Technical Report F

Groundwater impact assessment

Viva Energy Gas Terminal Project

Prepared for
Viva Energy Gas Australia Pty Ltd
ABN: N/A

Technical Report F: Groundwater Impact Assessment

Viva Energy Gas Terminal Project

25-Feb-2022
Viva Energy Gas Terminal Project

Technical Report F: Groundwater Impact Assessment

Viva Energy Gas Terminal Project

Client: Viva Energy Gas Australia Pty Ltd

ABN: N/A

Prepared by

AECOM Australia Pty Ltd
Level 10, Tower Two, 727 Collins Street, Melbourne VIC 3008, Australia
T +61 3 9653 1234 F +61 3 9654 7117 www.aecom.com
ABN 20 093 846 925

25-Feb-2022

Job No.: 60642423

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 and ISO45001.

Table of Contents

Executive summary

This technical report provides a groundwater impact assessment conducted to support the Environment Effects Statement (EES) for the Viva Energy Gas Terminal Project (the project).

In December 2020, the Victorian Minister for Planning determined that the project requires assessment through an EES under the *Environment Effects Act 1978* (Vic). The reasons for the decision were primarily related to the potential for significant adverse effects on the marine environment of Corio Bay and the potential for contributing to greenhouse gas emissions. Secondarily, the EES was required to assess the effects of the project on air quality, noise, land use, Aboriginal and historic heritage, native vegetation, groundwater, traffic, and transport as well as visual amenity.

In January 2021, the project was also determined to require assessment and approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* ('EPBC Act') due to the potential for the project to have a significant impact on wetlands of international importance, listed threatened species and communities, and listed migratory species. The EES process is the accredited environmental assessment process for the controlled action decision under the EPBC Act in accordance with the bilateral agreement between the Commonwealth and Victorian governments.

Overview

Viva Energy Gas Australia Pty Ltd (Viva Energy) is planning to develop a floating gas terminal using a ship known as a floating storage and regasification unit (FSRU), which would be continuously moored at Refinery Pier in Corio Bay, Geelong. The key objective of the project is to facilitate supply of a new source of gas for the south-east Australian gas market where there is a projected supply shortfall in coming years.

The FSRU would store liquefied natural gas (LNG) received from visiting LNG carriers (that would moor directly adjacent to the FSRU), and regasify the LNG as required to meet industrial, commercial and residential customer demand. A 7-kilometre gas transmission pipeline would transfer the gas from the FSRU to the Victorian Transmission System (VTS) at Lara.

The gas terminal would be located adjacent to, and on, Viva Energy's Geelong Refinery in a heavily industrialised setting and would benefit from Viva Energy's experience and capability as an existing Major Hazard Facility (MHF) operator and potential synergies between the two facilities such as reuse of the FSRU seawater discharge within the refinery operations.

Existing conditions

The groundwater study area is defined using a 200-metre buffer around three sub-areas where below ground activities or below ground infrastructure are proposed, and therefore have the potential to intersect groundwater. These are the proposed Shell Parade culvert sub-area (for the aboveground pipeline), treatment facility sub-area and the underground pipeline sub-area. The focus of the study was on the upper five to ten metres of the subsurface to capture the majority of below ground construction and infrastructure, A depth of 20 to 25 metres was considered along the proposed horizontal directional drilling sections.

The study area is in the Port Phillip Basin which forms a bowl like structure infilled with sediments. The upper aquifers of the basin formed the focus of the study; the Quaternary Alluvium aquifer (including Darley Gravels and coastal lagoon deposits), the Upper Tertiary - Quaternary Basalt aquifer (including Newer Volcanics basalt flows) and the Upper Tertiary (Marine) aquifer (including the Sandringham Sandstone).

The water table in the study area (including Shell Parade culvert, treatment facility and southern extent of the underground pipeline) occurs in the outcropping Upper Tertiary sediments of the Sandringham Sandstone. Further north, the Sandringham Sandstone sediments are overlain by the Upper Tertiary/Quaternary Newer Volcanics basalt flows, which were found to be unsaturated. Groundwater flow in these aquifers is anticipated to be generally east to southeast towards Corio Bay, but with a component of north-easterly flow towards Hovells Creek in the northern portion of the study area.

Groundwater levels in the Shell Parade culvert sub-area are typically three to four metres deep in the monitoring wells closest to this short section of proposed aboveground pipeline that would cross

underneath Shell Parade through the proposed new culvert. Beneath the treatment facility sub-area, the groundwater levels are typically between four and seven metres below ground surface (mbgs).

Further north, beneath the underground pipeline sub-area, the depths to groundwater increase from approximately five metres below ground surface (at GW01) to greater than 8.5 mbgs (GW02 – GW04). A depth to groundwater of 2.9 mbgs was measured in GW05; installed in lower lying ground close to an unnamed watercourse towards the northern extent of the study area.

The four metre deep thrust bore bell holes and two-metre deep trenched sections of the underground pipeline are not expected to intersect groundwater. If horizontal directional drilling (HDD) is used along certain sections of the underground pipeline route, to depths of 20 to 25 metres, it is likely that groundwater could be intersected.

Groundwater across Victoria is divided into 'segments' based on the salinity (as total dissolved solids), and these segments define the environmental values (previously known as beneficial uses) that need to be achieved and maintained. Based on regional salinity mapping and site specific data from refinery monitoring wells, and GW01, GW02, GW03, GW04 and GW05 (installed as part of the site investigations for this project) the following environmental values were identified: water dependent ecosystems and species, potable mineral water supply, agriculture and irrigation (irrigation and stock watering), industrial and commercial, water-based recreation (primary contact recreation), Traditional Owner cultural values, buildings and structures, and geothermal properties.

No aquatic or terrestrial groundwater dependent ecosystems (based on regional or national assessment) were mapped as being within the study area.

No potential for groundwater-surface water interaction was identified in the study area which is intersected by one unnamed minor watercourse. This is a constructed lined channel draining to a constructed dam in a low part of the landscape proximal to the Princes Freeway.

Of the 21 registered bores in the study area, one is licensed for consumptive use purposes, three for unknown use (including two bores listed as 'not used') and the remaining 17 for groundwater investigation/monitoring within the Geelong Refinery.

Impact assessment

Only a limited number of impact pathways were identified with the potential to adversely affect groundwater levels and flows.

During the construction phase of the project these were:

i. temporary trench dewatering causing reduced groundwater levels or flow impacting groundwater users, and

ii. groundwater bores within or close to the pipeline construction right of way becoming damaged or destroyed.

During the operational phase of the project, the potential issues identified that could affect groundwater levels and flow, and impact groundwater users were

iii. the buried pipeline creates preferential flow and/or impedes groundwater flow,

iv. HDD sections of the pipeline alters groundwater levels and flow, and

v. foundations or piles beneath structures within the treatment facility impede groundwater flow.

Potential impacts and mitigation to avoid, minimise and manage potential impacts related to project components intersecting contaminated groundwater are addressed in Technical Report G: *Contamination and acid sulfate soils impact assessment*.

No additional impacts from decommissioning, beyond those identified for the construction and operational phase, were identified. It has been assumed that decommissioning of the pipeline would require and adhere to regulatory approval at that time. Currently, AS2885 refers to APGA's Code of Environmental Practice Onshore Pipelines which includes the need for a decommissioning strategy to be developed and approved.

Summary of mitigation measures and residual impacts

The following mitigation measure was recommended:

MM ID	Mitigation measure	Project phase
MM-GW01	**Loss of registered bores:** Through continued liaison with landholders, the location of potentially affected bores (due to damage, destruction or loss of access) should be confirmed prior to construction and make-good arrangements agreed if required.	Construction

All potential residual impacts to groundwater environmental values and groundwater users were assessed as being negligible in magnitude and extent with standard industry practice and appropriate mitigation measures in place. Groundwater environmental values and users were found to be protected from any adverse consequences caused by the construction, operation or decommissioning of the project, and the EES evaluation objectives can be met.

Abbreviations and glossary of terms

Abbreviation	Definition
AECOM	AECOM Australia Pty Ltd
CEMP	Construction Environmental Management Plan
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DELWP	Department of Environment, Land, Water and Planning
EES	Environment Effects Statement
EMF	Environmental Management Framework
EPA	Environment Protection Authority
EPBC	Environment Protection and Biodiversity Conservation https://www.environment.gov.au/epbc
FSRU	Floating storage and regasification unit
GDE	Groundwater dependent ecosystem
GDE Atlas	Groundwater Dependent Ecosystems Atlas
GIS	Geographic information system
GMA	Groundwater Management Areas
GMU	Groundwater Management Units
GW	Groundwater
HDD	Horizontal directional drilling
LNAPL	Light Non-Aqueous Phase Liquid
LNG	Liquified natural gas
mAHD	Metres Australian Height Datum
mbgs	Metres below ground surface
mbtoc	Metres below top of casing
MHF	Major Hazard Facility
O&M	Operation and Maintenance
QA	Quaternary Aquifer
ROW	Right of way
SRW	Southern Rural Water
SW	Surface water
SWP	South West Pipeline
UTAM	Upper Tertiary Aquifer (Marine)
UTB	Upper Tertiary/Quaternary Basalt
VTS	Victorian Transmission System
WMIS	Water Measurement Information System

Glossary term	Definition
APGA	Australian Pipelines and Gas Association
Construction Environmental Management Plan (CEMP)	Document that identifies and manages construction activities that may impact the environment
Environmental Management Framework (EMF)	Provides an integrated governance framework to manage environmental aspects as described in the Environment Effects Statement (EES)
Gaining stream	A stream that receives groundwater, which adds to its overall flow.
Groundwater dependent ecosystem (GDE)	A terrestrial or aquatic ecosystem that requires access to groundwater to meet all or some of their requirements.
Groundwater users	GDEs and users of existing registered bores
Hydraulic conductivity	The ease with which a fluid (usually water) can move through pore spaces or fractures.
Preferential flowpath	The uneven and often rapid movement of water and solutes through porous media.
Watertable	The surface where the water pressure head is equal to the atmospheric pressure.

1.0 Introduction

This technical report provides a groundwater impact assessment conducted to support the Environment Effects Statement (EES) for the Viva Energy Gas Terminal Project (the project).

Viva Energy Gas Australia Pty Ltd (Viva Energy) is planning to develop a gas terminal using a ship known as a floating storage and regasification unit (FSRU), which would be continuously moored at Refinery Pier in Corio Bay, Geelong. The key objective of the project is to facilitate supply of a new source of gas for the south-east Australian gas market where there is a projected supply shortfall in coming years

The FSRU would store liquefied natural gas (LNG) received from visiting LNG carriers (that would moor directly adjacent to the FSRU) and would convert LNG back into a gaseous state by heating the LNG using seawater (a process known as regasification) as required to meet industrial, commercial, and residential customer demand. A 7-kilometre gas transmission pipeline would transfer the gas from the FSRU to the Victorian Transmission System (VTS) at Lara.

The project would be situated adjacent to, and on, Viva Energy's Geelong Refinery, within a heavily developed port and industrial area on the western shores of Corio Bay between the Geelong suburbs of Corio and North Shore. Co-locating the project with the existing Geelong Refinery and within the Port of Geelong offers significant opportunity to minimise potential environmental effects and utilise a number of attributes that come with the port and industrial setting.

In December 2020, the Victorian Minister for Planning determined that the project requires assessment through an EES under the *Environment Effects Act 1978 (Vic)*. The reasons for the decision were primarily related to the potential for significant adverse effects on the marine environment of Corio Bay and the potential for contributing to greenhouse gas emissions. Secondarily, the EES was required to assess the effects of the project on air quality, noise, land use, Aboriginal and historic heritage, native vegetation, groundwater, traffic and transport as well as visual amenity.

In January 2021 the project was also determined to require assessment and approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* ('EPBC Act') due to the potential for the project to have a significant impact on the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site (a wetland of international importance), listed threatened species and communities, and listed migratory species. The EES process is the accredited environmental assessment process for the controlled action decision under the EPBC Act in accordance with the bilateral agreement between the Commonwealth and Victorian governments.

1.1 Purpose

This groundwater impact assessment identifies, evaluates and characterises potential environmental impacts on groundwater environmental values and groundwater users due to changes in groundwater levels and groundwater flow associated with the construction, operation and decommissioning of the project.

The report identifies and recommends mitigation measures to avoid, minimise and manage potential impacts which will inform the development of an Environmental Management Framework (EMF) for the project. The mitigation measures listed in the EMF would be implemented in the approvals and management plans for the project.

Potential impacts to groundwater quality are addressed in Technical Report G*: Contamination and acid sulfate soils impact assessment*.

1.2 Why understanding groundwater is important

The project has the potential to intersect shallow groundwater during construction and operation which could potentially affect groundwater levels and flow. It is important to assess whether these could adversely impact the environmental values of groundwater and/or groundwater users.

Groundwater users include people who pump water from existing groundwater bores, and groundwater dependent ecosystems (GDEs). GDEs are those ecosystems that require access to groundwater to

meet all or some of their water requirements to maintain the terrestrial and aquatic communities and ecological processes they support, and ecosystem services they provide[1]. These can include streams or lakes that groundwater flows into, vegetation with roots that access groundwater or biota living in groundwater systems.

Potential impacts to groundwater quality from the project are considered in Technical Report G*: Contamination and acid sulfate soils impact assessment*.

1.3 Project area

The project would be located adjacent to, and on, the Geelong Refinery and Refinery Pier in the City of Greater Geelong, 75 kilometres (km) south-west of Melbourne. The project area is within a heavily developed port and industrial area on the western shores of Corio Bay between the Geelong suburbs of Corio and North Shore. The Geelong central business district is located approximately 7 km south of the project.

Corio Bay is the largest internal bay in the south-west corner of Port Phillip Bay and is a sheltered, shallow basin at the western end of the Geelong Arm, with an area of 43 square kilometres (km^2). The Point Wilson/Limeburners Bay section of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is located along the northern shoreline of Corio Bay, approximately one kilometre to the north-east of the project.

The Port of Geelong has been in operation for over 150 years and is the largest industrial bulk cargo port in Victoria, attracting over 600 ship visits and handling more than 14 million tonnes of product annually. Geelong's shipping channels extend 18 nautical miles through Corio Bay from Point Richards through to Refinery Pier. Ports Victoria (formerly Victorian Regional Channels Authority) manages commercial navigation in the port waters in and around Geelong and is responsible for the safe and efficient movement of shipping, and for maintaining shipping channels and navigation aids. The channels are man-made having been deepened and widened through periodic dredging to support port trade development.

Refinery Pier is the primary location within the Port of Geelong for movement of bulk liquids. Vessels up to 265 metres in length currently utilise the four berths at Refinery Pier which service Viva Energy refinery operations. The majority of ship visits to the port are to Refinery Pier, with Viva Energy accounting for over half of the trade through the Port of Geelong.

The Geelong Refinery has been operating since 1954 with both the refinery and the co-located LyondellBasell plant being licensed Major Hazard Facilities (MHFs). A range of industrial activities are situated in the Port environs including wood fibre processing and chemical, fertiliser and cement manufacturing.

To the north of the Geelong Refinery, along the proposed underground pipeline corridor, the area is predominantly rural. There are several other existing Viva Energy-owned underground pipelines running between the refinery and the connection point to the South West Pipeline (SWP) at Lara. The proposed pipeline route follows already disturbed pipeline corridors, where possible, through a mix of land uses.

The project area is shown in Figure 1-1.

[1] Definition from *Ministerial Guidelines for Groundwater Licensing and the Protection of High Value Groundwater Dependent Ecosystems*, dated 13 April 2015.

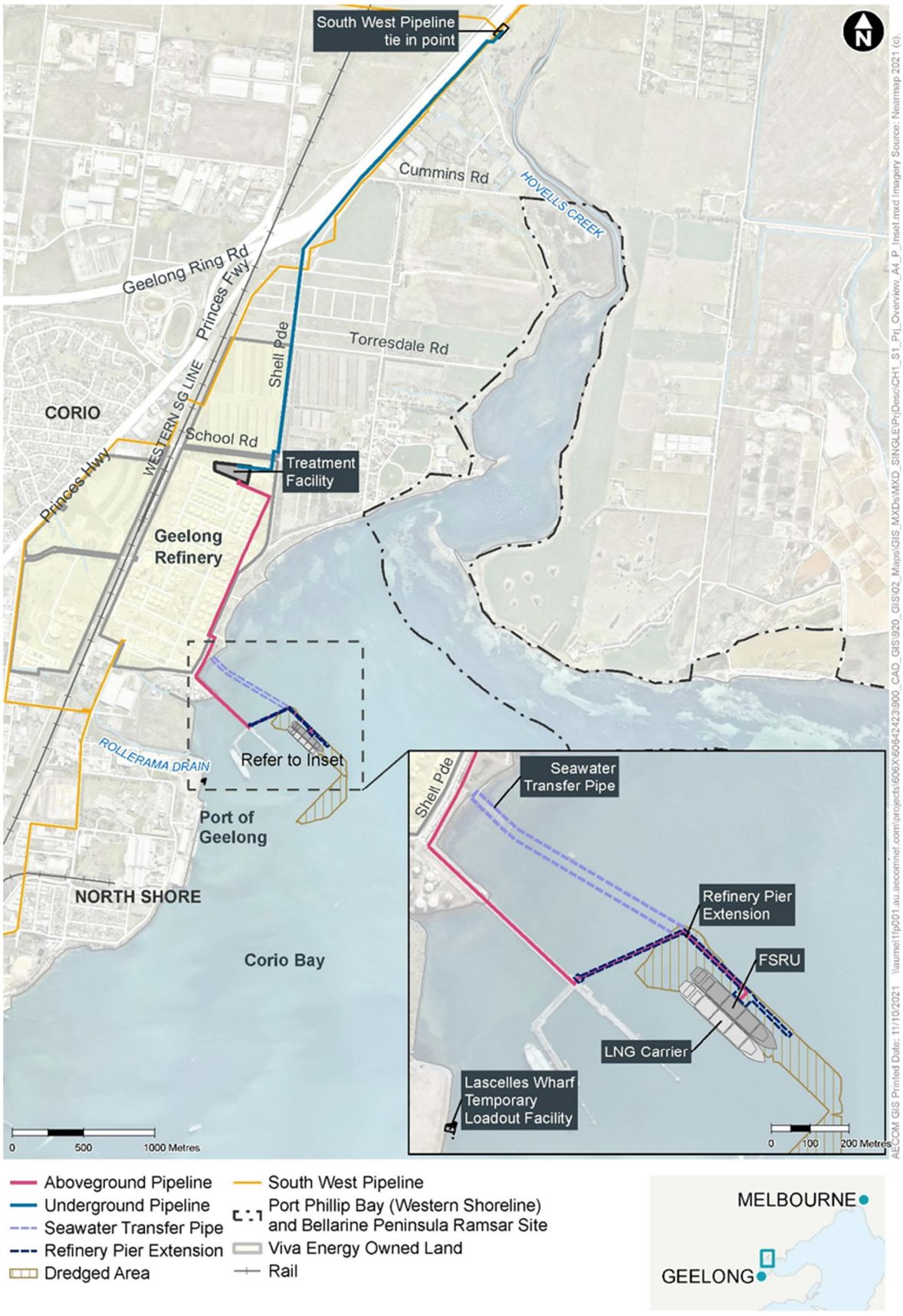


Figure 1-1 Project Overview

1.4 Project description

This section summarises the project as described in Chapter 4 *Project description*. Key components of the project include:

- extension of the existing Refinery Pier with an approximately 570 metre (m) long angled pier arm, new berth and ancillary pier infrastructure including high pressure gas marine loading arms (MLAs) and a transfer line connecting the seawater discharge points on the FSRU to the refinery seawater intake
- continuous mooring of an FSRU at the new Refinery Pier berth to store and convert LNG into natural gas. LNG carriers would moor alongside the FSRU and unload the LNG
- construction and operation of approximately 3 km of aboveground gas pipeline on the pier and within the refinery site connecting the FSRU to the new treatment facility
- construction and operation of a treatment facility on refinery premises including injection of nitrogen and odorant (if required)
- construction and operation of an underground gas transmission pipeline, approximately 4km in length, connecting to the SWP at Lara.

The Refinery Pier extension would be located to the north-east of Refinery Pier No. 1. The new pier arm would be positioned to allow for sufficient clearance between an LNG carrier berthed alongside the FSRU and a vessel berthed at the existing Refinery Pier berth No. 1. Dredging of approximately 490,000 cubic metres of seabed sediment would be required to allow for the new berth pocket and swing basin.

The FSRU vessel would be up to 300 m in length and 50 m in breadth, with the capacity to store approximately 170,000 cubic metres (m^3) of LNG. The FSRU would receive LNG from visiting LNG carriers and store it onboard in cryogenic storage tanks at about -160 °C.

The FSRU would receive up to 160 PJ per annum (approximately 45 LNG carriers) depending on demand. The number of LNG carriers would also depend on their storage capacity, which could vary from 140,000 to 170,000 m^3.

When gas is needed, the FSRU would convert the LNG back into a gaseous state by heating the LNG using seawater (a process known as regasification). The natural gas would then be transferred through the aboveground pipeline from the FSRU to the treatment facility where odorant and nitrogen would be added, where required, to meet Victorian Transmission System (VTS) gas quality specifications. Nitrogen injection would occur when any given gas cargo needs to be adjusted (diluted) to meet local specifications. Odorant is added as a safety requirement so that the normally odourless gas can be smelt when in use. From the treatment facility, the underground section of the pipeline would transfer the natural gas to the tie-in point to the SWP at Lara.

