



■ **Table 3 - Groundwater Observation Bore Summary**

Bore Id	GDA94 Co-ordinates		Location Description	Depth (m)	Screen		Screened Formation	Monitoring Record		Comments
	Easting	Northing			To	From		From	To	
G8010294/01	364,745.4	5,861,611	Devlin Bridge Melba Hwy	36	0	36	Shale	Feb 2005	May 2007	
G8010291/01	364,383.5	5,873,578	Yea River Melba Hwy North of Murrindindi	5	0	5	Sand	Feb 2005	May 2007	
144711	358,264.3	5,881,014	~ 1 km north west of Yea	9.6	4	8.5	Sand	9/10/2001		Only one water level measurement taken.
144709	357,241.3	5,881,206	~ 1 km north west of Yea	16	Unknown	Unknown	Silty clay & gravel	9/10/2001		Only one water level measurement taken.
144708	357,409.3	5,881,421	~ 1 km north west of Yea	16	Unknown	Unknown	Silty clay & gravel	9/10/2001		Only one water level measurement taken.
144710	358,069.3	5,881,189	~ 1 km north west of Yea	16	Unknown	Unknown	Silty clay & gravel	9/10/2001		Only one water level measurement taken.



hydrograph suggests a declining trend of about 0.1m/y. The reason for this trend, and whether it relates to local or regional hydrogeological or climatic conditions, is unknown.

4.4.4 Groundwater Flow

4.4.4.1 Flow Systems, Recharge and Discharge

Three primary groundwater flow systems exist:

- Alluvial/colluvial systems in which groundwater is restricted to unconsolidated sediments contained within well defined river valleys and in which groundwater flow is predominantly down-gradient as through-flow within the confines of the valleys (generally northwards north of the Great Dividing Range and southwards to the south of the Range)
 - Bedrock fracture systems in which groundwater flows through interconnected fracture systems which are predominantly oriented north-west / south-east in line with regional structural features and which may or may not be hydraulically connected with the alluvial/colluvial aquifers
 - Regolith aquifers which occur where bedrock has been extensively weathered and is saturated, groundwater flow is predominantly down-gradient under the influence of gravity and the water table is a subdued reflection of topography.
- All three aquifer systems are principally recharged by infiltrating precipitation. The alluvial / colluvial aquifers are also likely to receive recharge from the regolith aquifer and may or may not receive recharge from the fractured rock aquifers. Recharge rates are unknown.

4.4.5 Groundwater Use

The GMS database was examined to determine groundwater use within the pipeline option corridors. A summary of findings is provided in Table 4.

- **Table 4 - Groundwater Use**

Use Category	Number of Bores / Aquifer			Total
	Quaternary sediments	Devonian Granite	Silurian – Devonian Basement	
Domestic / Stock	2	2	75	79
Irrigation	1	0	12	13
Commercial / Industrial	2	0	3	5
Not Known	5	0	2	17
Observation	5	0	1	6
Total	15	2	93	120



4.4.5.1 Groundwater Resources / Management

DSE has recognised areas of intensive groundwater use throughout Victoria. These areas have been defined as Groundwater Management Areas (GMA) for resource management purposes. Depending upon the amount of groundwater licensed allocations in an area, the Minister may declare a Water Supply Protection Area (WSPA) to enable tighter management of groundwater resources.

The pipeline option corridors cross the Kinglake GMA in the vicinity of Mountain Creek 1,000m west of the Melba Highway, which is within the pipeline option corridors. The remainder of the corridors fall outside of recognised groundwater management areas and are described as being ‘unincorporated’.

4.4.6 Aquifer Properties

4.4.6.1 Bore Yields

Bore yields in the fractured Silurian – Devonian basement aquifer are highly variable. Table 5 summarises bore yields from the underlying aquifers. It should be noted that most bores are stock / domestic and not necessarily constructed as high yielding production bores.

■ Table 5 - Summary of Bore Yields

Aquifer	Yield
Quaternary sediments	No Information
Devonian Granite	No Information
Silurian – Devonian Basement	0.1 to 5.7 L/sec

4.4.7 Groundwater Quality

4.4.7.1 Classification of Groundwater

The Groundwater SEPP (1988) provides that groundwater is categorised into segments on the basis of its intrinsic salinity, with each segment having a particular identified beneficial use. The segments and their associated beneficial uses are summarised in Table 6.

