/cement, pipeline materials, etc.	These impacts can be mitigated by engineering controls e.g. using materials compatible with the groundwater (and backfill material) chemistry.
		Groundwater quality, specifically high salinity, may create issues with water disposal.	These impacts can be mitigated or prevented by implementing appropriate environmental management actions as part of the works.

Potential Impact Timing	Potential Impact	Description	Mitigation Measures
On-going / Post Construction	Preferential pathway for groundwater migration	The pipeline and backfill materials may be more permeable relative to the surrounding geological formations. In saturated conditions, the pipe trench may act as a drain for shallow groundwater systems and perched water tables. Depending upon the pipeline location, this on-going drainage effect could affect: ▪ Down-gradient GDE through the interception of flow and dewatering; ▪ Up-gradient water levels may decline until equilibrium is achieved. The resultant new water table depth may impact GDE. ▪ Natural spring flow from bedrock or regolith aquifers; ▪ Seepage and base-flows to surface water systems. ▪ The anticipated depths of burial / bedding materials would suggest a limited influence of drainage; however the influence is unknown and dependent upon the geologic materials.	This could be mitigated by installing cut-offs within the trench to prevent the lateral migration of groundwater along the alignment of the pipe. In the bedrock and regolith aquifer systems the trench cut-offs may be located at spacings of several hundred metres. In alluvial terrains, or at river crossings, trench cut-off spacing is likely to be significantly smaller e.g. tens of metres. Where the pipeline trench intersects a perched aquifer, the maintenance of the perched layers has to be achieved during backfilling (i.e. prevention of vertical migration). If the perched layer cannot be maintained, trench cut-offs would be required to prevent lateral migration and dewatering of the system.
		Pipelines crossing beneath farm dams or up-gradient with the catchment of a farm dam could intercept flow destined for dams and drain this via the permeable pipeline backfill / bedding materials.	

Potential Impact Timing	Potential Impact	Description	Mitigation Measures
	River Crossings	In some areas, particularly those where the depth of burial of the pipeline is greater than 4m, there is potential for the pipeline to intersect multiple aquifers, or perched layers within a single aquifer. This may lead to increased hydraulic connection affecting water qualities, hydraulic gradients, and flow regimes in both the surface water or groundwater systems. This may cause the development of recharge conditions to groundwater i.e. surface water flows converted to groundwater recharge, or upper aquifer flows to deeper aquifers. Conversely it may promote influent or recharge conditions to the surface water system / recharge to the shallow aquifer from a deeper aquifer. It is considered that the likelihood of this occurring along the investigation corridors is low to unlikely, as the bedrock aquifer and shallow alluvial systems are expected to be hydraulic connected along the majority of the route. Lateral migration could also occur as creek waters preferentially migrate along pipeline backfill materials.	Where the pipeline trench intersects a perched aquifer, the maintenance of the perched layers has to be achieved during backfilling (i.e. prevention of vertical migration). This could be mitigated by installing cut-offs within the trench to prevent the lateral migration of groundwater along the alignment of the pipe. In the bedrock and regolith aquifer systems the trench cut-offs may be located at spacings of several hundred metres. In alluvial terrains, or at river crossings, trench cut-off spacing is likely to be significantly smaller e.g. tens of metres.
	Quality	For those areas of the trench located below the water table, the composition of backfill materials and imported sand bedding materials may leach or remobilise naturally occurring, or introduce contaminating, constituents which adversely impact groundwater quality. The fate and transport of impacted groundwater is unknown but dependent upon the contaminant, geologic materials and hydrogeological processes occurring.	Bedding sand or imported fill constituents can be sampled to confirm clean fill classification. The use of excavated materials as backfill is suspected to minimise adverse quality impacts as the groundwater chemistry would be influenced by the materials through which it is stored and transmitted. The remobilisation of constituents is expected to be a short term process. When significant oxidation or chemical change is likely to occur, e.g. exposure or excavation of acid sulphate soils, an environmental management plan would be required. This may require additional treatments e.g. addition of pH controls.