1.4.1 Key construction activities

Construction of the project would occur over a period of up to 18 months. The key construction activities relate to:

- localised dredging of seabed sediments to enable the FSRU and LNG carriers to berth at Refinery Pier and excavation of a shallow trench for the seawater transfer pipe
- construction of a temporary loadout facility at Lascelles Wharf
- construction of the new pier arm and berthing infrastructure, and aboveground pipeline along Refinery Pier and through the refinery
- construction of the treatment facility on a laydown area at the northern boundary of the refinery site
- construction of the buried pipeline
- construction at the tie-in point to the SWP at Lara

There are no construction activities required for the FSRU component of the project. The vessel would be built, commissioned and all production and safety systems verified prior to being brought to site.

An estimated 490,000 cubic metres (m^3) of dredging would be required, over an area of approximately 12 hectares (ha), adjacent to the existing shipping channel to provide sufficient water depth at the new berth and within the swing basin for visiting LNG carriers to turn. Dredging within the new berth would be undertaken to a depth of 13.1 metres and the swing basin would be dredged to a depth of 12.7 metres. The dredging footprint is shown in Figure 1-1. It is planned to deposit the dredged material within Port's Victoria's existing dredged material ground (DMG) in Port Phillip Bay to the east of Point Wilson, approximately 26 km from Refinery Pier.

The temporary loadout facility at Lascelles Wharf would be the first construction activity to take place in order to facilitate the Refinery Pier extension. This would involve the installation of 10 piles using hydraulic hammers.

Construction of the pier arm would be carried out once dredging was complete, primarily from the water using barge-mounted cranes. Steel piles would be driven into the seabed by cranes mounted on floating barges and pre-cast concrete and pre-fabricated steel components would be transported to site by barge and lifted into position. The installation of pier infrastructure such as the marine loading arms (MLAs), piping from the FSRU to the existing refinery seawater intake (SWI) and aboveground pipeline would also be undertaken from the water using barge-mounted cranes and construction support boats.

Installation of the 3 km above ground pipeline along the pier and through the refinery is anticipated to take 3.5 months to complete. The above ground pipeline would run along the pier to the existing pipe track east of Shell Parade within the pier foreshore compound. It would then pass through a road under-crossing to the existing refinery pipe track. The pipeline would then run north along the existing refinery pipe track to an existing laydown area where the treatment facility would be located.

The treatment facility would be located within an existing laydown area in the refinery site and cover an area of approximately 80m x 120m. Construction of the treatment facility would take approximately 18 months and would be undertaken by specialist crews across distinct phases of work. These would include initial earthworks and civil construction, mechanical installation and electrical and instrumentation works.

The 4km underground pipeline would be installed in stages over an approximate 4 month period within a corridor which has been selected to avoid watercourses or other environmental sensitivities, where possible. Firstly, a construction right of way (ROW) would be established, clearly identified and fenced off where required. Typically, this would be between 15 and 20m wide, and minimised where possible to reduce disturbance. Once the construction ROW is established, vegetation would be removed, and a trench excavated to a maximum depth of 2m and a maximum width of 1m for the pipeline to be placed. Following the placement of the pipeline, the construction ROW would be rehabilitated to its pre-existing condition as far as practicable for the purposes for which it was used immediately before the construction of that part of the pipeline.

Trenchless construction (including thrust boring or horizontal directional drilling (HDD)) would be used to install the underground pipeline in areas that are not suited to open trenching techniques, such as at intersections with major roads. Trenchless construction would involve boring or drilling a hole beneath the ground surface at a shallow angle and then pushing or pulling a welded length of pipe through the hole without disturbing the surface. It is anticipated that the maximum depth of the trenchless section would be 25 m.

The anticipated trenching, HDD and thrust bore locations are presented in Figure 1-2. It is possible that along the northern section of Macgregor Court the pipeline would also be constructed using HDD, however, this would be confirmed during detailed design.

Construction at the tie-in point to the SWP at Lara would be undertaken by specialist crews across the distinct phases of works, as with the treatment facility.

Figure 1-2 Proposed location of trenching construction techniques for the underground pipeline including open trenching, HDD and thrust boring

1.4.2 Key operation activities

The project is expected to be in operation for a approximately 20 years. Key activities relating to project operation include:

- Receipt of up to 45 LNG carriers each year at Refinery Pier – the number and frequency of LNG carriers arriving each year would depend on their storage capacity and gas demand
- Regasification of LNG onboard the FSRU using seawater as a heat source, which would then be reused within the refinery as cooling water
- Injection of nitrogen and odorant into the gas prior to distribution via the VTS
- Monitoring and maintenance of the pipeline easement.

1.4.3 Key decommissioning activities

The FSRU, which continues to be an ocean-going vessel throughout the operation of the project, would leave Corio Bay on completion of the project life to be used elsewhere.

It is anticipated that the Refinery Pier berth and facilities would be retained for other port related uses. The underground pipeline would likely remain in situ subject to landholder agreements and either decommissioned completely or placed into care and maintenance arrangements.

Decommissioning activities may be subject to change, subject to legislative requirements at the time and potential repurposing of the infrastructure at the end of the project.

1.4.4 Project activities relevant to the assessment

The groundwater impact assessment addresses potential effects on groundwater level and flow for the onshore component of the project; with no impact pathways considered for offshore activities and infrastructure.

Specifically, the groundwater impact assessment focuses on those activities that have the potential to intersect and interact with groundwater:

- Foundations or piles beneath structures within the treatment facility to be located on an existing laydown area at the northern boundary of the refinery site
- Installation of the aboveground pipeline through a culvert beneath Shell Parade – via trenching or via thrust boring
- Installation of the underground pipeline –via trenching, HDD and thrust boring as per Figure 1-2..

A summary of the buried pipeline methods is provided below, with more detail provided in Chapter 4 *Project description.*

1.4.4.1 Trenching

Pipeline construction would comply with all relevant codes and standards including ASNZS2885.1-2018: Pipelines – Gas and liquid petroleum (design and construction) and the Australian Pipelines and Gas Association Code of Environmental Practice. The construction would also be in accordance with the environmental requirements to be specified in a Construction Environmental Management Plan (CEMP) prepared in compliance with the Victorian *Pipelines Act 2005 (Vic)* and Pipelines Regulations 2017 and approved by the relevant Minister before construction.

Figure 1-3 shows a typical layout for a construction right of way (ROW), which will typically be 15-20m wide for the project.

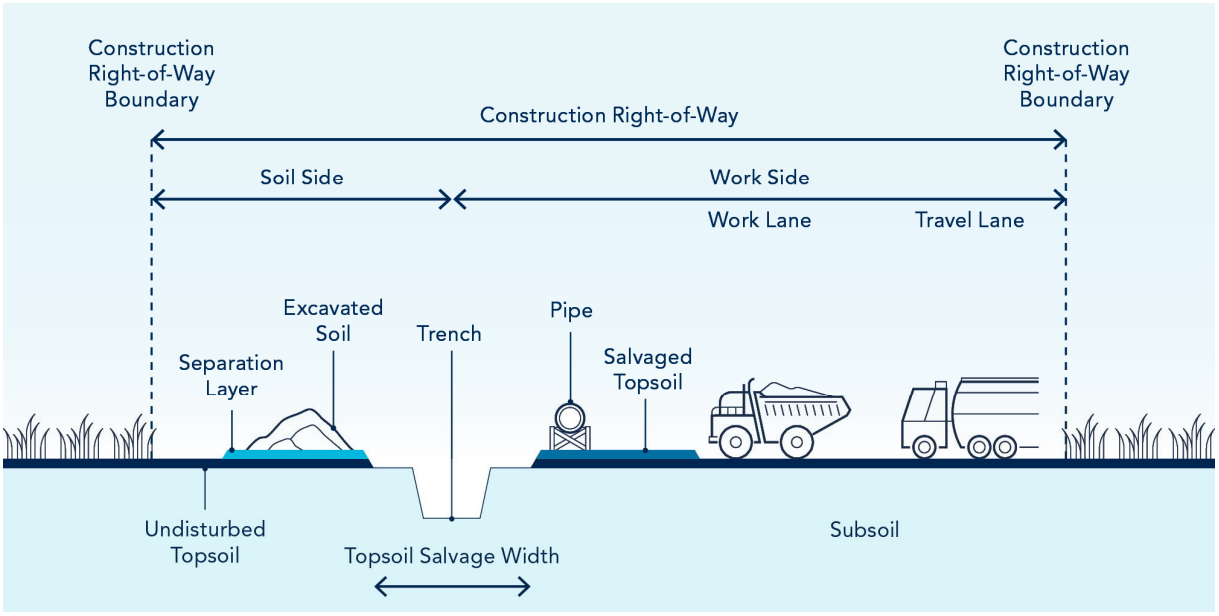


Figure 1-3 Typical construction ROW layout for a pipeline

Excavators would be used to dig the pipeline trench to a depth of typically 2mto achieve a depth of cover to natural ground level of approximately 1.2m.

Water that has collected in the trench (such as groundwater, incidental rainwater or a combination of both) would be removed immediately prior to the pipe being installed. The duration of dewatering is minimised to reduce the volumes of water to be managed and to avoid slumping of the trench. It is anticipated that pumping from the trench and installation of the pipe would be completed on the same day. The disposal of trench dewatering (surface water runoff and/or groundwater that has been intersected) is addressed in Technical Report G: *Contamination and acid sulfate soils impact assessment.*

Fine grained bedding and padding material may be placed around the pipe to protect the pipe coating from damage due to materials in the excavated spoil. The preference would be to use bedding and padding material produced by sieving the excavated material on site or imported materials would be used if excavated materials were unsuitable.

The trench would then be backfilled using the excavated spoil and excess excavated material may be used to re-establish surface contours or collected and transported for disposal at appropriately licensed facilities in accordance with Environment Protection Authority (EPA) Victoria's waste classification and spoil transportation requirements.

1.4.4.2 Horizontal Directional Drilling

Trenchless construction may be used to install the underground pipeline in some areas where open trenching techniques are not suitable, such as beneath sealed road or crossing of third-party assets (such as water, gas and oil pipelines, and power lines, etc.).

The installation of a pipeline by HDD involves drilling a pilot hole at a shallow angle beneath the surface from an entry point on one side of the crossing to an exit point on the other side of the crossing, as shown in Figure 1-4. The entry and exit pits are typically about 3m wide, 5m long and 2m deep. The hole is enlarged by reaming to allow for the welded pipe string to be pulled back through the drill hole from the exit point to the entry point without damaging the coating.

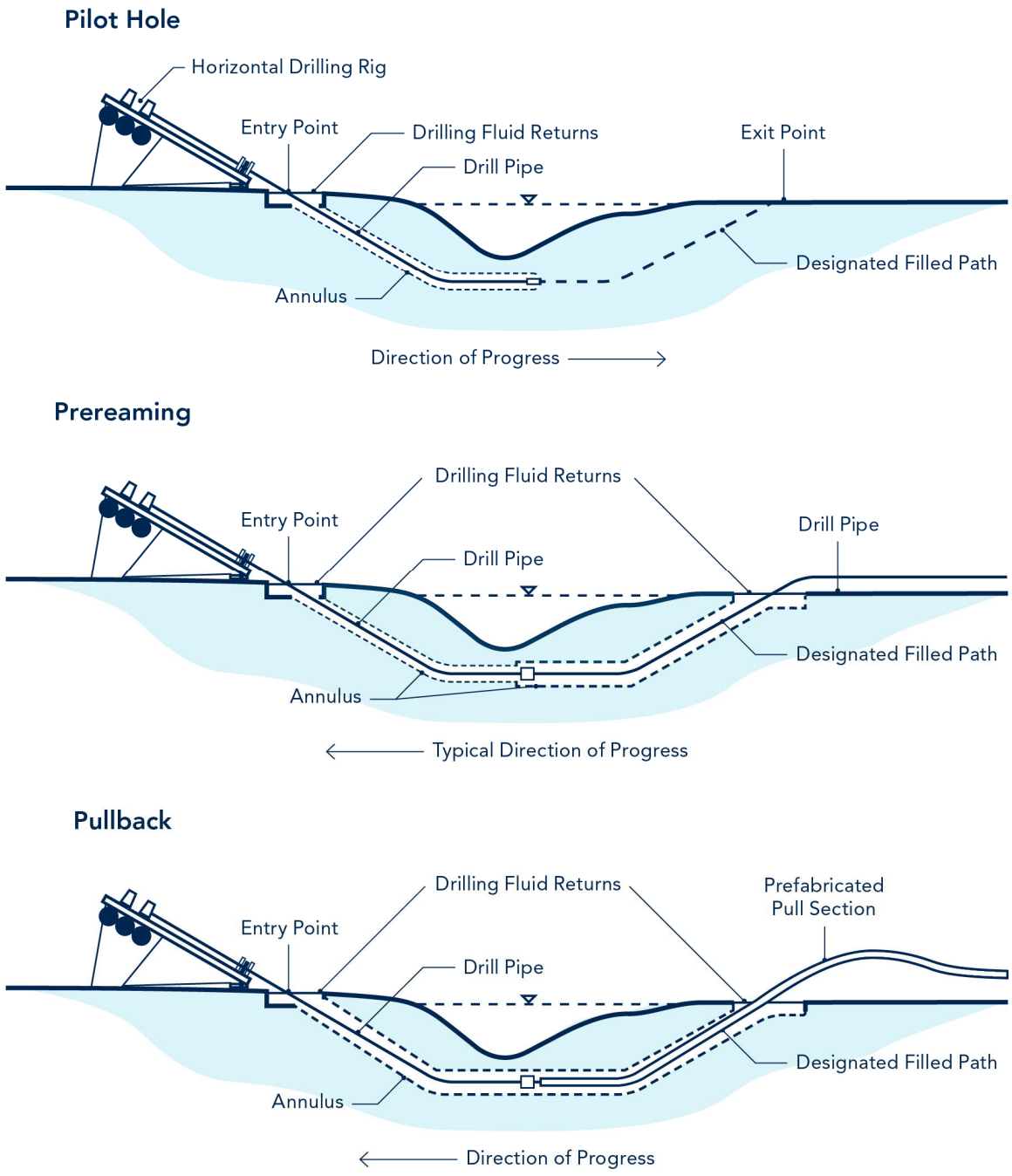


Figure 1-4 Typical HDD process

HDD construction involves the use of bentonite-based muds (bentonite slurry) during drilling that create a 'filter cake' along the walls of the borehole to create a barrier between the borehole and formation (as well lubricating the drill head and return drill cuttings to the entry pit) (ASTT, 2010). The filter cake limits the amount of fluid loss into the formation and, together with the positive head pressure maintained by the flooded hole and weighted mud (relative to groundwater head outside the borehole), prevents any ingress of groundwater into the bore during drilling.

Post drilling, the gas pipe is pulled back through the drilled open hole with the filter cake still in place, and with the hole only marginally larger than pipe diameter, essentially resulting in little or no annulus space. Once the pipe is in place the formation and residual filter cake seal any remaining space in the bore annulus. This provides an effective seal between aquifers and prevents the creation of a preferential pathway between or within aquifers.

Groundwater extraction/dewatering is not required as part of the HDD process.

1.4.4.3 Thrust-boring

Shallow horizontal boring (referred to as thrust boring or micro-tunnelling) involves construction of a horizontal bore hole to allow pipeline installation beneath sensitive surface features, roads and underground services.

Bell holes are excavated on both sides of the feature. The entry bell hole is enlarged to allow a boring machine to operate within it and tunnel under the relevant constraint. Entry bell holes would be approximately 10 metres long, four metres wide and typically four metres deep. The exit bell hole would typically be seven metres long, four metres wide and up to four metres deep. The bell holes are maintained dry during construction and therefore temporary dewatering and/or other controls could be required to limit groundwater ingress into the excavation.

The boring machine is located within the entry pit, which uses a hydraulic ram to jack the pipe section, behind a cutting head, in a straight line through the ground to the receiving pit.

It is proposed to construct one segment of thrust boring beneath School Road, and it is anticipated that it could take up to two weeks to complete. Thrust boring could also occur on Shell Parade where the new culvert for the aboveground pipeline is proposed to be constructed adjacent to the existing culvert

A typical thrust bore set up is shown in Figure 1-5.

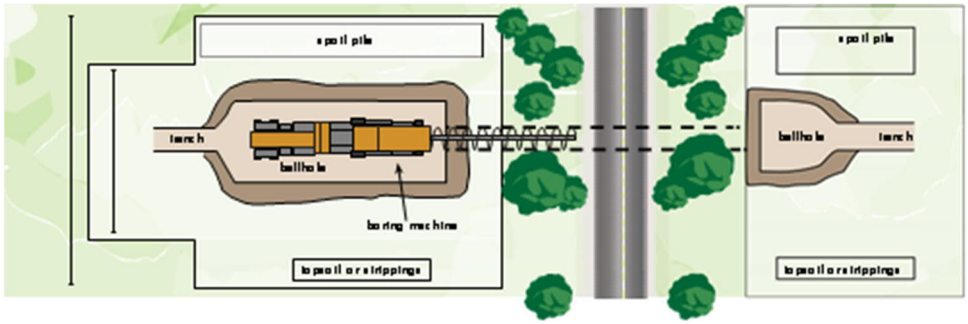


Figure 1-5 Typical thrust bore set up

2.0 Scoping requirements

The scoping requirements for the EES set out the specific environmental matters to be investigated in the EES. The scoping requirements include a set of evaluation objectives. These objectives identify the desired outcomes to be achieved in managing the potential impacts of constructing and operating the project.

The following evaluation objective is relevant to the groundwater impact assessment:

- **Water and catchment values** – To minimise adverse effects on water (in particular wetland, estuarine, intertidal and marine) quality and movement, and to the ecological character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site.

The scoping requirements of relevance to this groundwater impact assessment and where they are addressed shown in Table 2-1.

Table 2-1 Scoping requirements relevant to groundwater

Aspect	Scoping requirement	Section addressed
Key issues	The potential for adverse effects on the functions and environmental values of surface water environments, such as interception or diversion of flows or changed water quality in downstream water environments due to the project, in the context of climate change projections during construction and operations.	Refer to Technical report E: *Surface water impact assessment* and Technical Report G*: Contamination and acid sulfate soils impact assessment* and Attachment II *Risk to the project from climate change*
	The potential for adverse effects on the functions, environmental values and the ecological character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site.	Refer to Technical Report A*: Marine ecology and water quality impact assessment*
	The potential for adverse impacts on water quality and environmental values due to dredging and sediment mobilisation, spills or other incidents during construction or operation.	Refer to Technical Report E*: Surface water impact assessment* and Technical Report G*: Contamination and acid sulfate soils impact assessment*
Existing environment	Describe marine, estuarine, intertidal and freshwater waters and their environmental values that could be affected from changed water quality, or water movement, due to the project.	Section 5.0
	Describe the ecological character of the Ramsar site, and related hydrological and environmental values protected under the EPBC Act, including their acceptable limits for change.	Refer to Technical Report A*: Marine ecology and water quality impact assessment*
	Characterise the interaction between surface water and marine waters within the project and broader area.	Refer to Technical report E*: Surface water impact assessment*

Aspect	Scoping requirement	Section addressed
	Characterise the areas hydrodynamics and coastal processes and modelling techniques utilised to do so.	Refer to Technical Report A*: Marine ecology and water quality impact assessment*
Likely effects	Identify and evaluate effects of the project and alternatives on groundwater, surface water, waterways and wetlands near the project works, including the likely extent, magnitude and duration (short and long term) of changes to water quality, water level, temperature or flow paths during construction and operation, considering appropriate climate change scenarios and possible cumulative effects resulting in combination with other existing or proposed projects of actions.	Section 6.0 Section 7.0
	Assess the impacts of the construction and operation of the project on the Ramsar site, in particular any potential substantial and/or measurable change to the hydrological regime, in the context of ecological character description and acceptable limits for change.	Section 6.0 Section 7.0 and refer to Technical report E*: Surface water impact assessment*
	Assess likely cumulative effects on the waters of Corio Bay that might result from the project in combination with other projects or actions taking place or proposed nearby	Refer to Technical Report A*: Marine ecology and water quality impact assessment*
	Ensure a systems-based assessment is undertaken with marine water quality, hydrodynamics and marine ecology studies undertaken together.	Refer to Technical Report A*: Marine ecology and water quality impact assessment*
Mitigation measures	Identify and evaluate aspects of project works and operations, and proposed design refinement options or measures, that could avoid or minimise significant effects on water, wetlands and marine environments.	Section 6.0 Section 7.0 Section 9.0
	Describe further potential and proposed design options and measures that could avoid or minimise significant effects on environmental values of surface water, groundwater and downstream water environments during the project's construction and operation, including response measures for environmental incidents.	
Performance objectives	Describe any further methods that are proposed to manage risks of effects on groundwater and surface water and catchment values, as well as water quality, to form part of the EMF.	Section 9.0 and refer to Technical report E*: Surface water impact assessment*

3.0 Legislation, policy and guidelines

Table 3-1 summarises the key environmental legislation and policy that apply to the project in the context of this groundwater impact assessment, as well as the implications for the project and the required approvals (if any).

Additional guidelines and technical criteria relevant to groundwater are described in Section 3.1.