■ Table 6 - Beneficial Use Segments

Use	Segment (mg/L TDS)				
	A1	A2	B	C	D
	0 – 500	501 – 1,000	1,001 – 3,501	3,501 – 13,000	>13,000
Maintenance of Ecosystems	✓	✓	✓	✓	✓
Potable Water					
Desirable	✓				



	Segment (mg/L TDS)						
Acceptable		✓					
Potable Mineral Water Supply	✓	✓	✓				
Agriculture, parks and gardens	✓	✓		✓			
Stock Watering	✓	✓	✓	✓	✓		
Industrial water use	✓	✓	✓	✓	✓	✓	
Primary contact recreation (e.g. swimming / bathing)	✓	✓	✓	✓	✓		
Buildings and structures	✓	✓	✓	✓	✓	✓	✓

Note: TDS – Total Dissolved Solids (mg/L)

4.4.7.2 Groundwater Salinity

The groundwater salinity within the pipeline option corridors has been determined from information obtained from the GMS. The salinities have been used to generate a groundwater beneficial use map using the groundwater classifications presented in Section 4.4.7.1. The groundwater beneficial use map is presented in Figure 6.

Groundwater is variable in the Silurian-Devonian fractured rock aquifer, varying from more than 5,000 to less than 100 mg/L TDS. Generally good quality groundwater is found in the alluvial aquifers, where salinity is generally less than 500 mg/L TDS. The highest salinity groundwaters are found south of the Great Dividing Range, where values of between 3,000 to 5,000 mg/L TDS are recorded.

4.4.7.3 Other Analyses

Limited groundwater chemistry data is available in the GMS. Available data is provided in and summarised below in Table 7, which indicates that significant variability in chemistry occurs throughout the study area.

■ Table 7 - Summary of Groundwater Chemistry

Analyte	TDS	pH	Chloride	Bicarbonate	Sulphae	Nitrate	Calcium	Magnesium	Sodium	Potassium	Total Iron
Median	558.6	7.62	140.0	231.7	13.0	0.2	16.0	32.0	98.0	5.0	6.0
ST Dev	1,008.0	0.58	5190	308.0	24.4	2.1	37.9	52.9	245.0	6.6	7.6

Note: All concentrations in mg/L except pH (pH units).



5. Assessment of Potential Impacts

5.1 Conceptual Hydrogeological Models

Based on the above information, three conceptual hydrogeological models have been formulated for the anticipated hydrogeological conditions within the pipeline option corridors. The hydrogeological models may occur individually or in combination with each other and are described below. These models will need to be reviewed after the field investigations to confirm their significance and refine the assumptions made.

5.1.1 Model 1: Bedrock Aquifer *Description*

This model represents conditions where the pipeline will be traversing the Silurian – Devonian bedrock. The conceptual model is shown in Figure 7, which indicates three primary forms - undulating surface, relatively steep topography, and natural depressions.

An aquifer is formed in bedrock where groundwater is principally stored and transmitted in the fractures, joints and other discontinuities within the rock mass. The fracture systems parallel the major north-west / south-east oriented geological structures (refer Section 4.3.1.2) and are generally less than 200m deep (Nahm, 1985).

The volume of groundwater contained within the bedrock aquifer and the ability of the aquifer to transmit water is largely a function of the degree of fracturing and extent of interconnection of the fracture systems. Hydraulic conductivities are typically highly variable depending on the nature of the fracturing and range from 10 - 7 m/day for shale, to between 0.001 and 10 m/day for fractured and weathered indurated rock (Bouwer, 1978). Primary porosity flow mechanisms are not expected to dominate.

Groundwater is recharged by infiltrating rainfall over the bedrock aquifer. Where the terrain is steep, groundwater recharge may be lessened because of increased surface water run-off.

Groundwater discharge is expected to occur at the topographically lower areas, such as the break of slopes, or colluvial / alluvial filled depressions. In steep areas, the fracture systems are likely to be dry, although saturated conditions may exist in flatter regions (refer to Model 2 below). Local, lateral discharge into streams provides base-flow, which for many upland streams, persists throughout summer (Leonard, 1992).