Table 13 - Discussion on Groundwater Constraints on Pipeline Option Corridors

Impact	Impact Summary Description	Description of Constraint on Pipeline Location	Preferred Route from Groundwater Perspective
Construction			
Dewatering	Impact to other groundwater users, GDE, subsidence.	Avoid areas of shallow water. Avoid alluvial aquifers. Avoid unconsolidated sediments.	Keep the route away from the flatter floodplain areas where groundwater levels are expected to be shallower. If the floodplains cannot be avoided: - Minimise the length of pipeline within floodplain; - Keep to the margins of floodplain (or higher elevations); - Keep to areas of low permeability or deeper water tables.
Quality	Management of saline or contaminated waters.	Avoid areas where saline water occurs within the zone of construction.	Preliminary mapping suggests most areas within the pipeline corridors have relatively fresh groundwater (Segment A). This requires further investigation to confirm.
	Impact to groundwater quality from construction	Potential to occur anyway along pipeline corridors.	This will not drive selection of pipeline route.
	Impact on pipeline construction materials	Avoid areas where saline water occurs within the zone of construction.	Preliminary mapping suggests most areas within the pipeline corridors have relatively fresh groundwater (Segment A). This requires further investigation to confirm.
On-going			
Preferential pathway for groundwater migration	Pipeline 'drainage' effect	Avoid areas of shallow water.	Keep the route margin away from the flatter floodplain areas where groundwater levels are expected to be shallower. If the floodplains cannot be avoided: - Minimise the length of pipeline within floodplain; - Keep to the margins of floodplain (or higher elevations); - Keep to areas of low permeability or deeper water tables. River crossings are unavoidable. There is insufficient understanding of surface water / groundwater interaction to determine the influence on pipeline route selection.
River Crossings (development of	Alteration of groundwater flow – creation of migration pathways	Minimise number of crossings Cross rivers where groundwater and surface	River crossings are unavoidable. There is insufficient understanding of surface water / groundwater interaction to

Impact	Impact Summary Description	Description of Constraint on Pipeline Location	Preferred Route from Groundwater Perspective
Construction			
recharge)		water interaction is known to exist. Avoid areas where confining layers will be penetrated.	determine the influence on pipeline route selection.
Quality	Impact to groundwater quality from construction backfills, bedding, or excavation	Potential to occur anyway along pipeline corridors. Avoid areas of acid sulphate or contaminated soils.	This will not drive selection of pipeline route. Minimise areas intersecting acid sulphate or contaminated soils.

- Refinement of salinity mapping, particularly near surface water systems
- Aquifer pumping tests to determine hydraulic parameters as input to the dewatering program
- Collation of the data and revisiting of the desktop assessment
- Review of conceptual hydrogeological model.

7.3.1 Suggested Stage 1 Investigations

It is expected that the field investigation program will be staged, with the works being refined as the pipeline alignment is finalised. The Stage 1 works are aimed at broadly characterising the data deficiencies of the desktop assessment. As the information is processed (from the various intrusive programs), new issues, or refinement of the investigations may occur e.g. the refinement of the water table may identify areas where dewatering is unlikely to be required. The program will be undertaken in conjunction with geotechnical drilling investigations to maximise the data collected from these programs. A suggested Stage 1 program is provided below:

- Bore installations (estimated 48 sites of which 24 would be geotechnical engineering sites):
  - Plant site / Goulburn River off-take
  - Yea River and Wetlands at Yea
  - River crossings within pipeline corridors (as per geotechnical investigations).
- Geophysics traverses at 6 locations across the Yea River, Dixons Creek and Steels Creek at select locations and correlation with drilling results
- Pumping tests (estimated 6 sites). Locations would be finalised on the basis of drilling results and an understanding of pipeline construction methods to be adopted, but would most likely include:
  1) Goulburn River off-take
  2) Yea wetlands east of Yea
  3) Glenburn
  4) Steels Creek alluvium near Hunts or Pinnacle Lanes
  5) Steels Creek alluvium near Gulf Road
  6) Alluvium adjacent to the Melba Highway, north-east of Yarra Glen
  7) Possibly residential area immediately west of Yarra Glen, depending on whether alluvium is encountered in bores in this area (land subsidence issues).
- Water level monitoring:
  - Monthly monitoring at all sites
  - Automated monitoring at selected creek crossings (Yea River, Goulburn River).
- Water Quality monitoring:
  - Initial monitoring episode for characterisation

- Quarterly monitoring leading up to construction.

8. Conclusions

This study comprised a review of existing hydrogeological information along the length of the Sugarloaf Pipeline. The objectives of the study were to:

- Provide background information on groundwater conditions along the pipeline option corridors
- Identify critical data gaps and prepare a scope of works to resolve data deficiencies
- Evaluate potential groundwater impacts along the corridors
- Present possible impact mitigation measures.

The study identified three main aquifer types as follows:

- Alluvial and colluvial aquifers
- Bedrock aquifers
- Regolith aquifers.

It is considered that there will be little impact on groundwater resource volumes or qualities as a consequence of the project.

The key potential impact relates to the interception and diversion of shallow groundwater along the comparatively high conductivity material of the trench backfill, with a resultant decline in groundwater levels down gradient of the trench. The hydraulic conductivity, thickness of the sediments and depth of the trench would determine the volumes of water that would need to be pumped out during pipeline construction.

A major unknown is the potential impacts on GDE. A field program has been developed to resolve this and other knowledge gaps and includes:

- Installation of monitoring bores to determine / confirm watertable depths and salinity
- Geophysics traverses to define the thickness and nature of alluvial sediments
- Pumping tests to determine aquifer hydraulic parameters
- Water level and quality monitoring to characterise background hydrogeological conditions.

Impacts on GDE during and following construction would be contingent on the value placed upon the ecosystems. In this respect, the findings of this report need to be considered in light of the Flora and Fauna Assessment (January 2008).

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