Table 3-1 Key legislation and policy – groundwater

Legislation/policy	Description	Implications for the project	Approval required
Commonwealth			
Legislation			
Environment Protection and Biodiversity Conservation Act 1999 (Cth) ('EPBC Act').	The EPBC Act is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage Matters of National Environmental Significance (MNES) including, but not limited to, World Heritage Properties, National Heritage Places, Ramsar sites, nationally listed threatened species and ecological communities and listed migratory species. The EPBC Act states that 'controlled' actions i.e. actions that are determined as likely to have a significant impact on a MNES are subject to assessment and approval under the EPBC Act.	On 21 January 2021, the delegate for the Commonwealth Minister for the Environment determined the project to be a controlled action due to potential significant impact on the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site, listed threatened species and ecological communities and listed migratory species. The EES process is accredited to assess impacts on MNES under the EPBC Act through the Bilateral Assessment Agreement between the Commonwealth and the State of Victoria. Therefore, the project will be assessed under the bilateral agreement.	Approval of controlled action required
State			
Legislation			

Legislation/policy	Description	Implications for the project	Approval required
Water Act 1989 (Vic) ('Water Act')	The Water Act provides the legal framework for the integrated management of Victoria's water resources. The main purpose of the Water Act is to promote the efficient and equitable use of water resources and ensure water resources are conserved and appropriately managed for sustainable use. The Water Act provides a formal means of protecting and enhancing waterway flow, water quality and catchment conditions.	Under the Water Act, Southern Rural Water was formed as a Water Corporation in July 1995, and is responsible for managing irrigation districts, the regulation of surface water and groundwater licensing, and storage dams across the southern third of Victoria.	Bore construction licences for installation of groundwater monitoring wells
Environment Protection Act 2017 (Vic) ('Environment Protection Act')	The Environment Protection Act aims to protect Victoria's air, water and land by adopting a 'general environment duty' (GED) which imposes a broad obligation on entities and individuals to take proactive steps to minimise risks of harm to human health and the environment from pollution or waste. The Victorian Environment Protection Authority (EPA) administers the Environment Protection Act and subordinate legislation.	The Environment Protection Act regulates discharges to land, surface water or groundwater by a system of development and operating licences. Any discharge into a waterway or groundwater during the construction or operation of the project must be in accordance with the requirements of the Environment Protection Act and subordinate legislation. The GED requires all reasonably practicable steps be taken to minimise impacts to human health and the environment from the construction and operation of the project.	The FSRU component of the project would require a Development and Operating Licence. The Geelong Refinery would require a Development Licence or exemption.
Pipelines Act 2005 (Vic) ('Pipelines Act')	This is the primary act governing the construction and operation of pipelines in Victoria. The Pipelines Act covers 'high transmission' pipelines for the conveyance of gas, oil and other substances. The Department of Environment, Land, Water and Planning (DELWP) and Energy Safe Victoria (ESV) are responsible for administering the Pipelines	The project requires a pipeline licence(s) under the Pipelines Act for the construction and operation of the pipeline. The Construction Environmental Management Plan (CEMP), required prior to construction of the pipeline, would include measures to minimise impacts on groundwater during construction.	Pipeline Licence(s) required

Legislation/policy	Description	Implications for the project	Approval required
	Act and the Pipelines Regulations 2017.		
Policy			
Environment Reference Standard (ERS)	This Environment Reference Standard (ERS) is made under Section 93 of the *Environment Protection Act 2017 (Vic)*. It sets out the environmental values of the ambient air, ambient sound, land and water environments that are sought to be achieved or maintained in Victoria and standards to support those values. Environmental values are the uses, attributes and functions of the environment that Victorians value. Standards for the environmental values are comprised of objectives for supporting different uses of the environment and indicators that can be measured to determine whether those objectives are being met.	The project would seek to minimise the potential for impacts on groundwater to ensure that existing environmental values are protected, with priority given to maintaining environmental values of areas of high conservation value (Ramsar sites).	No approvals required but ERS used to inform EPA's decision making under Environment Protection Act.

3.1 Guidelines

3.1.1 State guidelines

Relevant guidelines and publications developed by the EPA include:

- Publication 668: Hydrogeological Assessment (Groundwater Quality) – provides guidance on the development of hydrogeological conceptual model of the hydrogeology, contamination and potential human and ecological risks.
- Publication 1834: Civil construction, building and demolition guide– provides general information on how to avoid and minimise environmental impacts from construction activities.
- Publication 1856: Reasonably practicable – provides guidance on what is 'reasonably practicable' in terms of *proportionate controls to mitigate or minimise the risk of harm*.
- Publication 1992: Guide to Environment Reference Standard – provides guidance on how the ERS should be applied and how to interpret environmental values, indicators and objectives for each element of the environment

It is noted that new publications and guidance documents are continuously being released by EPA in support of the Environment Protection Act.

4.0 Methodology

This section describes how the groundwater assessment was conducted to describe the existing environment and potential adverse effects on groundwater levels and flow. The following sections outline the study methodology.

4.1 Existing conditions assessment method

4.1.1 Study area

This groundwater impact assessment considers intrusive works and infrastructure in the project area that may intersect groundwater, as well as surrounding areas where groundwater levels and flows could be impacted, for the onshore components of the project.

The groundwater study area is defined as the following three project components together with a 200-metre buffer zone around them:

- culvert beneath Shell Parade to accommodate the aboveground pipeline
    - although the preferred option is to widen the existing culvert via shallow trenching across Shell Parade, shallow thrust boring is also being considered beneath the road.
- treatment facility
    - foundations or pilings may be required beneath the nitrogen tanks which have the potential to intersect and affect groundwater levels and flow
- underground pipeline between the treatment facility and the South West Pipeline tie-in point
    - sections of trenching, thrust boring and HDD as per Figure 1-2. It is possible that along the northern section of Macgregor Court the pipeline would also be constructed using HDD, however, this would be confirmed during detailed design

The depth of assessment for most of the groundwater study area is the upper five to ten metres of the subsurface due to the shallow nature of proposed pipeline trenching and treatment facility foundations. A depth of 20 to 25 metres has been considered for potential HDD sections of the alignment.

The groundwater study area is shown in Figure 4-1 below, and Figure F1 (Appendix A).

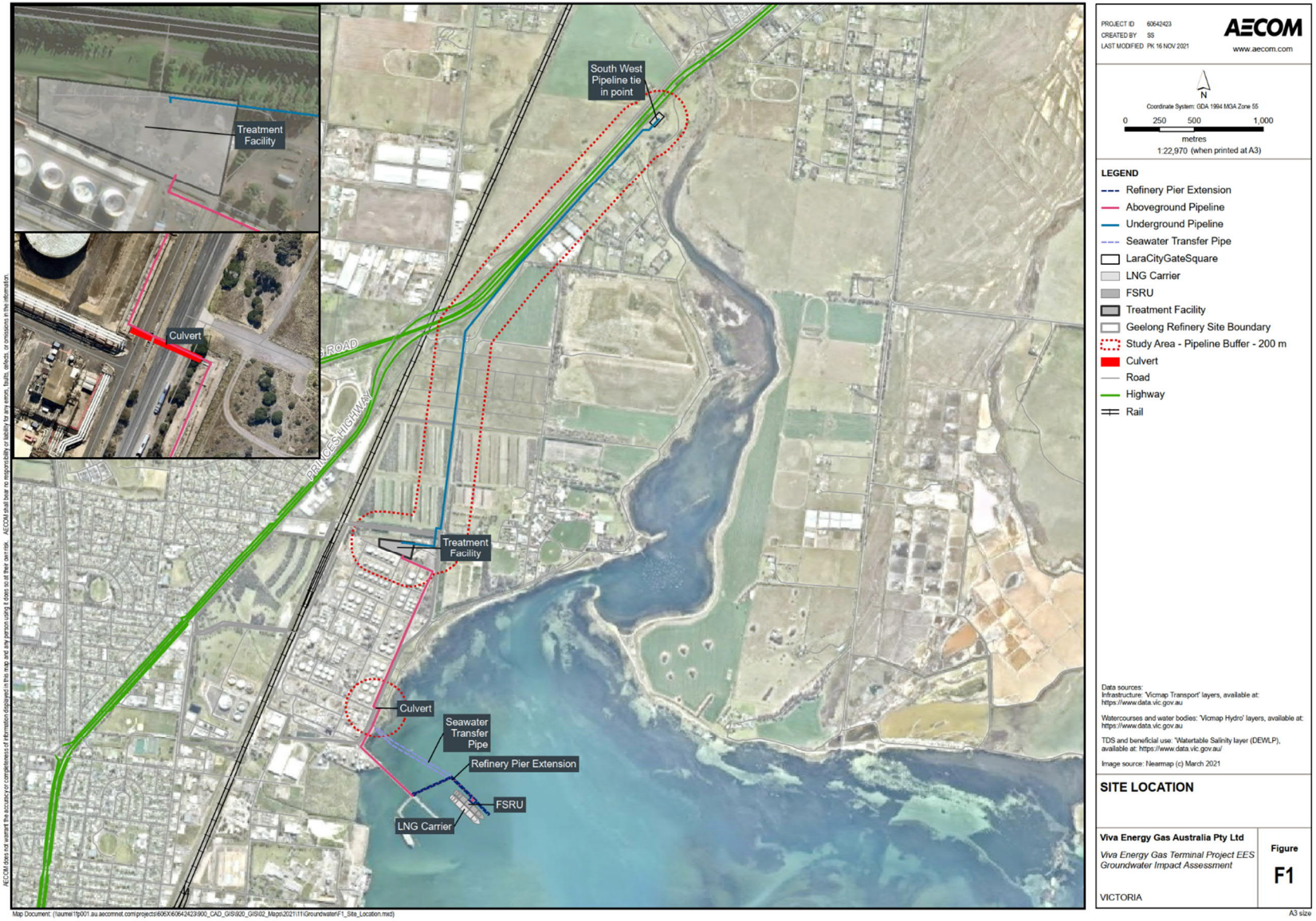


Figure 4-1 Groundwater study area

4.1.2 Desktop assessment

A desktop assessment was conducted to identify and describe existing conditions for the study area using publicly available information, and existing Geelong Refinery groundwater data.

The desktop assessment was subsequently updated, and existing condition descriptions refined, based on data collected during field investigations conducted in May 2021 (refer to Section 4.1.3).

The data used in the desktop assessment are summarised in Table 4-1.

Table 4-1 Desktop assessment data sources

Data	Source
Hydrology	• Corangamite Regional Catchment Strategy 2013–2019 https://ccma.vic.gov.au/about-us/regional-plans-strategies/ • Corangamite Waterway Strategy 2014-2022 (2015), https://ccma.vic.gov.au/about-us/regional-plans-strategies/ • Vicmap Hydro spatial data. Available for download: https://discover.data.vic.gov.au/dataset/vicmap-hydro-1-25-000 • Moorabool River Basin Local Management Plan (Southern Rural Water, 2014): http://www.srw.com.au/publications/
Geology	• Victorian Seamless Geology 1:250,000 (Earth Resources, Victorian State Government) 2014: https://www.data.vic.gov.au
Aquifer units	• Victorian Aquifer Framework (VAF) definitions and 3D surfaces (GHD, 2012). Spatial data available for download at: http://data2.cerdi.edu.au/dataset • Groundwater resource reports, DELWP: https://www.water.vic.gov.au/groundwater/groundwater-resource-reports • Port Phillip and Western Port Groundwater Atlas (Southern Rural Water, 2014): http://gwhub.srw.com.au/links-resources
Groundwater levels and flow dynamics	• Water Management Information System (WMIS), DELWP: http://data.water.vic.gov.au/monitoring.htm • Watertable depth to groundwater spatial data. Available for download: https://discover.data.vic.gov.au/dataset/watertable-depth-to-groundwater • Geelong Refinery 2020 quarterly groundwater gauging data, AECOM (2021).
Groundwater management	• Port Phillip and Western Port Groundwater Atlas (Southern Rural Water, 2014): http://gwhub.srw.com.au/links-resources • West Port Phillip Bay Groundwater Catchments Statement (Southern Rural Water, June 2016)
Groundwater salinity	• Watertable salinity and beneficial use spatial data: 'Watertable Salinity layer (DEWLP), available at: https://www.data.vic.gov.au/ • Geelong Refinery 2020 quarterly groundwater sampling data, AECOM (2021).
Registered bores	• WMIS database (DELWP): http://data.water.vic.gov.au/monitoring.htm • Geelong Refinery groundwater bore construction database (AECOM, 2021)
Groundwater dependent ecosystems	• GDE Atlas (Bureau of Meteorology): http://www.bom.gov.au/water/groundwater/gde/map.shtml
Groundwater - surface water interactions	• Australian Hydrological Geospatial Fabric Surface Hydrology Catchments dataset: https://www.data.vic.gov.au/data/dataset/groundwater-surface-water-interaction

4.1.3 Field investigation

The main objective of the groundwater field program was to confirm areas where groundwater could be intersected by the project and to identify the potential for groundwater – surface water interaction.

The Geelong Refinery's existing monitoring bore network was sufficient to describe existing conditions and assess potential impacts at the proposed Shell Parade culvert and treatment facility.

The fieldwork program was developed based on a preliminary desktop assessment of existing conditions and review of the project description, with the potential to extend the scope dependent on the conditions encountered. No material data gaps were identified, and the number and location of groundwater bores installed is considered appropriate to define existing conditions and assess potential impacts to groundwater.

Five groundwater monitoring bores (GW01 to GW05) were installed along the underground pipeline corridor (refer to Figure F1, Appendix A):

- GW01 at the lower lying southern extent of the proposed underground pipeline, close to School Road; where depth to groundwater was anticipated to be potentially shallower
- GW02, GW03 and GW04 as infill monitoring wells to confirm depth to groundwater along the pipeline corridor in the vicinity of potential HDD crossing points
- GW05 at a lower lying area near an unnamed water course to the north and close to the South West Pipeline tie in point, where depth to groundwater was anticipated to be potentially shallower

A summary of the completed groundwater investigation activities is provided in Table 4-2, results of fieldwork are provided in Appendix B and borelogs are provided in Appendix C.

Table 4-2 Field program summary table

Bore ID	Date Installed	Screen (mbgs)	Date Developed	Date Gauged	Date Sampled	Date Surveyed
GW01	7/5/2021	3.5 – 9.5	13/5/2021	28/7/2021	28/7/2021	28/7/2021
GW02	7/5/2021	5.5 – 9.5	13/5/2021	28/7/2021	28/7/2021	28/7/2021
GW03	30/6/2021	6.5 – 9.5	13/7/2021	28/7/2021	NS - dry	28/7/2021
GW04	2/7/2021	6.6 – 9.8	13/7/2021	28/7/2021	NS - dry	28/7/2021
GW05	25/6/2021	4.0 – 10.0	13/7/2021	28/7/2021	28/7/2021	28/7/2021

Results of the groundwater field program were combined with the desktop assessment to describe existing conditions in Section 5.0.

Aquifer testing (in the form of slug tests) was included as a provisional task in the fieldwork program. This was not required based on the depths to groundwater encountered and limited potential for groundwater to be intersected by the project (as discussed in Section 5.0 and Section 6.0).

Additional geotechnical bores and monitoring wells are proposed along the planned 20 to 25-metre-deep HDD sections in November and December 2021. The findings of those investigations will be reviewed and relevant or material information (if any) will be incorporated into subsequent versions of this groundwater technical report.

4.2 Risk screening method

A risk-based screening approach was used for the EES assessment in accordance with the requirements outlined in the 'Ministerial guidelines for assessment of Environmental Effects under the *Environment Effects Act 1978 (Vic)*' (page 14). The risk screening was undertaken to ensure that the level of investigation conducted in each technical study was adequate to inform an assessment of the significance and acceptability of the project's potential environmental impacts.

An environmental, social and economic issues risk screening tool was used to prioritise and focus the proposed investigations, assessments and approaches to avoiding, minimising or managing potential impacts. The issue screening process involved an evaluation of the potential environmental, social and economic issues associated with the project based on the information collected through a series of initial assessments undertaken into the potential effects of the project.

A risk workshop convened by a qualified risk practitioner and comprising technical specialists from the proponent, project design team and EES team conducted the initial risk screening. The risk screening process utilised knowledge of the project infrastructure and design, existing environment and land use setting to assess potential risks based on the specialised knowledge of the technical experts.

The purpose of the issues screening approach was to assist in identifying:

- Significant issues, uncertainties and/or potential impacts that require more detailed characterisation and/or assessment within the EES
- Matters or potential impacts considered to be already well understood or less significant.

A high, medium, or low screening value was assigned to potential issues to determine the level of assessment required to identify and investigate impacts.

Each potential issue was given a score (1, 2 or 3) against the categories of:

- Community and stakeholder interest
- Significance of assets, values and uses
- Potential impact (spatial, temporal and severity).

The scores were added together, or the highest score across the three contributing categories were used, to give a 'screening value' of high, medium or low, which gives an indication of the level of impact assessment that is required. Issues that were assigned a screening value of high or medium required detailed assessment in the EES at a level commensurate with them being considered primary level issues.

Issues that were assigned a screening value of low were proposed to be documented and managed with some investigation and assessment in the EES at a level commensurate with them being considered secondary level issues.

4.2.1 Criteria and consequence ratings

Risks, issues, and potential impact pathways were identified for both construction and operation of the project. Table 4-3 defines the criteria and consequence ratings for each of the three categories that were used to inform the issues screening. The sum of the scores against each of the three categories gives the 'screening value'.

Table 4-3 Issues screening criteria and consequence ratings

Rating	Community and stakeholder interest	Significance of assets, values and uses	Potential impact (spatial, temporal and severity)
1	Low interest and perceived impact	Locally significant asset, value or use	Potential for localised, temporary impact
2	Some interest and targeted perceived impacts	Regionally significant asset, value or use	Potential for significant temporary, or localised permanent impact
3	Broad community and stakeholder interest or impacts	State or nationally significant asset, value or use	Potential for significant permanent impact

The screening values are then used to determine the level of assessment required as shown in Table 4-4.

Table 4-4 Issue investigation categories

Screening score	Screening value	Potential consequences	Complexity of mitigation	Level of assessment
7, 8 or 9 or the highest rating across any one of the three contributing categories is 3	High	Potential for elevated, longer term impacts, significant assets or values may be affected with enduring changes. Considers both impacts and benefits, or Issue may not be well defined and insufficient information is available for the impact assessment, or High level of community interest.	Stringent management measures may be required	Detailed assessment required
4, 5 or 6 or the highest rating across any one of the three contributing categories is 2	Medium	Potential for moderate level impacts, significant assets or values may be affected over an extended time frame with some resultant changes. Considers both impacts and benefits, or Issue may be moderately understood, and some information is available, however more is required for the impact assessment, or Medium level of community interest.	Standard management measures are available that can be adopted with some modification	Moderate assessment required
3 or the highest rating across any one of the three contributing categories is 1	Low	Potential for short term and localised impact. Asset or values may be temporarily affected but recovery expected, or Issue is well understood and there is enough information available for the impact assessment, or Low level of community interest.	Standard management measures are available.	Some assessment required

Further information about the risk screening process is detailed in Chapter 7 *Assessment framework.*

Outcomes from the risk screening process are outlined in Section 4.2.2 below.

4.2.2 Risk screening results

Table 4-5 provides the key potential issues related to changes in groundwater level and flow identified as part of the risk screening process for the project and presents the screening value for each issue.

In the screening process, it was determined that, based on existing knowledge, there was limited potential for groundwater to be intersected and for groundwater levels and flows to be impacted based on the proposed project infrastructure (Section 1.4). This was reflected in the low risk ratings for the limited number of potential issues identified and provided Table 4-5. The initial risk ratings have been confirmed by the findings of this study.

Potential risks and impacts to groundwater quality are assessed in Technical Report G: *Contamination and acid sulfate soils impact assessment.*

Table 4-5 Issue screening results for groundwater

Aspect	Issue	Community & stakeholder perceived impacts	Significance of assets, values & uses	Potential impact (spatial, temporal & severity)	Screening Score	Screening Value
Construction						
Groundwater	Temporary trench dewatering during pipe installation reduces groundwater level or flow at GDE or consumptive use bore.	1	1	1	3	Low
Groundwater	Groundwater bores become damaged, lost (destroyed) or inaccessible thereby affecting bore user.	1	1	1	3	Low
Operation						
Groundwater	Underground pipeline (including HDD sections) alters groundwater levels or flows and impacts groundwater users.	1	1	1	3	Low
Groundwater	Foundations or piles beneath structures within treatment facility alter groundwater levels or flows and impacts groundwater users.	1	1	1	3	Low

4.3 Impact assessment method

The groundwater impact assessment focusses on changes to groundwater levels and flow with the potential to adversely affect groundwater environmental values and users.

Potential impacts on groundwater quality from the project are addressed in Technical Report G*: Contamination and acid sulfate soils impact assessment*.

4.3.1 Construction

The construction phase impact assessment focuses on the potential changes to groundwater levels and flow due to intrusive project activities such as trenching, HDD, thrust boring and piling. The impact assessment methodology included:

- Identification of relevant project components such as infrastructure and construction methods that have the potential to affect groundwater
- A summary of existing conditions in the study area based on desktop assessment and site-specific field investigations
- Identification of potential impacts on environmental values of groundwater and groundwater users from construction activities
- Identification of mitigation measures (where required).