A distinctive feature of the fractured rock aquifer is the occurrence of springs where saturated faults intersect the ground surface. Such springs occur at the foothills (Nahm, 1985). Yields are often less than 3 L/sec (Leonard, 1992) but can be highly variable even over short distances (Nahm,



1985). Yields are strongly dependent on of nature of the geology and degree of weathering, with sandstones weathering to sands, which have higher hydraulic properties than siltstones and mudstones (Leonard, 1992).

Salinities are largely dominated by the amount of rainfall and the drainage systems of the area. Where rainfall is greater than 1,000 mm/y the salinity would be less than 1,000 mg/L TDS (Nahm, 1985).

Type Localities

Bedrock aquifers are expected to occur in the Castella or Dixons Creek region, particularly where the topography is steep or undulating i.e. remote from surface water features.

Potential Pipeline Impacts

Generally, a pipeline traversing fractured rock aquifers may encounter:

- Unsaturated conditions in excavations along the steeper topographic areas where water tables are expected to be deep
- Wet conditions in pipeline excavations where fractures are saturated
- Variable seepage rates into excavations depending on the size and degree of interconnection of the fracture systems. Dewatering may yield high initial flow rates, which decline as fracture storage is depleted.

5.1.2 Model 2: Regolith Aquifer

Description

The upper parts of the bedrock aquifer may be weathered and saproplitic. The extent (thickness, lateral extent) and weathering products forming the weathered zone will be variable depending upon the nature of the parent material. Shale and mudstone sequences will develop lower permeable zones whereas sandstones will result in areas of increased permeability.

In cases where low permeability horizons are developed within the weathered zone or where underlying bedrock is massive (unfractured), rainfall recharge may result in the development within the regolith of a local perched aquifer, which may be ephemeral or permanent depending on the thickness of the weathered zone. The model is shown in Figure 8.

Hydraulically, the regolith aquifers behave as porous media aquifers in which groundwater is stored and transmitted through the void spaces between the grain particles making up the weathered zone, with hydraulic conductivities of ranging between 0.001 and 0.1 m/day (Bouwer, 1978).



Recharge is from rainfall and discharge is expected to occur as seeps along the base of slopes or by through-flow to alluvial aquifers where they are in direct hydraulic contact.

In general the weathered zone is thicker on gentle slopes. Regolith aquifers yield only small quantities of water (Nahm, 1985).

Type Localities

Regolith aquifers are expected to occur in the Castella or Dixons Creek region, where the topography is steep or undulating i.e. remote from surface water features.

Potential Pipeline Impacts

Generally, a pipeline traversing regolith aquifers is likely to encounter:

- Weathered zone of varying thickness overlying massive bedrock and containing a perched water table or seepage at the interface of the regolith and bedrock
- Weathered zone of varying thickness overlying fractured bedrock but containing a low permeability horizon above which is a perched water table
- Variable (tending to low) seepage rates into excavations
- Dewatering that yields high initial flow rates, which decline as regolith storage is depleted.

5.1.3 Model 3: Alluvial Aquifer

Description

This model has been developed for those areas where extensive areas of saturated Quaternary sediments overlie the Silurian – Devonian bedrock. The conceptual hydrogeological model has been schematically represented in Figure 9. It shows a flat floodplain both overlying in part, and abutting the bedrock.

The alluvial sediments comprise variable mixtures of sands, gravels, silts and clays deposited by rivers and streams within valleys eroded into the underlying bedrock. The aerial distribution of sediments is generally confined within a narrow valley, but they are often thick enough to store groundwater, particularly where the stream gradient is gentle (Nahm, 1985). The physical nature of sediments depends on the environment of deposition, with sand and gravel deposited in the high energy flow environments of the stream channels as they meandered across the valley floor, and silts and clays deposited in broad sheets in the low energy flow environments of the flood plains.

In a three-dimensional sense, this aquifer comprises moderate to high hydraulic conductivity linear sand and gravel “stringers” contained within a larger, predominantly low hydraulic conductivity, silt and clay matrix.



The alluvial sediments are recharged by infiltrating rainfall, through-flow from the bedrock aquifer, leakage from the surface water systems (under effluent stream conditions) or during flooding and over-bank events. Groundwater discharge occurs predominantly as down-valley through-flow into the sedimentary basins to the north.

Groundwater is often hydraulically connected to the surface water systems in a dynamic relationship in which the aquifer sometimes recharges the river, and sometimes the river recharges the aquifer depending on their relative heads. Groundwater supplies stream base-flow during dry seasons (Nahm, 1985; Leonard, 1992).