4.3.2 Operation

The operation phase impact assessment focuses on the potential changes to groundwater levels and flow due to permanent infrastructure (for example buried pipeline and foundations/piles) and project activities such as planned pipeline maintenance and testing. The impact assessment included:

- Identification of relevant project infrastructure and operational activities that have the potential to affect groundwater
- Summary of study area existing conditions based on desktop assessment and site-specific field investigations
- Identification of potential operational impacts on environmental values of groundwater and groundwater users
- Identification of mitigation measures (where required)

4.3.3 Decommissioning

The impact assessment for the decommissioning phase of the project included:

- Identification of relevant decommissioning activities with the potential to affect groundwater
- Summary of existing conditions in the study area based on desktop assessment and site-specific field investigations
- Identification of potential decommissioning impacts on environmental values of groundwater and groundwater users
- Identification of mitigation measures (where required).

4.4 Stakeholder and community engagement

Stakeholders and the community were consulted over the course of the EES development process to support the preparation of the technical studies, inform the development of the project and to communicate potential impacts related to the project.

Engagement with landholders (Geelong Council and VicRoads) was undertaken to obtain access and approval to undertake investigations and install groundwater wells as part of this study. In accordance with the EES scoping requirements, a Technical Reference Group (TRG) was convened and chaired by DELWP on behalf of the Minister for Planning. The TRG has provided input throughout the EES process. Chapter 6 *Stakeholder and community stakeholder engagement* provides a summary of the project's key engagement activities.

4.5 Assumptions and limitations

Assumptions and limitations relating to this impact assessment are as follows:

- The assessment focuses on activities with the potential to intersect groundwater and impact groundwater levels and flow.

Potential impacts on groundwater quality are not covered in this report and are addressed in Technical Report G*: Contamination and acid sulfate soils impact assessment*.

- The assessment relies on publicly available information, data from the existing Geelong Refinery monitoring network and the partially completed project geotechnical and onshore contamination investigations.
- Various standards and guidelines may be updated as the project progresses.

This study should be read in the context of limitations and assumptions mentioned above and the purpose for which it was intended.

4.5.1 Linkages to other technical studies

The groundwater impact assessment should be read in conjunction with other relevant technical reports forming part of the EES. Other potential impacts relating to surface water, biodiversity and contamination have been considered in detail in other technical reports:

- Technical Report A: *Marine ecology and water quality impact assessment*
- Technical Report D: *Terrestrial ecology impact assessment*
- Technical Report E: *Surface water impact assessment*
- Technical Report G: *Contamination and acid sulfate soils impact assessment*

5.0 Existing conditions

Section 5.1 provides an overview of the hydrological and hydrogeological setting of the study area, and Sections 5.2, 5.3 and 5.4 provide more detailed, local scale geological and hydrogeological descriptions for each of the sub-areas within the overall study area.

5.1 Overview

5.1.1 Hydrological setting

Elevation contours, watercourses and waterbodies in the study area are shown in Figure F2 (Appendix A).

The general topography of the area slopes from west to the east, with elevations west of Princes Highway in the order of 30 mAHD and falling away east and southeast to Corio Bay.

The project site is located within the Moorabool River basin and Hovells Creek sub-catchment of the Corangamite catchment region and is managed by the Corangamite Catchment Management Authority (CCMA).

The Moorabool River is approximately 6.5 km to the south-east of the project area and Hovells Creek is approximately 300 m to the east of the proposed tie-in point to the SWP at Lara.

There is one unnamed minor watercourse located within the study area which the proposed underground pipeline would cross. The watercourse is several metres wide and is a shallow constructed rock-lined channel with low hierarchy (contains low or minor importance features). The watercourse flows from the north-west beneath Rennie Street and the Princes Highway before draining into a constructed dam built in the low point of the landscape. The dam fills after heavy rainfall events and only overflows to Hovells Creek following significant rainfall events.

Hovells Creek is a small creek that rises in the southern foothills of the You Yangs and flows into Corio Bay via Limeburners Lagoon. The creek is a high value and priority waterway within the landscape zone due to its environmental condition and social amenity value and is the main river of the Hovells landscape zone which includes several wetlands, including Limeburners Lagoon State Nature Reserve.

These wetlands are part of the internationally significant Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site. The Ramsar site comprises six distinct areas, including Point Wilson/Limeburners Bay which is located along the northern shoreline of Corio Bay approximately one kilometre to the north-east of the project site (refer to Figure 5-1).

Figure 5-1 Point Wilson/Limeburners Bay Ramsar site boundary and the project

5.1.2 Hydrogeological setting

The study area is in the West Port Phillip Bay Groundwater Catchment consisting of four designated groundwater management units (GMUs):

- three Groundwater Management Areas (GMAs) Cut Paw Paw, Lancefield and Merrimu – being discrete areas where groundwater quality suitable for irrigation, commercial or stock and domestic use is available or expected to be available; and
- the Deutgam Water Supply Protection Area (WSPA) – being an area declared under the *Water Act 1989 (Vic)* to protect groundwater through development of a groundwater management plan to ensure equitable management and long-term sustainability (SRW, 2016).

The study area is outside the designated GMUs and is managed through a local management plan. No cap has been placed on the volume of groundwater that can be extracted from these areas outside of the GMUs. The local management plan applies no restrictions on taking groundwater, although extraction is authorised under a groundwater licence; other than for domestic and stock use (SRW, 2016).

The surface geology in the study area is shown in Figure F3 (Appendix A) sourced from published 1:250,000 Seamless geology (DELWP, 2018).

The Tertiary age Black Rock Sandstone (now known as the Sandringham Sandstone) is shown as outcropping at surface at the proposed Shell Parade culvert and to the south of the proposed treatment facility. The Sandringham Sandstone (and predecessor unit names) has variously been described as

ranging from quartzose calcareous sandy clay to coarse grained quartz sandstone, and sandy silt, fine sandstone, sandy conglomerate to pebbly sandstone, clayey sand, clayey gravel, and carbonaceous bands including plant fossils[2].

Further north the Sandringham Sandstone is shown to be overlain by the Upper Tertiary/Quaternary age Newer Volcanic Group basalt flows, scoria and pyroclastics.

At the northern extent of the study area, beneath the South West Pipeline tie-in point, Newer Volcanic Group is mapped as being overlain by Quaternary age Darley Gravel comprising gravels, sands and silts. Immediately east and north east of the study area, Quaternary age coastal lagoon deposits are mapped as being present around the low-lying areas of Hovells Creek.

The study area lies at the onshore edge of the groundwater basin known as the Port Phillip Basin. The northern margin is bounded by outcropping pre-Tertiary basement bedrock (which form the Southern Uplands), the Rowsley Fault marks the western margin and the Selwyn Fault the eastern margin of the basin (GHD, 2010).

The shallow aquifers of the basin relevant to the groundwater report are summarised in Table 5-1 (based on Victorian Aquifer Framework layers within https://www.vvg.org.au/).

Table 5-1 Hydrostratigraphy of the study area

Aquifer	HGU[1]	Depth (mbgs)	Thickness (m)	Study area zone
Quaternary Alluvium [QA]	Various fluvial/lacustrine/alluvial/ colluvial sediments	0	up to 5	Shell Parade culvert and northern extent of underground pipeline
Upper Tertiary/ Quaternary Basalt [UTB]	Newer Volcanics basalt flows, scoria and pyroclastics	0 to 5	0 to 30	treatment facility and underground pipeline
Upper Tertiary Aquifer (Marine) [UTAM]	Sandringham Sandstone	0 - 30	0 - 20	All (except northern portion of underground pipeline)

NOTES: mbgs – metres below ground surface; 1 - Hydrogeological Groundwater Unit

The UTAM is the water table aquifer in the southern portion of the project area where it outcrops. Further north, the UTAM is overlain by the UTB aquifer. Depending on the groundwater elevation, the water table will be hosted by the unconfined UTB aquifer, or the underlying UTAM. At the northern extent of the study area, the QA would locally form the water table aquifer.

Recharge to the aquifer units will principally occur via direct rainfall infiltration where they outcrop and may be locally influenced by additional recharge via irrigation, leaking underground infrastructure (such as water supply, stormwater, sewers) and temporary discharge from ephemeral watercourses. Upwards or downward vertical leakage between aquifers, depending on hydraulic gradients, may also occur (SRW, 2014).

The groundwater table is often observed to be a subdued version of the ground surface. As such, shallower groundwater would be anticipated beneath the southern and northern portions of the study area (in lower lying areas close to the coast and in the Hovells Creek area, respectively) and greater depths beneath the central portion of the underground pipeline alignment. Regional groundwater flow will be towards the east and southeast beneath the study area as groundwater flows from higher ground towards the discharge areas of Corio Bay, and potentially localised groundwater discharge to Hovells Creek (refer to Section 5.1.6).

Depths to groundwater based on regional scale interpretation and mapping are shown as being between 5 to 10 metres below ground surface (mbgs) within the study area and locally increasing to 15

[2] https://asud.ga.gov.au/search-stratigraphic-units/results/80411

to 20 mbgs beneath higher topography in the east based on regional scale mapping and interpretation (refer to Figure F4, Appendix A).

Further details on groundwater occurrence is provided for each sub-area in Sections 5.2, 5.3 and 5.4.

5.1.3 Environmental values

The Environment Reference Standard (ERS) is promulgated under Section 93 of the *Environment Protection Act 2017 (Vic)* ('Environment Protection Act'). It sets out the environmental values of the ambient air, ambient sound, land and water environments that are sought to be achieved or maintained in Victoria and standards to support those values.

The ERS identifies environmental values that need to be achieved and maintained and provides a method to assess those environmental values in locations across the Victoria.

The ERS divides groundwater across Victoria into seven 'segments'. These segments are defined by salinity ranges measured as total dissolved solids (TDS). Within each segment (or range of TDS) a number of environmental values are identified that need to be achieved and maintained (refer to Table 5-2).

TDS from regional mapping and from existing refinery monitoring wells was reviewed to assess the environmental values of groundwater to be protected within the study area.

Regional mapping shows groundwater to have a TDS beneath much of the study area falling within Segment B (1,201 to 3,100 mg/L TDS). The groundwater is mapped as being Segment C (3,001 to 5,400 mg/L) beneath the northern portion of the proposed underground pipeline corridor (refer to Figure F5).

TDS[3] data from 2015 to 2020 was compiled from 25 refinery monitoring bores within the study area and is presented in Figure 5-2. Overall, the data suggest that most of the groundwater (~70%) beneath the study area ranges between Segment C and Segment E.

[3] TDS values are from field parameters including TDS and electrical conductivity converted to TDS (where TDS = EC * 0.55)

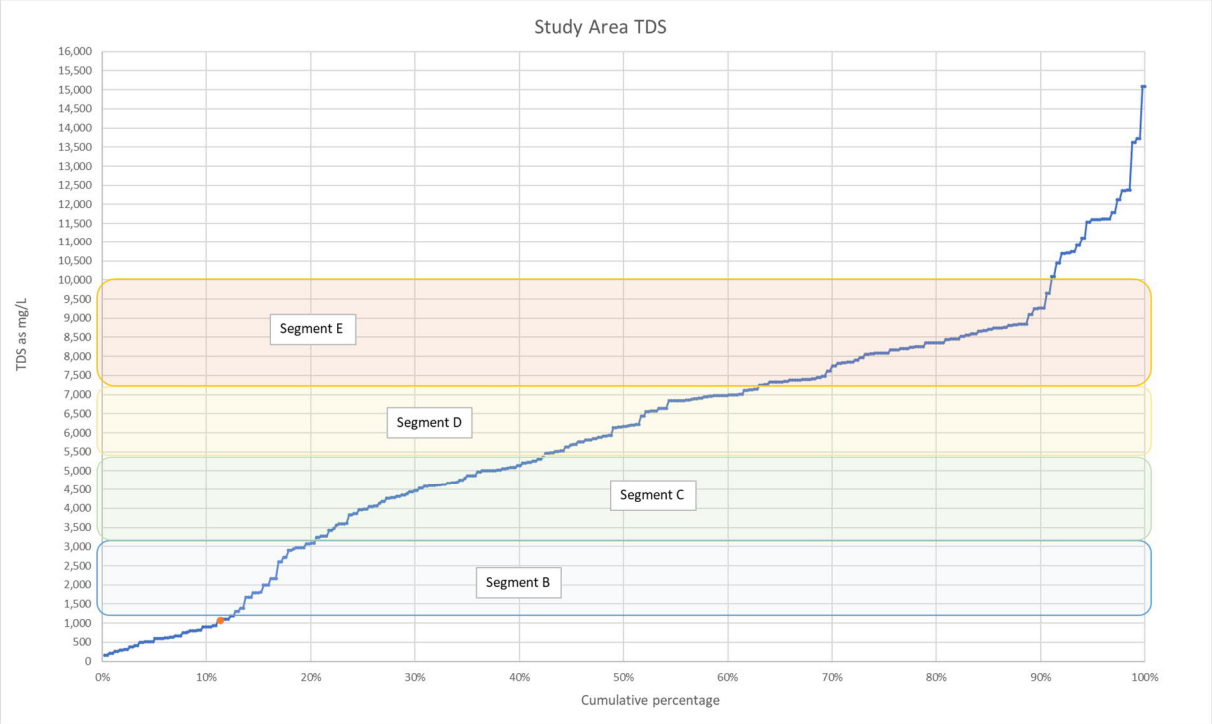


Figure 5-2 Study Area Groundwater TDS

TDS was also estimated from field electrical conductivity samples collected on 28 July 2021 from GW01 (2,278 mg/L), GW02 (3,785 mg/L) and GW05 (915 mg/L). It is possible that the lower TDS at GW05 may be influenced by recharge from lower salinity discharge from the nearby surface water dam.

For the purposes of this groundwater report and identifying groundwater users to be protected, the groundwater salinity has been conservatively assessed as being Segment B, with the associated environmental values shown in Table 5-2.

The key groundwater users that could be affected include users of groundwater bores for irrigation, stock watering and industrial/commercial uses, as well as groundwater dependent features that may support ecosystems or have cultural values to Traditional Owners.

Table 5-2 Environmental values of groundwater

Environmental Values	Segment (TDS mg/L)						
	A1 (0-600)	A2 (601-1200)	B (1,201-3,100)	C (3,101-5,400)	D (5,401-7,100)	E (7,101-10,000)	F (>10,000)
Water dependent ecosystems and species	✓	✓	✓	✓	✓	✓	✓
Potable water supply (desirable)	✓						
Potable water supply (acceptable)		✓					
Potable mineral water supply	✓	✓	✓	✓			
Agriculture and irrigation (irrigation)	✓	✓	✓				
Agriculture and irrigation (stock watering)	✓	✓	✓	✓	✓	✓	
Industrial and commercial	✓	✓	✓	✓	✓		

Environmental Values	Segment (TDS mg/L)						
	A1 (0-600)	A2 (601-1200)	B (1,201-3,100)	C (3,101-5,400)	D (5,401-7,100)	E (7,101-10,000)	F (>10,000)
Water-based recreation (primary contact recreation)	✓	✓	✓	✓	✓	✓	✓
Traditional Owner cultural values	✓	✓	✓	✓	✓	✓	✓
Buildings and structures;	✓	✓	✓	✓	✓	✓	✓
Geothermal properties	✓	✓	✓	✓	✓	✓	✓

5.1.4 Groundwater users

A search of the WMIS registered groundwater bore database was completed for the study area; and results summarised in Table 5-3 and presented on Figure F4 (Appendix A).

Table 5-3 Licensed uses for registered bores within the study area

Licensed use category	Licensed uses	Number of bores	Depth range (m)	Distance from pipeline route (m)
WMIS Database				
Consumptive	Domestic	1	35	125
Monitoring/ Observation	Groundwater investigation, observation	17*	5.2 to 13	70 – 200
Unknown	Use not known	3^	25	10 – 170

* - all associated with the Geelong Refinery monitoring network.
^ - two unknown use bores are listed as being 'not used'.

A summary of the WMIS database consumptive use bore and three potentially consumptive use bores is provided below (from north to south along the alignment):

- 104976 - registered use 'unknown'. Mapped as being approximately 115 metres northwest of the proposed pipeline alignment. Construction details not known..
- WRK982178 - bore status is listed as 'not used' and registered use 'not known'. Mapped as being approximately 10 metres southeast of the proposed pipeline alignment. The screened interval is not listed, but total depth recorded as 25 metres.
- 115471 - consumptive use bore registered for domestic use. Mapped at 125 m southeast of the proposed pipeline alignment. It is recorded as being screened from 27 to 35 mbgs in a sand lithology;
- WRK984684 - bore status is listed as 'not used' and registered use 'not known'. Mapped as being approximately 160 metres northwest of the proposed pipeline alignment. The screened interval is not listed, but total depth recorded as 25 metres.

5.1.5 Groundwater dependent ecosystems

The Groundwater Dependent Ecosystems Atlas (the Atlas) was developed as a national dataset of Australian GDEs (http://www.bom.gov.au/water/groundwater/gde/map.shtml).

The Atlas contains information about aquatic ecosystems that rely on the groundwater that discharges to the surface (including rivers, springs and wetlands), terrestrial ecosystems that rely on the

subsurface presence of groundwater (including vegetation) and subterranean ecosystems that live in caves and aquifers[4].

The mapping is from national scale assessment based on available geographic information system (GIS) data and a set of rules that describe the potential for groundwater and ecosystems to interact, and: more detailed regional assessment by state and/or regional agencies using field work, satellite imagery or application of conceptual models.

The identification of potential GDEs in the Atlas does not confirm that a particular ecosystem is groundwater dependent.

There are no potential aquatic GDEs mapped as being within the study area, and no terrestrial GDEs within the underground pipeline corridor and treatment facility sub-areas based on national and regional studies (refer to Figure F6, Appendix A).

There are high potential (from national assessment) terrestrial GDEs mapped within the Shell Parade culvert sub-area. These are described as coastal saltmarsh/mangrove shrubland mosaic and are located on the area of foreshore reserve between Shell Parade and Corio Bay (refer to Figure F6, Appendix A).

5.1.6 Groundwater- surface water interaction

The study area is intersected by an unnamed minor watercourse located approximately 140 metres southwest of the South West Pipeline tie-in point. This is a constructed shallow rock lined channel several metres wide that drains into a dam built in the low point of the landscape. Neither feature is mapped as being a potential GDE (refer to Figure F6, Appendix A) and both are thought to be fed by surface water.

Although Hovells Creek is mapped as being a high potential GDE (from national assessment), it is located beyond the study area, approximately 300 metres southeast of the proposed underground pipeline corridor.

There is limited potential for groundwater – surface water (GW-SW) interaction within the study area and no nationally classified GW-SW interactions are reported for streams within the study area.

5.2 Shell Parade culvert sub-area

5.2.1 Geology

Borelogs from the refinery monitoring wells nearest to the proposed culvert beneath Shell Parade (MW046, MW238 and MW239) describe the lithology as varying from clay to silty clay to sandy clay, with occasional cemented calcareous sand layers to depths of up to seven metres (being the total depth of the monitoring wells). This is consistent with regional scale mapping that shows outcropping Sandringham Sandstone sediments in this area, which can include quartzose calcareous sandy clay, sandy silt, and clayey sand.

5.2.2 Groundwater Occurrence

Groundwater levels are gauged at monitoring wells in the vicinity of the proposed Shell Parade culvert as part of the refinery's ongoing groundwater monitoring program, and recent results are summarised in Table 5-4.

Table 5-4 Recent groundwater levels - Shell Parade

Bore ID	Screened Interval	Standing water level (SWL)		Date
	mbgs	mbgs*	mAHD	
MW237	2.0 to 7.0	3.87	1.23	12/2/2020
		3.66	1.50	25/11/2020

[4] The GDE Atlas does not contain information regarding subterranean GDESs for Victoria but is not considered relevant to this study based on the geological formations intersected by the project's shallow construction activities.

Bore ID	Screened Interval	Standing water level (SWL)		Date
	mbgs	mbgs*	mAHD	
MW238	2.0 to 7.0	3.69	1.44	12/2/2020
		3.54	1.60	25/11/2020
MW240	1.5 to 7.5	2.63	1.61	26/11/2020
MW250	2.0 to 6.0	3.31	0.72#	18/11/2020
MW046	1.0 to 6.0	3.45	0.61#	11/2/2020
		3.24	0.81#	18/11/2020
MW239	1.5 to 7.0	3.18	0.69	11/2/2020
		2.95	0.92	25/11/2020
MW309	2.0 to 4.8	3.20	0.72	11/2/2020
		3.03	0.89	18/11/2020
MW254	1.0 to 6.0	2.93	0.34#	11/2/2020
		2.61	0.67#	19/11/2020
MW340	1.0 to 3.3	1.65	0.44	11/2/2020
		1.41	0.67	19/11/2020
MW155	1.0 to 6.0	0.84	0.53	19/11/2020
MW156	1.0 to 5.0	1.35	0.25	12/2/2020
		1.04	0.56	25/11/2020
MW344	0.3 to 3.2	1.14	0.73	17/11/2020

Notes: * - Headworks all flush gatic and therefore mbgs approximated as being equal to mbtoc; # - Corrected groundwater elevation to account for presence of in-well LNAPL

Depths to groundwater near the proposed Shell Parade culvert are between three and four metres below ground surface based on data from the nearest monitoring wells: MW046, MW238 and MW239 (refer to Table 5-4 and Figure 5-3). This is one to two metres below the anticipated depth of trenching across Shall Parade.

The seasonal fluctuation between end-winter ('high' water table) and end-summer ('low' water table) is seen to be less than 0.5 metre at these monitoring wells.

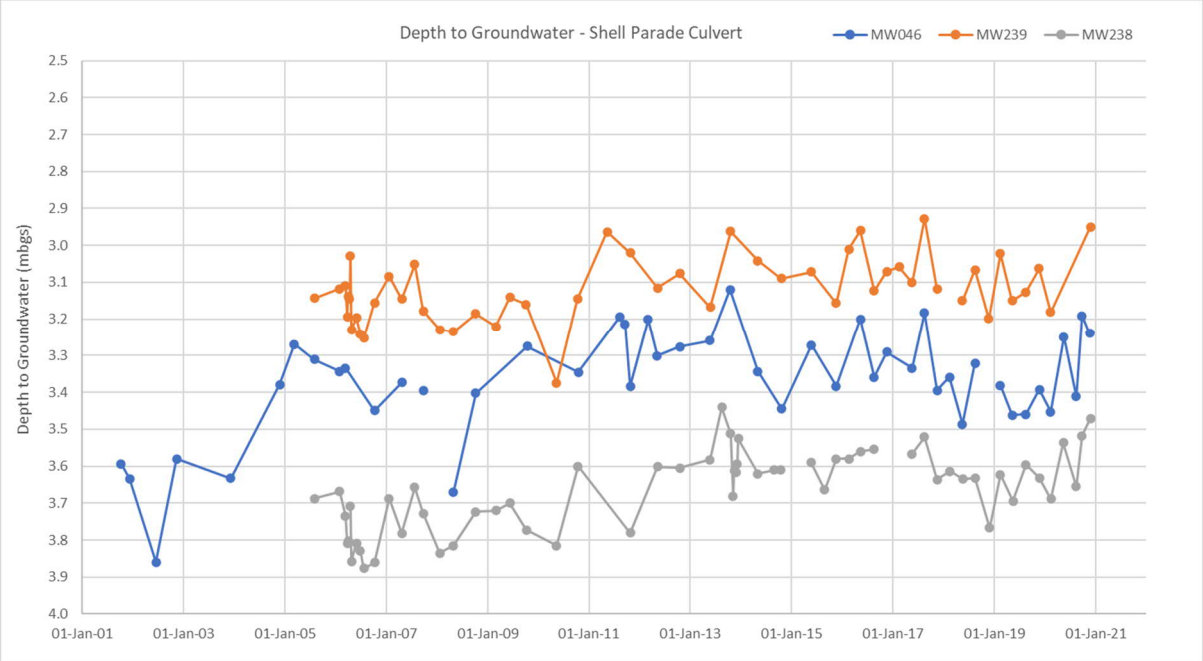


Figure 5-3 Depth to groundwater near proposed Shell Parade culvert

Groundwater elevations are higher in monitoring wells closer to Shell Parade (e.g. MW237, MW238, MW239 and MW240) and lower to the east beneath the foreshore area (e.g. MW254, MW340, MW155 and MW156) as shown in Figure F7 (Appendix A). The inferred groundwater flow direction in this area is consistent with the anticipated broader regional groundwater flow direction being east to southeast towards Corio Bay.

In this area, the refinery's central and foreshore groundwater interception trenches, shown in Figure F7 (Appendix A), may influence groundwater levels and flow patterns immediately adjacent to them. The trenches are designed to capture light non-aqueous phase liquid (LNAPL) and dissolved phase hydrocarbons (DPH) impacted shallow groundwater at the refinery's eastern boundary and foreshore area and may create small drawdowns adjacent to them. LNAPL are hydrocarbons that do not mix with the groundwater, forming a separate 'layer' at the watertable. This is distinct from the DPH that have dissolved/partitioned into the groundwater.

Trenching across Shell Parade is not expected to intersect groundwater based on data from nearby monitoring wells and on the basis of an anticipated two-metre-deep trench and culvert. A shallow thrust bore crossing is also being considered as an alternative methodology. It is anticipated that the thrust bore would be less than three metres deep and is therefore not expected to intersect groundwater.

Potential impacts to groundwater levels and flow from the proposed Shell Parade culvert are assessed in Section 6.0.

5.3 Treatment facility sub-area

5.3.1 Geology

The area proposed for the treatment facility is approximately 80 m by 120 m in size and located in an existing laydown area within the refinery. This area, bound to the east by Shell Parade, to the south west by refinery Road 16, and to the north by School Road is commonly described as Nerita Gardens in various Geelong Refinery groundwater assessment reports.

The geology of Nerita Gardens area has historically been described as predominantly clay, silty and sandy clay, and silty and clayey sand. Laterally discontinuous sand lenses have also been noted, as

have indurated[5] calcareous sediments (AECOM, 2016). The depth of previous investigations was typically up to six to eight metres below ground surface.

As part of ongoing project site investigations, additional geotechnical bores are proposed to a depth of approximately ten metres but are not expected to encounter significantly different lithologies than historically encountered.

The ground conditions encountered are consistent with regional scale mapping that shows outcropping Sandringham Sandstone sediments in this area which can include quartzose calcareous sandy clay, sandy silt, and clayey sand.

5.3.2 Groundwater Occurrence

Groundwater levels are gauged at monitoring wells in the vicinity of the proposed treatment facility as part of the refinery's ongoing groundwater monitoring program, and additional monitoring was completed as part of this groundwater impact assessment. The most recent results are summarised in Table 5-5.

Table 5-5 Recent groundwater levels – treatment facility

Bore ID	Screened Interval	Standing water level (SWL)		Date
	mbgs	mbgs*	mAHD	
MW029	3.5 to 7.5	4.87	2.87	13/2/2019
		4.65	3.10	17/11/2020
		4.59	3.15	29/10/2021
MW119	2.0 to 7.0	6.81	2.32	4/3/2009
		Dry at 3.14	-	29/10/2021
MW120	2.0 to 7.0	6.00	2.07	19/11/2018
		6.12	1.95	7/5/2021
MW121	2.0 to 7.0	5.11	2.04	20/11/2017
		4.95	2.20	13/5/2021
		4.43	2.72	29/10/2021
MW139	2.2 to 7.2	NR	NR	10/2/2020
		4.05	2.12	17/11/2020
		3.68	2.50	29/10/2021
MW138	2.0 to 6.0	NR	NR	10/2/2020
		3.71	2.07	19/11/2020
MW212	2.0 to 8.0	NR	NR	10/2/2020
		2.91	1.70	19/11/2020
MW214	2.5 to 8.0	5.46	3.32	14/5/2018
		5.32	3.46	17/11/2020
		5.29	3.49	29/10/2021

[5] Induration is the hardening of rocks by heat, cementation, or compaction.

Bore ID	Screened Interval	Standing water level (SWL)		Date
	mbgs	mbgs*	mAHD	
MW326	3.0 to 6.0	4.10	1.69	10/2/2020
		3.92	1.87	19/11/2020
MW293	3.0 to 6.0	3.70	1.67	10/2/2020
		3.51	1.85	19/11/2020
MW294	3.5 to 6.0	3.68	1.78	10/2/2020
		3.50	1.97	19/11/2020
MW348	2.0 to 6.0	3.52	1.46	10/2/2020
		3.40	1.64	19/11/2020
MW329	2.5 to 5.0	3.35	1.42	10/2/2020
		2.92	1.85	27/11/2020
MW332	3.0 to 6.0	3.68	1.60	10/2/2020
		3.51	1.77	19/11/2020
MW315	1.5 to 6.0	3.12	1.59	10/2/2020
		2.96	1.76	19/11/2020
MW350	2.0 to 6.0	2.81	1.51	10/2/2020
		2.64	1.69	19/11/2020
Notes: * - Headworks all flush gatic, and mbgs approximated as being equal to mbtoc; NR – not recorded				

Depths to groundwater near the proposed treatment facility are typically between four and six metres below ground surface, based on data from the nearest monitoring wells: MW029, MW120, MW121 and MW139 (refer to Table 5-5 and Figure 5-4).

The seasonal fluctuation between end-winter (‘high’ water table) and end-summer (‘low’ water table) is generally less than 0.5 metre at these monitoring wells.

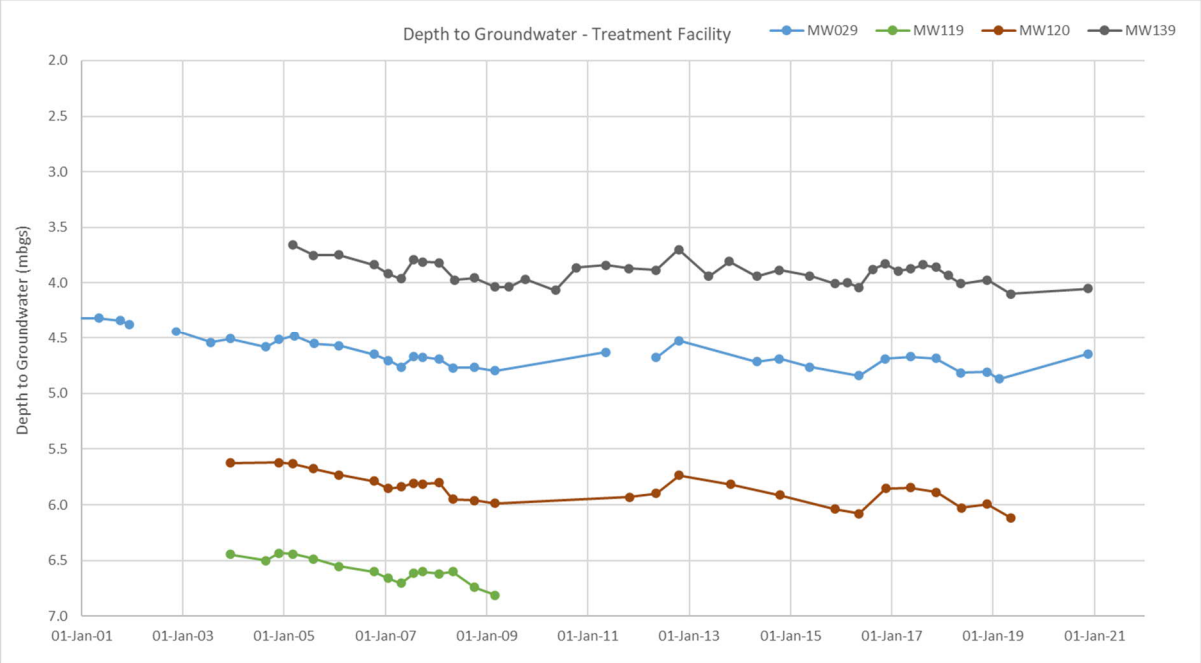


Figure 5-4 Depth to groundwater - proposed Treatment Facility

Groundwater elevations are typically higher in monitoring wells to the west (e.g., MW214, MW029 and MW121) and lower to the east (e.g., MW332, MW315, MW350 and MW212) as shown in Figure 8, Appendix A. Consistent with the anticipated broader regional groundwater flow direction, the data indicate flow is generally east to southeast towards Corio Bay.

The only aspect of the treatment facility construction with the potential to intersect groundwater is the installation of foundations or piles beneath the nitrogen tanks; however, the deepest foundations are likely to be only in the order of 1.5 metres below ground surface. The potential impacts to groundwater levels and flow associated with the proposed treatment facility are assessed in Section 7.3.

The potential for contaminated groundwater to be intersected, and the associated impacts from construction and operation of the project, will be addressed in Technical Report G*: Contamination and acid sulfate soils impact assessment*.

5.4 Underground pipeline sub-area

5.4.1 Geology

Groundwater monitoring wells GW01 to GW05 were installed along the proposed underground pipeline route, between School Road in the south and the unnamed watercourse to the north (refer to Figure F3, Appendix A).

At GW01 the lithology is described as clay overlying predominantly fine to medium grained sand to clayey sand, with minor limestone intervals to a depth of 9.5 mbgs; interpreted as being Sandringham Sandstone based on regional geological mapping.

Further north, basalt was intersected below fill and recent sediments in GW02 to GW04 at depths of between one and 1.5 mbgs. At GW02 basalt was encountered to a final depth of 9.5 metres. The base of basalt was encountered at 5.5 mbgs (GW03) and 5.3 mbgs (GW04). Underlying the basalt was predominantly fine-grained sand with some sandy clay deposits, and occasional thin sandstone and calcrete layers. At these locations it has been inferred that the Sandringham Sandstone formation underlies the Newer Volcanics basalt.

GW05 was drilled towards the northern extent of the underground pipeline near the unnamed watercourse. The lithology included clay, sandy clay, clayey sand, and occasional calcrete layers.

These sediments are inferred to be alluvium sediments associated with a previously incised drainage feature through the overlying basalt (now missing at this location). Overall, the geology is consistent with regional mapping that shows Sandringham Sandstone sediments outcropping beneath the refinery, which are overlain by the Newer Volcanic basalts in the northern portion of the study area. However, recent drilling suggests that the contact between the basalts and underlying Sandringham Sandstone sediments is between GW01 and GW02; further north than inferred by regional mapping.

5.4.2 Groundwater Occurrence

Groundwater levels are gauged at monitoring wells at the southern extent of the proposed underground pipeline sub-area as part of the refinery's ongoing groundwater monitoring program. Recent results from the existing refinery bores, and those recently drilled, are summarised in Table 5-6 and shown in Figure F9 (Appendix A).

Depths to groundwater between the proposed treatment facility and School Road are approximately 4.5 to 5.5. mbgs (MW121, MW145 and GW01). The seasonal fluctuation between end-winter ('high' water table) and end-summer ('low' water table) is generally less than 0.5 metre at monitoring wells MW121 and MW145, where temporal data sets are available (refer to Table 5-6 and Figure 5-5)

Depths to groundwater increase to more than 8.5 mbgs at monitoring bores GW02, GW03 and GW04 located further to the north. The bore logs and groundwater levels indicate that the Newer Volcanics basalts are unsaturated at GW03 and GW04, and that the regional water table occurs within the underlying sediments (inferred to be Sandringham Sandstone). At GW02 groundwater was present within the basalt sequence at 9 mbgs.

Groundwater is shallower at GW05 (2.86 mbgs) due to its location in a lower lying part of the landscape, close to the unnamed watercourse and dam.

Table 5-6 Recent groundwater levels – Underground Pipeline

Bore ID	Screened Interval	Standing water level (SWL)		Date
	mbgs	mbgs	mAHD	
MW121	2.0 to 7.0	5.11	2.04	20/11/2017
		4.95	2.20	13/5/2021
MW145	2.0 to 6.0	4.57	1.79	19/11/2018
		4.41	1.95	16/5/2021
MW333	3.0 to 5.4	4.54	1.73	20/11/2018
		4.38	1.89	13/5/2021
MW325	3.0 to 6.0	4.00	1.89	19/11/2020
		4.05	1.84	13/5/2021
GW01	3.5 to 9.5	5.53	2.25	28/7/2021
GW02	5.5 to 9.5	9.03	3.55	28/7/2021
GW03	6.5 to 9.5	Dry at 9.12	< 5.44	28/7/2021
GW04	6.6 to 9.8	Dry at 8.46	< 6.67	28/7/2021
GW05	4.0 to 10.0	2.86	2.67	28/7/2021
Notes: mbgs – metres below ground surface, mAHD – metres Australian Height Datum				

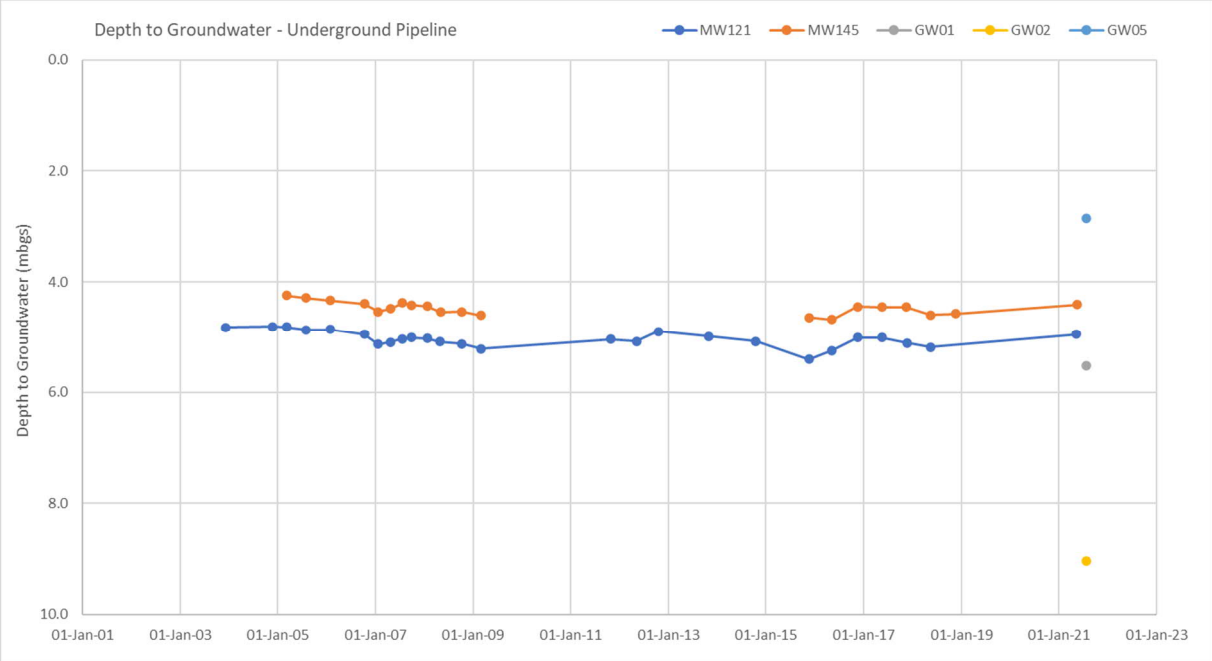


Figure 5-5 Depth to groundwater – proposed underground pipeline corridor

Overall, the depths to groundwater and groundwater elevations at the newly installed monitoring wells (GW01 – GW05) are consistent with the groundwater table being a subdued version of topography; with greater depths to groundwater beneath topographic highs and shallower depths to groundwater beneath lower lying topography.

Based on depths to groundwater, topography and assumed groundwater discharge areas, it is anticipated that:

- the predominant groundwater flow direction beneath the underground pipeline sub-area will be southeast towards Corio Bay;
- there may be a groundwater divide beneath the flatter and higher topography between the lower lying Corio Bay to the southeast and Hovells Creek to the north and northeast; and
- there may be a component of more easterly to north easterly flow to towards Hovells Creek beneath the northern portion of the study sub-area.

Gauging data from existing refinery monitoring bores and recently installed groundwater monitoring wells GW01 – GW05 show that groundwater is unlikely to be intersected by bell holes associated with thrust boring beneath School Road, or by trenching between the treatment facility and South West Pipeline tie-in point. This includes the lower lying topography at the unnamed watercourse and dam (140 m southwest of the tie-in point) where the depth to groundwater was 2.86 mbgs at GW05.

Groundwater will be intersected where HDD sections of up to 25 metres deep are being considered.

The potential impacts to groundwater levels and flow from the proposed underground pipeline are assessed in Sections 6.0.

6.0 Construction impacts

This section provides an overview of the potential groundwater level and flow impacts associated with construction of the project. Mitigation measures have been recommended to manage potential impacts where appropriate.

6.1 Trench dewatering reduces groundwater levels

A temporary and localised 'cone of depression' (that is, an area of reduced groundwater levels) is created away from the edge of an excavation when it is dewatered. This has the potential to affect groundwater levels and groundwater flow to nearby receptors such as consumptive use bores and GDEs. The extent of the cone of depression depends on several factors including: the depth of groundwater to be dewatered in the excavation, the ability of the material being dewatered to transmit groundwater (hydraulic conductivity), and the duration of dewatering. As these parameters increase so does the cone of depression.

As discussed in Section 5.0, trenching for the proposed underground pipeline is not expected to intersect groundwater.

The shallowest groundwater encountered was 2.86 mbgs (28 July 2021) at GW05, in the low-lying area close to the unnamed water course. This area has the greatest potential to be intersected by trenching, although still not anticipated. Should trenching be used to cross this unnamed watercourse, groundwater intersection (if any) would be along a limited portion of the trench and the duration of any dewatering would typically occur immediately prior to laying of the pipe (i.e. on the same day). Further, the clay and sandy clay encountered at GW05 would have a low hydraulic conductivity in the order of less than one metre per day (Fetter, 1994). Potential reductions in groundwater levels would therefore be expected to be small in magnitude, extent and duration; with drawdowns of greater than half a metre limited to within the construction ROW.

Overall, the need for dewatering to facilitate pipeline installation is not anticipated. Any potential impacts to groundwater environmental values and groundwater users from dewatering due to the unlikely intersection of groundwater would be negligible.

The disposal of trench dewatering (surface water and/or groundwater) is addressed in Technical Report G: *Contamination and acid sulfate soils impact assessment.*

6.2 Registered bores are destroyed or inaccessible

There is potential for groundwater bores within, or near, the proposed underground pipeline construction ROW to be damaged, lost (i.e., destroyed) or to become inaccessible during construction.

One consumptive use bore (115741; 126 m distant) and two unknown use bores (104976; 113 m distant and north of the Princes Freeway and WRK982178; 9 m distant) were identified within the study area. Other bores, such as unregistered bores or registered bores mapped to the wrong location, may also be affected during construction.

Following detailed design, the location of registered and unregistered bores should be visually confirmed on site relative to the pipeline and construction ROW.

Prior to construction, the potential for damage or loss of access to existing bores should then be established in consultation with the landholder/bore owner.

In instances where a bore is deemed to be impacted by the project, consultation should occur to facilitate an agreement between Viva Energy and the landholder/bore owner.

6.3 Summary of residual construction impacts

This assessment has found that groundwater is unlikely to be intersected by shallow trenching and no residual impacts associated with this construction activity have been identified for groundwater levels or flow.