The alluvial aquifer is classified as porous media aquifers as groundwater occurs within the voids between individual grain particles. The volume of groundwater stored within the aquifer and the ability of the aquifer to transmit groundwater are largely a function of the particle size of the material comprising the aquifer and the saturated thickness of the sediments.

The quality of groundwater varies and is similar to that in the surrounding rocks, generally being less than 1,000 mg/L TDS (Nahm, 1985), with yields of less than 12 L/sec (Nahm, 1985; Leonard, 1992).

Hydraulic conductivities are variable depending on the nature of the sediments. General ranges are as follows (Bouwer, 1978):

- Fine Sand 1 – 5m/day
- Medium sand 5 – 20m/day
- Coarse sand 20 – 100m/day
- Gravel 100 – 1000m/day
- Sand and gravel mix 5 – 100m/day
- Clay, sand and gravel mix 0.001 – 0.1m/day.

Nahm (1985) reports a transmissivity range of between 40 and 130 m/day.

The permeability and storage capacity of these geological materials would be significantly larger relative to models 1 and 2. Even under no flow or dry conditions within the creeks and streams, saturated sediments may yield considerable volumes of water.

Type Localities

Examples of the occurrence of this model include the floodplains of the Goulburn River north of Yea and adjacent the Yea River to the south of Yea.



Potential Pipeline Impacts

Generally, a pipeline traversing such hydrogeological conditions may encounter:

- Unconsolidated ground conditions
- A greater likelihood of intersecting water tables (relative to Models 1 and 2)
- High construction inflows requiring a greater dewatering effort.

5.2 Interaction with Sensitive Features

5.2.1 Rivers, Creeks and Swamps

The specific interactions of groundwater and the various surface water systems along the pipeline option corridors are unknown for a number of reasons. Interaction would depend upon the nature of stream bed and underlying aquifer material and relative water level heads. Some creeks have scoured out the alluvial sediments and residual soils, and flow directly over the bedrock aquifer (e.g. Yea River at Devils Bridge). Others have a broader, well developed floodplain e.g. Yea River at Yea and are located within alluvial sediments. Nevertheless, based on the conceptual hydrogeological models (refer to Section 5.1), the depth to water table mapping (refer to Figure 4) and the beneficial use mapping (refer to Figure 6), it is evident that key areas where groundwater related impacts may occur (from north to south) include the following:

- Adjacent to the Goulburn River alluvial trench (i.e. at the off-take)
- Within the Yea River valley north-east of Yea, southwards to Tea Tree Creek
- Within the Rellimeiggam Creek valley
- Caraman Creek crossing
- Yea River crossing at Devils Bridge
- Kalatha Creek crossing
- Katy Creek crossing
- Eagle Nest Creek crossing
- Wee Creek crossing
- Yea River just north of Castella
- Dixons Creek river valley from Hunts Lane to Yarra Glen
- Steels Creek river valley from the Old Kinglake Road – Steels Creek Road junction to Gulf Road.

The above constitute “hot spots” further investigation is required to evaluate specific risks. This will be undertaken as part of the field investigations.



5.2.2 Groundwater Dependent Ecosystems

As noted above, there is little understanding of the interaction of groundwater within surface water systems including the rivers, creeks and swamps within the pipeline option corridors. Whether these systems have some level of dependence on groundwater is unknown. There are potentially other areas, remote from the obvious surface water systems, where impacts on ecosystems may result from changes in the groundwater system e.g. lowering of water tables may damage vegetation growth.

Further work is required to identify GDE, characterise their hydrogeological regimes and potential for impact. A hierarchical approach to identifying sensitive ecosystems (vegetation, wetland and aquatic habitats) where the pipeline route will impact, before characterising the groundwater is suggested i.e. route selection is based on avoiding these habitats. This is based on the rationale that the management of groundwater impacts can be achieved through a broader range of mitigation measures.

5.2.3 Knowledge Gaps

The key knowledge gaps are:

- Understanding of accuracy of depth to water table mapping
- Hydraulic parameters and thickness of the geological materials requiring dewatering
- Interaction with sensitive features:
 - Hydrogeological dynamics at river and creek crossings
 - Groundwater quality adjacent surface water systems
 - GDE (location and dynamics).