The residual impacts of groundwater bores being lost, damaged or becoming inaccessible are considered negligible with implementation of the recommended mitigation measure (MM-GW01) of 'ground truthing' bore locations and liaison with the landholder/bore owner as outlined in Section 9.0.

7.0 Operation impacts

This section provides an overview of the potential groundwater level and flow impacts associated with operation of the project. Mitigation measures have been recommended to manage potential impacts where appropriate.

7.1 Underground pipeline changes groundwater level or flow

Trenching for the proposed underground pipeline is not expected to intersect groundwater. The potential for alteration of groundwater levels or flow due to i) preferential flow along the trench, or ii) groundwater flow being impeded by the trench and pipeline, is not anticipated.

If groundwater was intersected it would be along localised sections of the pipeline only, for example at the lower lying area near the unnamed minor watercourse and dam, and therefore any impacts would be of limited extent. The magnitude of any such impacts would be limited by the excavated and/or imported trench backfill being placed and compacted such that the permeability is similar to the unexcavated material (as per AS/NZS 2885.1[6]).

7.2 HDD sections of pipeline change groundwater levels or flow

The anticipated depth of HDD sections is up to 25 metres, which will intersect groundwater based on findings of this assessment (refer to Section 5.0).

As discussed in Section 1.4.4, the swelling of fines within the formation and residual filter cake seal in the bore annulus creates an effective seal to groundwater inflow during drilling and post-construction. This provides an effective seal between aquifers and prevents the creation of a preferential pathway between or within aquifers.

The potential for HDD installed sections of pipeline to impede groundwater flow and adversely impact groundwater uses or groundwater users is very unlikely. The small dimensions of the underground pipeline relative to the regional groundwater flow system means that groundwater would readily flow over or under the pipeline with negligible change in hydraulic gradient across it. HDD pipeline sections are not 'keyed into' underlying lower permeability materials, which is the case with cut-of walls for example. These types of structures are constructed across water bearing strata and into underlying lower permeability geology to prevent groundwater flow into excavations or cuttings. Such structures provide a much greater barrier to flow and can adversely impact upgradient and downgradient groundwater levels.

The magnitude and extent of any effects on groundwater levels and flow, and hence groundwater environmental values and groundwater users would be negligible.

It has been assumed that the project will engage a competent person (as per AS/NZS2885.1) in the development of a construction management plan for the HDD crossings (as per AS/NZS2885.1 and APGA Code of Environmental Practice[7]). The construction management plan should consider the site specific geological and hydrogeological conditions to be managed during construction.

7.3 Impeded groundwater flow due to foundations or piles

Groundwater flow has the potential to be impeded by foundations or piles where they extend below the watertable.. This can potentially result in impacts such as the reduction of groundwater levels at GDEs or bores (down-hydraulic gradient) and raising saline/brackish groundwater into the soil zone (up-hydraulic gradient).

[6] Australian Standards/New Zealand Standards 2885.1:2018. *Pipelines – Gas and Liquid Petroleum. Design and Construction.*
[7] Australian Pipelines and Gas Association – Code of Environmental Practice: Onshore Pipelines (rev 4, September 2015)

The magnitude of changes to the groundwater regime depends on the extent to which the aquifer perpendicular to groundwater flow has been impeded by the foundation/piles. Although the final design of the foundations or piles was not available at the time of writing, it is anticipated that they will be to a depth of only 1.5 metres below ground surface. These would not intersect groundwater given the depth to groundwater in this area is typically 4 to 6 mbgs. Should final design foundations be deeper and intersect groundwater, the geological profile and absence of groundwater users within 200 metres means that the potential for adverse impacts is considered very unlikely. Although changes to groundwater levels and flow (if any) would be permanent following re-equilibration of the groundwater system, the magnitude and extent of any impacts would be negligible.

Potential impacts on groundwater quality due to foundations/piling beneath structures within the treatment facility is addressed in Technical Report G: *Contamination and acid sulfate soils impact assessment.*

7.4 Summary of residual operation impacts

This assessment has found that groundwater is unlikely to be intersected by the underground pipeline. No residual impacts have been identified for trenched sections, and residual impacts (if any) from HDD sections would be negligible in extent and magnitude.

The magnitude and extent of any impacts to groundwater levels and flow associated with foundations/piles beneath structures within the treatment facility are also considered to be negligible.

8.0 Decommissioning impacts

No additional impacts, beyond those identified for the operational phase (Section 7.0), have been identified as having potentially adverse effects on groundwater levels or flow for the decommissioning phase.

It has been assumed that decommissioning of the onshore pipeline would require regulatory approval at that time. Currently AS2885 refers to APGA's Code of Environmental Practice Onshore Pipelines which includes the need for a decommissioning strategy to be developed and approved.

9.0 Recommended mitigation measures

Mitigation measures recommended to avoid, minimise and mitigate potential adverse effects on groundwater levels and flow are listed in Table 9-1

Table 9-1 Recommended mitigation measures

MM ID	Mitigation measure	Project phase
MM-GW01	**Loss of registered bores:** Through continued liaison with landholders the location of potentially affected bores (due to damage, destruction or loss of access) should be confirmed prior to construction and make-good arrangements agreed if required.	Construction

9.1 Performance monitoring and contingency measures

The intersection of groundwater is considered unlikely, and any dewatering due to the unexpected intersection of groundwater would be of a small scale and limited in duration based on the proposed project description (Section 1.4) and existing conditions (Section 5.0).

No performance monitoring or contingency measures are considered warranted in terms of effects on groundwater levels and flow, and the associated potential impacts on groundwater environmental values and groundwater users.

Performance monitoring in terms of groundwater quality (if any) is addressed in Technical Report G: *Contamination and acid sulfate soils impact assessment.*

10.0 Conclusion

The objective of this groundwater assessment was to determine potential effects of the project on groundwater levels and flow, and the associated potential impacts to groundwater environmental values and groundwater users. Management and mitigation measures have also been recommended where appropriate, to avoid, minimise and manage potential impacts.

The assessment focused on project construction activities and infrastructure that have the potential to intersect and alter groundwater level and flow. The sub-areas considered were Shell Parade culvert (for the aboveground pipeline section), treatment facility and underground pipeline section.

In addition to publicly available data and data from the Geelong Refinery groundwater monitoring network, data was also obtained from five new groundwater monitoring bores installed for the project.

It was concluded that there is very limited potential for groundwater to be intersected based on the proposed project infrastructure and understanding of existing conditions developed during the assessment.

A limited number of potential impact pathways for groundwater levels and flows to be adversely affected were identified. All potential impacts were assessed as being negligible in magnitude and extent:

- Groundwater was found to be from between 2.9 metres to greater than 8 mbgs beneath the study area. Bell holes associated with thrust boring beneath School Road would be in the order of four metres deep, and trenched sections of the underground pipeline would typically be two metres deep. The intersection of groundwater is therefore not anticipated.
- The residual impact from potential damage to, destruction of, or loss of access to groundwater bores during construction was also assessed. This was found to be negligible with the recommended mitigation measure (MM-GW01) of confirming bore locations through liaison with landholders/bore owners and agreeing make good arrangements if required.
- It is likely that HDD pipeline sections of up to 25 m in depth will intersect groundwater. Groundwater dewatering is not required as part of the HDD process. No potential impacts from the interconnection of groundwater within or between aquifers were identified due to the drilling methodology which effectively seals off the hole from the aquifer during drilling and post installation.
- Groundwater flow being impeded by HDD pipeline sections and foundations or piles beneath the treatment facility was also considered, with potential impacts to groundwater flows and levels found to be negligible.

Overall, the assessment of impacts to groundwater levels and flow found that, with standard industry practice and appropriate mitigation measures in place, groundwater environmental values and users would be protected from any adverse consequences caused by the construction, operation and decommissioning of the project, and that the EES evaluation objectives could be met.

11.0 References

AECOM (2016). Plume 2 Conceptual Site Model and Clean-up Strategy, Geelong Refinery. Final report dated 3 May 2016.

APGA (2017) Australian Pipelines and Gas Association Ltd Code of Environmental Practice Onshore Pipelines (Revision 4, September 2017)

ASTT (2010) Australian Society for Trenchless Technology Guidelines for Horizontal Directional Drilling, Pipe Bursting, Microtunnelling and Pipe Jacking (Revision 1, 3 Feb 2010)

Fetter, C.W. (1994). Applied Hydrogeology.

GHD (2010). Port Phillip CMA Groundwater Model: Transient model development report. Produced for Department of Sustainability and Environment, Victorian Government. Final report dated May 2010.

GHD (2012) Victorian Aquifer Framework, Updates for Seamless Mapping of Aquifer Surfaces. Prepared for the Department of Sustainability and Environment, May 2012.

SRW (2014). Port Phillip and Western Port Groundwater Atlas. Prepared for Southern Rural Water, July 2014.

SRW (2016). West Port Phillip Bay Groundwater Catchment Statement. Southern Rural Water, June 2016.

Appendix A

Figures

South West Pipeline tie in point

PRINCES HIGHWAY

Treatment Facility

Culvert

Seawater Transfer Pipe

Refinery Pier Extension

FSRU

LNG Carrier

PROJECT ID 60642423
CREATED BY SS
LAST MODIFIED PK 16 NOV 2021

AECOM
www.aecom.com

N

Coordinate System: GDA 1994 MGA Zone 55

0 250 500 1,000

metres

1:22,970 (when printed at A3)

LEGEND

- Refinery Pier Extension
- Aboveground Pipeline
- Underground Pipeline
- Seawater Transfer Pipe
- LaraCityGateSquare
- LNG Carrier
- FSRU
- Treatment Facility
- Geelong Refinery Site Boundary
- Study Area - Pipeline Buffer - 200 m
- Culvert
- Road
- Highway
- Rail

Data sources:
Infrastructure: 'Vicmap Transport' layers, available at: https://www.data.vic.gov.au

Watercourses and water bodies: 'Vicmap Hydro' layers, available at: https://www.data.vic.gov.au

TDS and beneficial use: 'Watertable Salinity layer (DEWLP), available at: https://www.data.vic.gov.au/

Image source: Nearmap (c) March 2021

SITE LOCATION

Viva Energy Gas Australia Pty Ltd

Viva Energy Gas Terminal Project EES Groundwater Impact Assessment

VICTORIA

Figure

F1

A3 size

Map Document: (\\aumel1fp001.au.aecomnet.com\projects\606X\60642423\900_CAD_GIS\920_GIS\02_Maps\2021\11\Groundwater\F1_Site_Location.mxd)

PROJECT ID 60642423
CREATED BY SS
LAST MODIFIED pk1 16 NOV 2021

AECOM
www.aecom.com

N

Coordinate System: GDA 1994 MGA Zone 55

0 237.5 475 950

metres

1:20,000 (when printed at A3)

LEGEND

- Installed Groundwater Bores (May-July 2021)
- Refinery Pier Extension
- Aboveground Pipeline
- Underground Pipeline
- Seawater Discharge Pipeline
- LaraCityGateSquare
- LNG Carrier
- FSRU
- Treatment Facility
- Geelong Refinery Site Boundary
- Culvert
- Study Area - Pipeline Buffer - 200 m
- Corangamite Catchment Management Authority
- Western Port Philip Bay Groundwater Catchment
- Ramsar Site
- Road
- Highway
- Rail
- Topographic Contours (5 m contours)
- Waterbody
- Watercourse

Data sources:
Infrastructure: 'Vicmap Transport' layers, available at: https://www.data.vic.gov.au

Registered bores : Water Measurement Information System (WMIS), DEWLP. Available at: http://data.water.vic.gov.au/

Outcropping geology: Victorian Seamless Geology (Earth Resources, Victorian State Government) 2014, available at: https://www.data.vic.gov.au

Image source: Nearmap (c) March 2021

TOPOGRAPHY AND SURFACE WATER

Viva Energy Gas Australia Pty Ltd

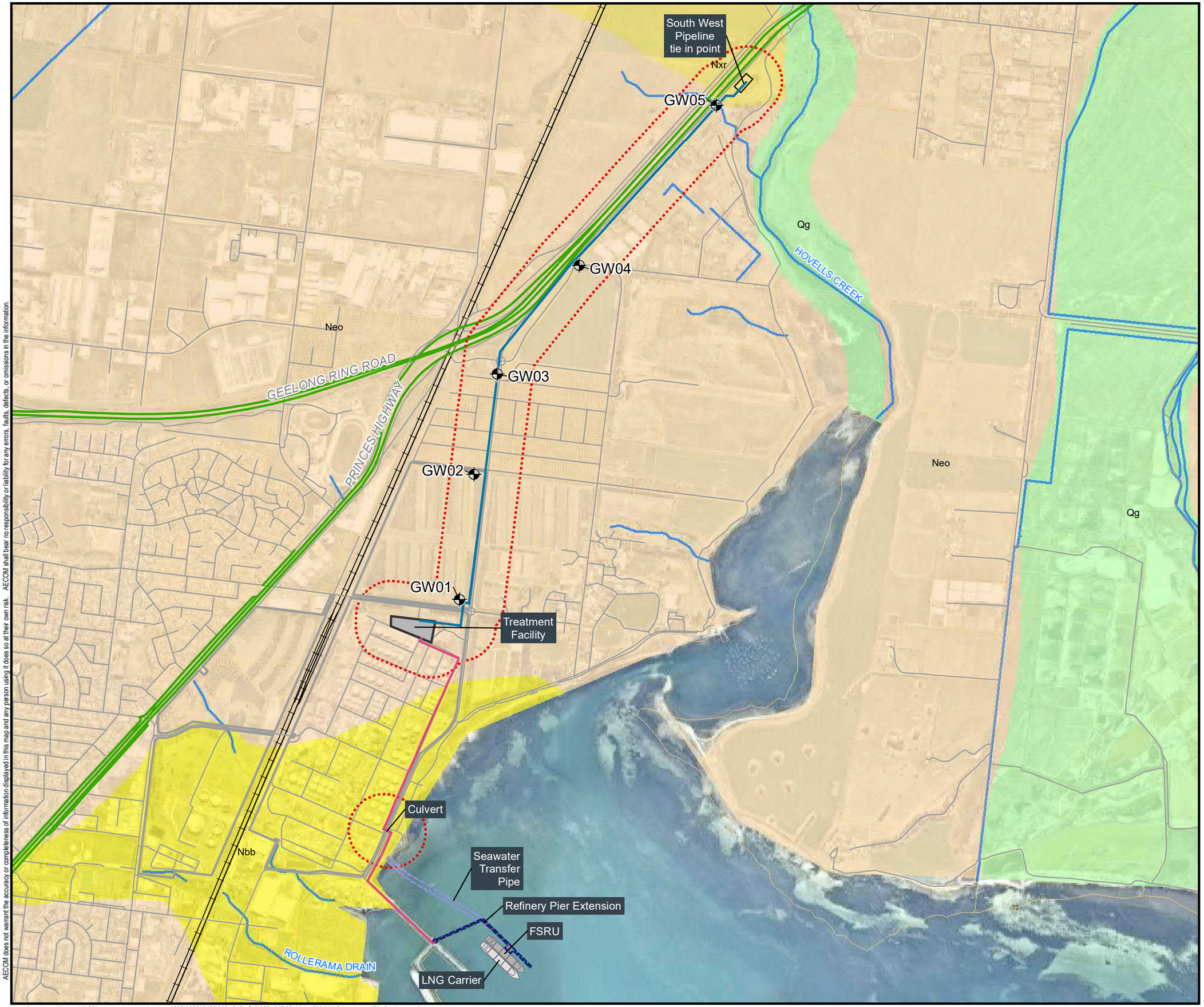
Viva Energy Gas Terminal Project EES Groundwater Impact Assessment

VICTORIA

Figure F2

Map Document: (\\aumel1fp001.au.aecomnet.com\projects\606X\60642423\900_CAD_GIS\920_GIS\02_Maps\2021\11\Groundwater\F2_Surfacewater_Topography.mxd)

A3 size



PROJECT ID 60642423
CREATED BY PK1
LAST MODIFIED BM 17 NOV 2021

AECOM
www.aecom.com

N

Coordinate System: GDA 1994 MGA Zone 55

0 237.5 475 950

metres

1:20,000 (when printed at A3)

LEGEND

- Installed Groundwater Bores (May 2021)
- Refinery Pier Extension
- Aboveground Pipeline
- Underground Pipeline
- Seawater Discharge Pipeline
- LaraCityGateSquare
- LNG Carrier
- FSRU
- Treatment Facility
- Geelong Refinery Site Boundary
- Culvert
- Study Area - Pipeline Buffer - 200 m
- Road
- Highway
- Rail
- Watercourse

Geology 1:250,000 Seamless Geology (Oldest to Youngest)

- Black Rock Sandstone (Nbb): generic
- Newer Volcanic Group - basalt flows (Neo): generic
- Darley Gravel (Nxr): generic
- Coastal lagoon deposits (Qg): generic

Data sources:
Infrastructure: 'Vicmap Transport' layers, available at: https://www.data.vic.gov.au

Watercourses and water bodies: 'Vicmap Hydro' layers, available at: https://www.data.vic.gov.au

Outcropping geology: Victorian Seamless Geology (Earth Resources, Victorian State Government) 2014, available at: https://www.data.vic.gov.au

Image source: Nearmap (c) March 2021

SITE GEOLOGY

Viva Energy Gas Australia Pty Ltd

Viva Energy Gas Terminal Project EES Groundwater Impact Assessment

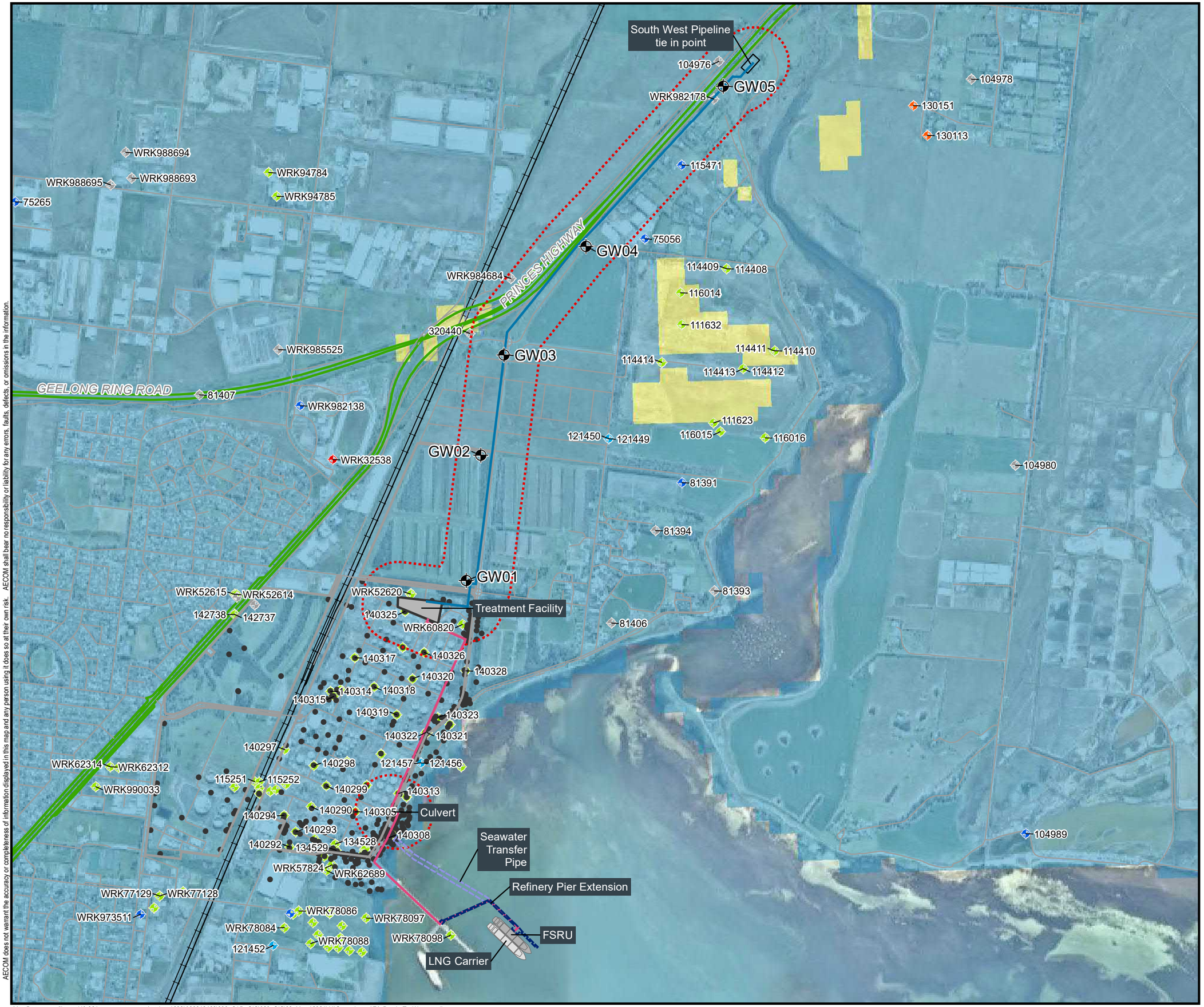
VICTORIA

Figure

F3

Map Document: (\\aumel1fp001.au.aecomnet.com\projects\606X\60642423\900_CAD_GIS\920_GIS\02_Maps\2021\11\Groundwater\F3_Geology.mxd)

A3 size



PROJECT ID 60642423
CREATED BY PK1
LAST MODIFIED BM 17 NOV 2021

AECOM
www.aecom.com

N

Coordinate System: GDA 1994 MGA Zone 55

0 237.5 475 950

metres

1:20,000 (when printed at A3)

LEGEND

- Installed Groundwater Bores (May-July 2021)
- Refinery Pier Extension
- Aboveground Pipeline
- Underground Pipeline
- Seawater Discharge Pipeline
- LaraCityGateSquare
- LNG Carrier
- FSRU
- Treatment Facility
- Geelong Refinery Site Boundary
- Culvert
- Study Area - Pipeline Buffer - 200 m
- Road
- Highway
- Rail

WMIS Registered Groundwater Bores

- Industrial
- Irrigation
- Stock and/or Domestic
- State Observation Bores
- Groundwater Investigation/ Observation/Environmental
- Unknown, Non-groundwater
- Geelong Refinery Monitoring Bores

Depth to Water (metres below ground surface)

- 5 - 10
- 15 - 20

Data sources:
Infrastructure: 'Vicmap Transport' layers, available at: https://www.data.vic.gov.au
Watercourses and water bodies: 'Vicmap Hydro' layers, available at: https://www.data.vic.gov.au
Depth to watertable: "Depth To Watertable" (DELWP), available at http://data2.cerdi.edu.au/dataset
Registered bores : Water Measurement Information System (WMIS), DEWLP. Available at: http://data.water.vic.gov.au/

Image source: Nearmap (c) March 2021

DEPTH TO WATER AND REGISTERED GROUNDWATER USERS

Viva Energy Gas Australia Pty Ltd

Viva Energy Gas Terminal Project EES Groundwater Impact Assessment

VICTORIA

Figure

F4

Map Document: (\\aumel1fp001.au.aecomnet.com\projects\606X\60642423\900_CAD_GIS\920_GIS\02_Maps\2021\11\Groundwater\F4_Depth_To_Water.mxd)

A3 size

PROJECT ID 60642423
CREATED BY PK1
LAST MODIFIED BM 17 NOV 2021

AECOM
www.aecom.com

N

Coordinate System: GDA 1994 MGA Zone 55

0 237.5 475 950

metres

1:20,000 (when printed at A3)

LEGEND

- Installed Groundwater Bores (May-July 2021)
- Refinery Pier Extension
- Aboveground Pipeline
- Underground Pipeline
- Seawater Discharge Pipeline
- LaraCityGateSquare
- LNG Carrier
- FSRU
- Treatment Facility
- Geelong Refinery Site Boundary
- Study Area - Pipeline Buffer - 200 m
- Culvert
- Road
- Highway
- Rail
- Watercourse

Beneficial Use Segment - Water Table Aquifer (mg/L)

- B (1201 - 3100 mg/L)
- C (3101 - 5400 mg/L)
- D (5401 - 7100 mg/L)

Data sources:
Infrastructure: 'Vicmap Transport' layers, available at: https://www.data.vic.gov.au

Watercourses and water bodies: 'Vicmap Hydro' layers, available at: https://www.data.vic.gov.au

TDS and beneficial use: 'Watertable Salinity layer (DEWLP), available at: https://www.data.vic.gov.au/

Image source: Nearmap (c) March 2021

GROUNDWATER SALINITY

Viva Energy Gas Australia Pty Ltd

Viva Energy Gas Terminal Project EES Groundwater Impact Assessment

VICTORIA

Figure

F5

Map Document: (\\aumel1fp001.au.aecomnet.com\projects\606X\60642423\900_CAD_GIS\920_GIS\02_Maps\2021\11\Groundwater\F5_Groundwater_Salinity.mxd)

A3 size

PROJECT ID 60642423
CREATED BY PK1
LAST MODIFIED BM 17 NOV 2021

AECOM
www.aecom.com

N

Coordinate System: GDA 1994 MGA Zone 55

0 237.5 475 950

metres

1:20,000 (when printed at A3)

LEGEND

- Installed Groundwater Bores (May-July 2021)
- Refinery Pier Extension
- Aboveground Pipeline
- Underground Pipeline
- Seawater Discharge Pipeline
- LaraCityGateSquare
- LNG Carrier
- FSRU
- Treatment Facility
- Geelong Refinery Site Boundary
- Study Area - Pipeline Buffer - 200 m
- Culvert
- Ramsar Site
- Road
- Highway
- Rail
- Waterbody
- Watercourse

Aquatic GDEs

- High potential GDE - from national assessment
- Moderate potential GDE - from regional studies
- Unclassified potential GDE - from regional studies

Terrestrial GDEs

- High potential GDE - from national assessment
- Moderate potential GDE - from national assessment
- Known GDE - from regional studies

Data sources:
Infrastructure: 'Vicmap Transport' layers, available at: https://www.data.vic.gov.au

Watercourses and water bodies: 'Vicmap Hydro' layers, available at: https://www.data.vic.gov.au

GDE data: The Groundwater Dependent Ecosystems Atlas (GDE Atlas). Available at: http://www.bom.gov.au/water/groundwater/gde

Image source: Nearmap (c) March 2021

GROUNDWATER DEPENDENT ECOSYSTEMS

Viva Energy Gas Australia Pty Ltd

Viva Energy Gas Terminal Project EES Groundwater Impact Assessment

VICTORIA

Figure

F6

Map Document: (\\aumel1fp001.au.aecomnet.com\projects\606X\60642423\900_CAD_GIS\920_GIS\02_Maps\2021\11\Groundwater\F6_GDEs.mxd)

A3 size

AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.

PROJECT ID	60642423
CREATED BY	PK 1
LAST MODIFIED	BM 17 NOV 2021

AECOM
www.aecom.com

N

Coordinate System: GDA 1994 MGA Zone 55

0 15 30 60
metres

1:1,600 (when printed at A3)

LEGEND

- Aboveground Pipeline
- Seawater Discharge Pipeline
- Geelong Refinery Site Boundary
- Culvert
- Groundwater Interception Trench
- Road

WMIS Registered Groundwater Bores

- Groundwater Investigation/ Observation/Environmental

Geelong Refinery Groundwater Bores

- Geelong Refinery Monitoring Locations - Not Gauged
- Geelong Refinery Groundwater Monitoring Bores - Gauged

Depth to Water (metres below ground surface)

- 5 - 10

Groundwater Bore Data

- 1.55 Depth to Groundwater (mbgs)
- 0.59 Groundwater Elevation (mAHD)
- 4100 Total Dissolved Solids (mg/L)

Data sources:
Infrastructure: 'Vicmap Transport' layers, available at: https://www.data.vic.gov.au
Watercourses and water bodies: 'Vicmap Hydro' layers, available at: https://www.data.vic.gov.au
Depth to watertable: "Depth To Watertable" (DELWP), available at http://data2.cerdi.edu.au/dataset
Registered bores : Water Measurement Information System (WMIS), DEWLP. Available at: http://data.water.vic.gov.au/

Image source: Nearmap (c) March 2021

GROUNDWATER - PROPOSED SHELL PARADE CULVERT SUB-AREA

Viva Energy Gas Australia Pty Ltd

Viva Energy Gas Terminal Project EES Groundwater Impact Assessment

VICTORIA

Figure

F7

Map Document: (\\aumel1fp001.au.aecomnet.com\projects\606X\60642423\900_CAD_GIS\920_GIS\02_Maps\2021\11\Groundwater\F7_Culvert.mxd)

A3 size

PROJECT ID 60642423
CREATED BY PK1
LAST MODIFIED BM 06 DEC 2021

AECOM
www.aecom.com

N

Coordinate System: GDA 1994 MGA Zone 55

0 20 40 80
metres
1:1,800 (when printed at A3)

LEGEND

- Aboveground Pipeline
- Underground Pipeline
- Treatment Facility
- Geelong Refinery Site Boundary
- Study Area - Pipeline Buffer - 200 m
- Groundwater Interception Trench

Investigation Locations

- Groundwater Bores
- Road

WMIS Registered Groundwater Bores

- Groundwater Investigation/ Observation/Environmental

Geelong Refinery Groundwater Bores

- Geelong Refinery Monitoring Locations - Not Gauged
- Geelong Refinery Groundwater Monitoring Bores - Gauged

Depth to Water (metres below ground surface)

- 5 - 10

Groundwater Bore Data

- 1.55 Depth to Groundwater (mbgs)
- 0.59 Groundwater Elevation (mAHD)
- 4100 Total Dissolved Solids (mg/L)

Note: GW data from Nov 2020, except those marked with "*" which are from Oct 2021.

Data sources:
Infrastructure: 'Vicmap Transport' layers, available at: https://www.data.vic.gov.au
Watercourses and water bodies: 'Vicmap Hydro' layers, available at: https://www.data.vic.gov.au
Depth to watertable: "Depth To Watertable" (DELWP), available at http://data2.cerdi.edu.au/dataset
Registered bores : Water Measurement Information System (WMIS), DEWLP. Available at: http://data.water.vic.gov.au/

Image source: Nearmap (c) March 2021

GROUNDWATER - PROPOSED TREATMENT FACILITY SUB-AREA

Viva Energy Gas Australia Pty Ltd

Viva Energy Gas Terminal Project EES Groundwater Impact Assessment

VICTORIA

Figure

F8

Map Document: (\\aumel1fp001.au.aecomnet.com\projects\606X\60642423\900_CAD_GIS\920_GIS\02_Maps\2021\11\Groundwater\F8_Treatment_Area.mxd)

A3 size

South West Pipeline tie in point
104976
GW05
WRK982178
GW05
2.86 mbgs
2.67 mAHD
917 mg/L
104978
130151
130113
115471
WRK94784
WRK94785
PRINCES HIGHWAY
GW04
75056
HOVELLS CREEK
114409
114408
WRK984684
GW04
Dry @ 8.46 mbgs
< 6.67 mAHD
116014
GW03
Dry @ 9.12 mbgs
< 5.44 mAHD
GEELONG RING ROAD
320440
111632
WRK985525
GW03
114411
114410
114415
114414
114413
114412
SHELL PARADE
WRK982138
GW02
9.03 mbgs
3.55 mAHD
3785 mg/L
111623
116015
121450
121449
116016
GW02
WRK32538
TORRESDALE ROAD
81391
GW01
5.53 mbgs
2.25 mAHD
2278 mg/L
ACM-BH03
MW145
4.57 mbgs
1.79 mAHD
3869 mg/L
81394
MW121
5.11 mbgs
2.04 mAHD
10152 mg/L
MW333
4.54 mbgs
1.73 mAHD
5550 mg/L
SCHOOL ROAD
GW01
81393
WRK52614
WRK52618
WRK52620
MW325
4 mbgs
1.89 mAHD
6881 mg/L
142737
140325
140327
Treatment Facility
81406
140324
140326
140317

Map Document: (\\aumel1fp001.au.aecomnet.com\projects\606X\60642423\900_CAD_GIS\920_GIS\02_Maps\2021\11\Groundwater\F9_UG_Pipeline.mxd)

PROJECT ID 60642423
CREATED BY PK1
LAST MODIFIED BM 17 NOV 2021

AECOM
www.aecom.com

N

Coordinate System: GDA 1994 MGA Zone 55

0 155 310 620
metres
1:13,000 (when printed at A3)

LEGEND

- Installed Groundwater Bores (May-July 2021)

Groundwater Monitoring Bores

- Geotechnical Borehole
- Groundwater Interception Trench
- Aboveground Pipeline
- Underground Pipeline
- LaraCityGateSquare
- Treatment Facility
- Geelong Refinery Site Boundary
- Study Area - Pipeline Buffer - 200 m
- Road
- Highway
- Rail

WMIS Registered Groundwater Bores

- Industrial
- Irrigation
- Stock and/or Domestic
- State Observation Bores
- Groundwater Investigation/ Observation/Environmental
- Unknown, Non-groundwater

Geelong Refinery Groundwater Bores

- Geelong Refinery Monitoring Locations - Not Gauged
- Geelong Refinery Groundwater Monitoring Bores - Gauged
- Waterbody
- Watercourse

Depth to Water (metres below ground surface)

- 5 - 10
- 15 - 20

Groundwater Bore Data

- 1.55 Depth to Groundwater (mbgs)
- 0.59 Groundwater Elevation (mAHD)
- 41 00 Total Dissolved Solids (mg/L)

Data sources:
Infrastructure: 'Vicmap Transport' layers, available at: https://www.data.vic.gov.au
Watercourses and water bodies: 'Vicmap Hydro' layers, available at: https://www.data.vic.gov.au
Depth to watertable: "Depth To Watertable" (DELWP), available at http://data2.cerdi.edu.au/dataset
Registered bores : Water Measurement Information System (WMIS), DEWLP. Available at: http://data.water.vic.gov.au/
GW01 and GW02 approximate groundwater elevations due to bores not yet surveyed
Image source: Nearmap (c) March 2021

GROUNDWATER - PROPOSED UNDERGROUND PIPELINE ALIGNMENT SUB-AREA

Viva Energy Gas Australia Pty Ltd

Viva Energy Gas Terminal Project EES Groundwater Impact Assessment

VICTORIA

Figure

F9

A3 size

Appendix B

Tables

Table B1. Well Construction and Development Record

Bore Construction Details									Bore Development		Gauging				Sampling							
Bore ID	Date installed	Easting	Northing	TOC (mAHD)	Ground Surface Elevation (mAHD)	Drilled Depth (mbgs)	Screen Interval (mbgs)	Screened Formation	Date Developed	Volume Removed (L)	Date Gauged	SWL (mbgs)	SWL (mAHD)	Total Depth (mbgs)	Date sampled	Temp (°C)	Dissolved Oxygen (mg/L)	Electrical Conductivity (µS/cm)	pH	Redox Field (mV)	Total Dissolved Solids (TDS) [1,2]	Redox Potential (Eh) [3]
GW01	7/05/21	270983.63	5783225.56	8.749	7.782	9.5	3.5 - 9.5	SAND/clayey SAND/CLAY/LMST bands	13/05/21	95	28/07/2021	5.53	2.25	9.00	28/07/2021	16.9	4.8	4141	7.80	45.5	2278	257.9
GW02	7/05/21	271066.25	5783940.33	13.279	12.575	9.5	5.5 - 9.5	BASALT	13/05/21	1.4	28/07/2021	9.03	3.55	9.30	28/07/2021	16.1	2.0	6881	7.70	56.5	3785	269.5
GW03	30/06/21	271198.45	5784511.49	14.472	14.557	9.5	6.5 – 9.5	Sandy CLAY/SAND	Dry bore		28/07/2021	Dry @ 9.12	<5.44	9.12	Dry bore. Not sampled							
GW04	2/07/21	271665.80	5785131.23	14.998	15.127	9.8	6.6 – 9.8	SAND	Dry bore		28/07/2021	Dry @ 8.46	<6.67	8.46	Dry bore. Not sampled							
GW05	25/06/21	272447.93	5786043.54	6.461	5.527	10.0	4.0 – 10.0	Sandy CLAY/CLAY/Clayey Sand/CALCRETE bands	13/07/21	112	28/07/2021	2.86	2.67	9.85	28/07/2021	17.2	0.5	1668	7.52	50.7	917	262.9

Notes

mAHD = metres above Australian Height Datum
mbgs = metres below ground surface
TOC = Top of Casing
mm = millimetres
* All wells constructed with 50 mm ND uPVC casing and screen
L = Litres

uS/cm = microsiemens per centimetre
mg/L = milligrams per litre
mV = millivolts
oC = degrees Celsius
(1) TDS = Total Dissolved Solids
(2) TDS approximated as Electrical Conductivity x 0.55
(3) Corrected Redox Potential = Field Redox Potential + (224.98 - 0.7443* Temperature) (Redox potential converted from Ag/AgCl electrode to H2 electrode)

Appendix C

Borelogs

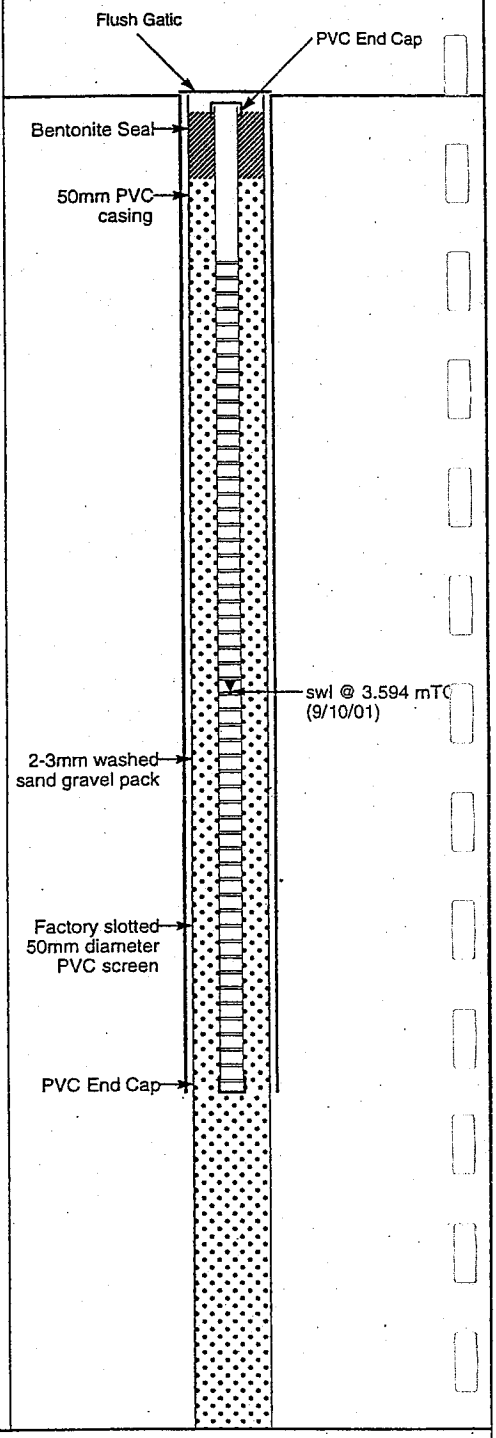
URS

MONITORING WELL MW46

AGC Woodward-Clyde Pty. Ltd.	Phone / Fax	Project Reference: Shell Geelong Refinery ESA/GME	Client: Shell Engineering Pty Ltd
Drilling Contractor: SOUTH WESTERN DRILLING		Project No.: 46144-131-5002	Location: Corio, VIC
Logged By: AL	Bore Size: 100 mm	Relative Level: 4205.00 mRL	Drill Type: Solid stem auger
Checked By: KH	Total Depth: 11.00 m	Coordinates: 5781698.04 mN 270489.05 mE	Drill Model: PIONEER 400
Date Started: 25-09-01	Casing Size: 50 mm	Permit No:	Drill Fluid: NONE
Date Finished: 25-09-01			

Sample Interval PID (ppm)	Sample ID	Legend	Classification	USC DESCRIPTION OF STRATA (Type, plasticity / particle size, colour, secondary / minor components (e.g., "trace"), moisture content, consistency / density, and additional observations)	Moisture	Depth (m)
			TOPS	TOPSOIL, silty CLAY, low plasticity, brown, grass and rootlets, organic, loose, slightly moist	D/M	0
12.4	MW46_0.5-0.6		CL	CLAY, low plasticity, dark brown, very stiff-platy, dry, friable, no odour	D	
NT	MW46_1.0-1.1		CL	CLAY, chips of white porcelien hard rock (<20 mm), light grey-white, no odour, dry	D	1
20.5	MW46_2.0-2.2		CL	CLAY, low plasticity, light grey with orange mottles, stiff, dry	D	2
471	MW46_3.0-3.1 QC05_25/9/01		CL	CLAY, low plasticity, light grey with orange mottles, slightly moist, hydrocarbon odour and spots of black staining	D/M	3
			CL	CLAY, medium plasticity, grey, soft, slightly moist, sections of black staining (<10mm), strong hydrocarbon odour	M	
289	MW46_4.0-4.1			As above, hydrocarbon odour, but may be from impacted water not soil	W	4
492	MW46_5.0-5.1					5
271	MW46_6.0-6.1					6
602	MW46_7.0-7.1					7

WELL CONSTRUCTION DETAILS



Remarks: NT - PID not taken due to insufficient sample.

☒ Split Spoon Sample

☐ Hand Auger Sample

WELL LOGS.GPJ WCC_AUS.GDT 22/01/02

URS

MONITORING WELL MW46

AGC Woodward-Clyde Pty. Ltd.	Phone Fax	Project No.: 46144-131-5002	Project Reference: Shell Geelong Refinery ESA/GME

Sample Interval	PID (ppm)	Sample ID	Legend	Classification	USC DESCRIPTION OF STRATA Type, plasticity / particle size, colour, secondary / minor components (e.g., "trace"), moisture content, consistency / density, and additional observations	Moisture	Depth (m)	WELL CONSTRUCTION DETAILS
☒	542	MW46_8.0-8.1					8	
☒	500	MW46_9.0-9.1					9	
☒	NT	MW46_10.0-10.1					10	
☒	NT	MW46_11.0-11.1			End of Hole @ 11m		11	
							12	
							13	
							14	
							15	
							16	
							17	

☒ Split Spoon Sample

☐ Hand Auger Sample

WELL LOGS.GPJ WCC_AUS.GDT 22/01/02

IT Environmental

Drilling Log

Monitoring Well **MW121**

Project	Shell Geelong Refinery, Corio	Owner	Shell Refinery Australia		
Location	Refinery Road, Corio, Victoria			Proj. No.	J307221E
Surface Elev.	NA	Total Hole Depth	7.0 m.	North	East
Top of Casing	NA	Water Level Initial	▽ 4.8 m.	Static	▼ 4.8 m. Diameter 150 mm.
Screen: Dia	50 mm.	Length	5 m.	Type/Size	Class 18 uPVC Slotted/0.5 mm.
Casing: Dia	50 mm.	Length	2 m.	Type	Class 18 uPVC
Fill Material	8/16 Sand			Rig/Core	Geoprobe
Drill Co.	South West Drilling	Method	Hand Auger/Geoprobe/Augers		
Driller	G. Bourke	Log By	K. Fairway	Date	13/11/03 Permit # 504
Checked By	K. Fairway	License No.	9018990		

COMMENTS
Original Log by: IT Environmental P/L
Project No.: J307221A
Project Name/Address/Client are the same as J307221E.

Depth (m)	Well Completion	PID (ppm)	Sample ID / % Recovery	Blow Count Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure)
0		18.4	MW121/0.2			SM	GRASS. Silty SAND: grey-brown, loose, dry.
		20.7	MW121/0.5			CL	Silty CLAY: dark brown, moisture content greater than plastic limit, tightly compacted, minor Sand grains.
1		24.7	MW121/1.0			SC	Clayey SAND: light brown-grey, medium to coarse grained, moisture content less than plastic limit, minor Limestone gravels.
						CL	Silty Sandy CLAY: brown, moisture content equal to plastic limit, minor Limestone gravel.
2		0.0	MW121/2.0				LIMESTONE: white-grey, highly weathered.
						CL	Silty Sandy CLAY: brown, moisture content equal to plastic limit, minor Limestone gravel.
3		0.0	MW121/3.0			SW	SAND: white-light brown, medium to coarse grained, grading to coarser grained with minor Limestone gravel, slightly moist.
							LIMESTONE: white-grey, highly weathered.
4		9.8	MW121/4.0			SC	Clayey SAND: white, moisture content less than plastic limit, minor Limestone gravel.
						SW	As above: some orange mottling. SAND: grey-orange, medium to coarse grained, minor Limestone gravel, increasing Clay content with depth, moist.
5		2.1	MW121/5.0			SC	Clayey SAND: grey, becoming more orange with depth, minor Limestone gravel, moist to wet.
6		2.7	MW121/6.0				
						SW	SAND: grey, minor orange mottling, minor Clay, some very coarse grained Quartz grains and Limestone gravels.
7		10.8	MW121/7.0			CL	Silty Sandy CLAY: orange-brown, moisture content equal to plastic limit, medium to coarse grained Sand. End of hole at 7.0m - Limit of investigation.
8							

Drilling Log

Monitoring Well **MW138**

Project: Shell Geelong Refinery | Owner: Shell Refining (Australia) Ltd

Location: Refinery Road, Corio, Victoria | Proj. No.: J307221E

Surface Elev.: 5.9 m. | Total Hole Depth: 6.0 m. | North: 5782994.62 m. | East: 270911.89 m.

Top of Casing: 5.780 m. | Water Level Initial: ▽ 4.0 m. | Static: ▼ 3.6 m. | Diameter: 125 mm.

Screen: Dia: 50 mm. | Length: 4.0 m. | Type/Size: Class 18 PVC/0.5 mm.

Casing: Dia: 50 mm. | Length: 2.0 m. | Type: Class 18 PVC

Fill Material: Sand, Bentonite, Grout | Rig/Core: 3300

Drill Co.: Numac Drilling | Method: Hand Auger/Hollow Auger

Driller: C. Hannaker | Log By: N. Krasic | Date: 2/12/04 | Permit #: 567

Checked By: N. Krasic | License No.: 9018990

COMMENTS

Depth (m.)	Well Completion	PID (ppm)	Sample ID / % Recovery / Blow Count Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure). Geologic descriptions are based on ASTM Standard D 2487-93 and the USCS.
0		5.9	MW138/0.15		FILL	SURFACE: Gravel.
						FILL: Silty Gravel: brown-blue, large Gravel pieces.
		1.9	MW138/0.5 QC17 QC18		CL	Silty CLAY: dark brown, slightly moist.
1		1.6	MW138/1.0			As above: becoming brown, grey-orange mottling.
						As above: grey-white, some Limestone pieces.
						LIMESTONE: grey-white, weathered.
2		5.1	MW138/2.0			
					CLS	Sandy CLAY: grey, slightly moist.
						LIMESTONE: grey-white, weathered.
3		5.3	MW138/3.0		CLS	Sandy CLAY: brown, orange-grey mottling, slightly moist.
	▼					
					CLS	As above: becoming grey, white-orange mottling.
						LIMESTONE: very small band.
4	▽	323	MW138/4.0			Sandy CLAY: grey-orange, minor bands of dark grey-black, strong hydrocarbon odour.
						LIMESTONE: small white band, Sandy Clay matrix.
		50.9	MW138/4.5 QC19 QC20		CLS	Sandy CLAY: grey, orange mottling, wet, strong hydrocarbon odour.
5		13.1	MW138/5.0			As above: brown, orange-grey mottling, grey-white Limestone band within Silty Clay, wet, no hydrocarbon odour.
						As above: brown-orange.
					CLS	LIMESTONE: grey-white.
						Sandy CLAY: brown-orange.
6		5.9	MW138/6.0		CLS	As above: grey mottling.
						LIMESTONE: white-grey.
						Sandy CLAY: brown-orange.
						End of hole at 6.0m - Limit of investigation.
7						
8						

IT_COMMERCIAL_UK Rev: 21/8/07 J307221E.GPJ IT_CORP.GDT 1/11/07

IT Environmental

Drilling Log

Monitoring Well **MW145**

Project	Shell Geelong Refinery, Corio	Owner	Shell Refinery Australia		
Location	Refinery Road, Corio, Victoria			Proj. No.	J307221E
Surface Elev.	6.5 m.	Total Hole Depth	6.0 m.	North	5783098.26 m.
Top of Casing	6.37 m.	Water Level Initial	▽ 3.4 m.	Static	▼ 4.3 m.
Screen: Dia	50 mm.	Length	4.0 m.	Type/Size	Class 18 PVC/0.5 mm.
Casing: Dia	50 mm.	Length	2.0 m.	Type	Class 18 PVC
Fill Material	Sand, Bentonite, Grout			Rig/Core	6620DT
Drill Co.	Numac Drilling	Method	Hand Auger/Push Tube/Solid Auger		
Driller	J. Boyd	Log By	N. Krasic/N. Green	Date	15/12/04
Checked By	N. Krasic	License No.	9018990		

East 271016.48 m. | Diameter 125 mm. | Permit # 716

COMMENTS

Depth (m)	Well Completion	PID (ppm)	Sample ID / % Recovery	Blow Count Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure)
0		0.0	MW145/0.15			FILL	BARK/GRASS.
		0.0	MW145/0.5				FILL: Silty Clay: dark brown, some bark, slightly moist. As above: moisture content less than plastic limit.
1		0.6	MW145/1.0			CLS	Sandy CLAY: brown, moderate plasticity, very fine grained, moisture content greater than or equal to plastic limit. As above: carbonate rich layer.
2		0.1	MW145/2.0			SC	Silty Clayey SAND: white-grey, sub-angular clear Quartz (mineral).
3		0.0	MW145/3.2			CL	CLAY: brown-grey, moderate plasticity, carbonaceous. As above: becoming moist.
4		0.8	MW145/4.4			SC	Clayey SAND: grey, orange mottling, fine to medium grained, clear sub-rounded Quartz. As above: becoming brown-orange, grey mottling, minor to heavy mineral grains. As above: becoming more iron-based, less minerals.
5							As above: moist.
6							As above: becoming grey. End of hole at 6.0m - Limit of investigation.
7							
8							

Geologic descriptions are based on ASTM Standard D 2487-93 and the USCS.

IT Environmental

Drilling Log

Monitoring Well **MW238**

Project	Shell Geelong Refinery, Corio	Owner	Shell Refinery Australia				
Location	Refinery Road, Corio, Victoria			Proj. No.	J307221E		
Surface Elev.	4.7 m.	Total Hole Depth	7.0 m.	North	270580.58 m.	East	5781895.82 m.
Top of Casing	4.49 m.	Water Level Initial	▽ 4.0 m.	Static	▼ 3.7 m.	Diameter	125 mm.
Screen: Dia	50 mm.	Length	5.0 m.	Type/Size	Class 18 PVC/0.5 mm.		
Casing: Dia	50 mm.	Length	2.0 m.	Type	Class 18 PVC		
Fill Material	Sand, Bentonite, Grout			Rig/Core	6610DT		
Drill Co.	South Western Drilling	Method	Hand Auger/ Push Tube/ Solid Auger				
Driller	B. Steenvoorden	Log By	K.McCort/N.Krasic	Date	04/04/05	Permit #	714
Checked By	D. Lam	License No.	9022041				

COMMENTS

Hand Augering done on 4/4/05.

Probing, drilling and installed done on 13/4/05.

Depth (m)	Well Completion	PID (ppm)	Sample ID / % Recovery	Blow Count Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure)
							Geologic descriptions are based on ASTM Standard D 2487-93 and the USCS.
0		0.0	MW238/0.2				FILL: Sandy CLAY: orange-brown, low plasticity, no hydrocarbon odour, some gravel present.
		0.0	MW238/0.5				FILL: Silty CLAY: light brown, low to moderate plasticity,dry. no hydrocarbon odour, some gravel present.
1		0.0	MW238/0.95				FILL: .Sandy CLAY: light brown-cream, low plasticity, dry. no hydrocarbon odour, some gravel present.
							FILL: Limestone band
							Band of cemented calcareous sands, dry, no hydrocarbon odour.
							Sandy CLAY: cream-orange, low to medium plasticity, dry, no hydrocarbon odour.
2		3.1	MW238/2.0				Band of cemented calcareous SANDS, dry, no hydrocarbon odour
							CLAY: light green with minor orange brown-red brown mottling, medium to high plasticity, methane odour detected. dry to moist.
							Band of cemented calcareous SANDS, dry.
3							CLAY: light green with minor orange brown-red brown mottling, medium to high plasticity, methane odour detected. dry to moist.
							Band of cemented calcareous SANDS
							CLAY: light green with minor orange brown-red brown mottling, medium to high plasticity, methane odour detected. moist to wet..
	▼						Lost Sample.
4	▽	71.3	MW238/4.0				SILT: light grey with orange-brown mottling, staining noted, low plasticity, strong hydrocarbon odour.
							Silty SANDS: light grey with darker grey staining and extensive orange-brown mottling, wet-saturated, strong hydrocarbon odour.
		38.9	MW238/4.7				
5							Silty CLAY: light grey with orange-brown mottling, medium plasticity, moist-wet, hydrocarbon odour and staining noted.
		11.2	MW238/5.2				
		0.4	MW238/5.5				CLAY: light grey, medium plasticity, saturated, no hydrocarbon odoour, minor carbonate fragments present.
6		0.4	MW238/6.0				Clayey SILT: light grey with minor orange-brown mottling, low plasticity, no hydrocarbon odour, minor bands of cemented sands.
							As above.with dominant orange brown mottling.
7		124	MW238/7.0				End Of Hole at 7.0m-Limit Of Investigation
8							

IT Environmental

Drilling Log

Monitoring Well **MW239**

Project	Shell Geelong Refinery, Corio	Owner	Shell Refinery Australia
Location	Refinery Road, Corio, Victoria	Proj. No.	J307221E
Surface Elev.	4.1 m.	Total Hole Depth	7.2 m.
North	5781918.94 m.	East	270614.75 m.
Top of Casing	3.87 m.	Water Level Initial	▽ 3.5 m.
Static	▼ 3.1 m.	Diameter	125 mm.
Screen: Dia	50 mm.	Length	5.5 m.
Type/Size	Class 18 PVC/0.5 mm.		
Casing: Dia	50 mm.	Length	1.5 m.
Type	Class 18 PVC		
Fill Material	Sand, Bentonite, Grout	Rig/Core	6610DT
Drill Co.	South Western Drilling	Method	Hand Auger/Push Tube/Hollow Auger
Driller	B. Steenvoorden	Log By	K. McCort/N. Krasic
Date	11/04/05	Permit #	714
Checked By	D. Lam	License No.	9022041

COMMENTS
Probed to 7.2m.
Well Installed to 7.0m.

Depth (m)	Well Completion	PID (ppm)	Sample ID / % Recovery	Blow Count / Recovery	Graphic Log	USCS Class.	Description (Color, Texture, Structure)
0		0.0	MW239/0.2				FILL: Silty CLAY: light brown, medium plasticity, dry, organic odour, some roots present
		0.0	MW239/0.5				FILL: CLAY: brown, high plasticity, dry, no hydrocarbon odour.
							FILL: becoming light brown with orange brown mottling, high plasticity.
1		0.0	MW239/1.0				Bands of calcareous cemented and indurated sands, cream, dry, no hydrocarbon odour
		0.0	MW239/1.7				CLAY: light grey with orange-brown mottling, high plasticity, dry, no hydrocarbon odour.
2							Coarse to medium calcareous sand, cream-orange, dry, no hydrocarbon odour.
							CLAY: light grey with orange-brown mottling, high plasticity, dry, no hydrocarbon odour.
							Coarse to medium calcareous sand, cream-orange, dry, no hydrocarbon odour.
3	▼	116	MW239/3.0				CLAY: light grey with orange-brown mottling, high plasticity, dry, no hydrocarbon odour.
	▽						Sandy SILT: light grey with orange-brown mottling, no hydrocarbon odour, dry-moist.
							Bands of calcareous cemented and indurated sands, cream, dry, no hydrocarbon odour
4		486	MW239/4.0 QC256 QC257				CLAY: grey with minor orange-brown mottling, medium to high plasticity, dry to moist, no hydrocarbon odour.
							As above: Hydrocarbon odour present. grey, coarse to medium grained sand, moist, hydrocarbon odour.
							Silty CLAY: light grey, medium plasticity, moist, hydrocarbon odour.
5		0.0	MW239/5.0				Clayey SILT: light grey with moderate orange brown mottling, low to medium plasticity, hydrocarbon odour present and grey staining.
							Cemented calcareous sands in clay matrix, moist, no hydrocarbon odour.
							Clayey SILT: . light grey with some orange-brown mottling, low to medium plasticity, wet, no hydrocarbon odour.
6		0.0	MW239/6.0				Sandy SILT: light grey, extensive orange-brown mottling, wet, no hydrocarbon odour.
7		0.0	MW239/7.0				End Of Hole 7.2m-Limit Of Investigation.
8							

Client: **Shell Refining (Australia) Pty Ltd**
Project No.: **0126249**
Project Name: **GEELONG WELL INSTALLATION**
Site Name: **Shell Geelong Refinery**
Site Address: **Refinery Road, Corio, VIC**

ID: MW293

ERM

ERM Australia Pty Ltd

Drill Start Date: **10/2/2011**	Total Depth (m): **6.0m**	Final Water Level (m bgl): **3.489 mTOC**
Drill Finish Date: **10/2/2011**	Hole Diam. / Width (mm): **135 mm**	Elevation (Ground): **5.518**
Drill Co: **South Western Drilling**	Casing Type: **SCH.40 PVC**	Elevation (Case): **5.362**
Driller: **Brett Steenvoorden & Mark Wauner**	Casing Diam. (mm): **50mm**	Easting (MGA): **270997.07**
Drill Method: **Push tube & Soild Stem Auger**	Surface Completion: **Flush gatic**	Northing (MGA): **5782970.93**
Hole Type: **Monitoring Well**	Water Strike (m bgl): **3.85 mbgs**	

Lithology	Symbol	Well	Depth (m)	Recovery	Sample Type	Analysed	PPT (kPa)	PID (ppm)	Sample Details	Remarks
Ground Surface			0							
Backfill (NDD) Sand and bentonite										
Clay (CL) Grey, moist, soft, high plasticity, homogenous, no staininig, no odour			1							
Clayey Silt (ML) White stiff, damp, medium plasticity, no staining, no odour, calcareous			2							
Silty Clay (CL) Grey, with orange mottling, damp, plastic, stiff, no staining, odour								0.7 2.8		
Silty Sand (CL) Grey to white, moist, little plasticity, odour			3							
Clayey Sand (SC) Mottled grey, orange, red, yellow, staining at 4.4 m - 4.6m, strong odour			4		PT PT			1236 361.7 43.5	MW293_021011_3.6-3.9 MW293_021011_4.4-4.6	
Sand Gray/ orange, wet, loose, non-plastic, fine grained sand, calache at 5.73 mbgs to 5.8 mbgs, strong odour.			5		PT			12.3 4.4 4.2	MW293_021011_5.1-5.4	
Silty Clay (CL) Wet, with sand inclusion.			6					4.0		
End of Log			7							

NOTE: This bore log is for environmental purposes only and is not intended to provide geotechnical information.

Log By: **NS**
Checked By: **NS**

Client: **Shell Refining (Australia) Pty Ltd**
Project No.: **0126249**
Project Name: **GEELONG WELL INSTALLATION**
Site Name: **Shell Geelong Refinery**
Site Address: **Refinery Road, Corio, VIC**

ID: MW294

ERM Australia Pty Ltd

Drill Start Date: **09/02/2011**	Total Depth (m): **6.0m**	Final Water Level (m bgl): **3.58 mTOC**
Drill Finish Date: **09/02/2011**	Hole Diam. / Width (mm): **135mm**	Elevation (Ground): **5.551**
Drill Co: **South Western Drilling**	Casing Type: **SCH.40 PVC**	Elevation (Case): **5.465**
Driller: **Brett Steenvoorden & Mark Wauner**	Casing Diam. (mm): **50**	Easting (MGA): **270986.80**
Drill Method: **Push tube & Soild Stem Auger**	Surface Completion: **Flush gatic**	Northing (MGA): **5782953.71**
Hole Type: **Monitoring Well**	Water Strike (m bgl): **5.0 mbgs**	

Lithology	Symbol	Well	Depth (m)	Recovery	Sample Type	Analysed	PPT (kPa)	PID (ppm)	Sample Details	Remarks
Ground Surface			0							
Backfill (NDD) Topsoil			1							
			2							
Sandy Clay (CL) White, damp, medium stiff, low plasticity, no odour.			3					0.2		0.29 m thick of caliche at 3.13 mbgs to 3.4 mbgs, gray to brown, odour
								0.1		
					PT	X		924	MW294_3.5_020911	Increased sand, fine to medium grained
Silty Sand (SM) Brown, dense, fine grained sand, poorly graded, moderate odour, increased moisture with depth.			4							
Sandy Clay (CL) Gray, damp, very stiff, medium plasticity, dark gray staining at 4.7m, moderate odour.					PT	X		368.7	MW294_4.6_020911	
Clayey Sand (SC) Gray, damp, fine to medium grained, poorly graded, slight odour.			5							
Sandy Clay (CL)										
Clayey Sand (SC) Damp, medium stiff, medium plasticity, no odour.					PT	X		0.1	MW294_6.0_020911	
Sandy Clay (CL) Orange/ gray, very stiff, low plasticity, no odour.			6							
End of Log			7							

NOTE: This bore log is for environmental purposes only and is not intended to provide geotechnical information.

Log By: **MM**
Checked By: **NS**

MONITORING WELL MW348

URS Australia Pty Ltd
Level 6, 1 Southbank Boulevard, Southbank VIC 3006
Phone 8699 7500
Fax 8699 7550

Drilling Contractor: **South Western Drilling**

Project Name: **Plume 2 Drilling September 2015**

Project No.: **43514142**

Client: **Viva Energy Australia**

Location: **Geelong Refinery**

Logged By:	**MR**	Bore Size:	**120 mm**	Relative Level (PVC)	**5.03 mRL**
Checked By:	**KAP**	Total Depth:	**6.00 m**	Coordinates:	**270969.40 mE**
Date Started:	**16-9-15**	Casing Size:	**50 mm**		**5782924.93 mN**
Date Finished:	**16-9-15**			Permit No:	**N/A**

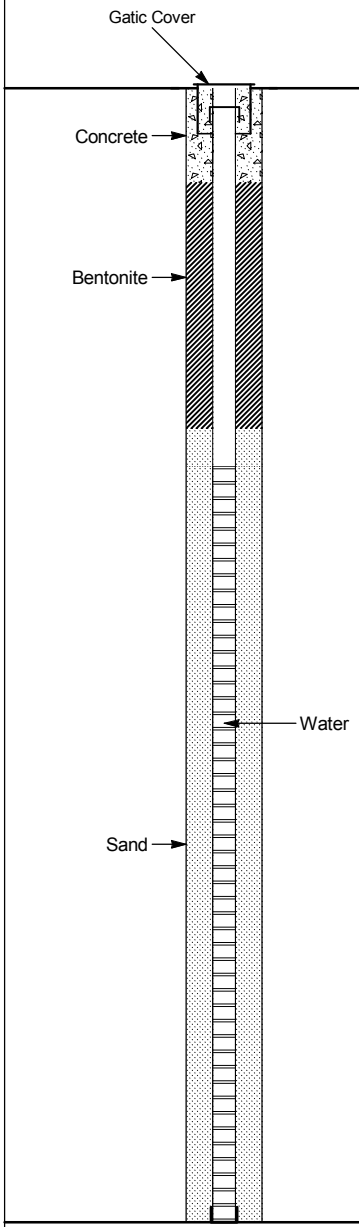
Drill Type: **Sonic Drill**

Drill Model: **SDC450**

Drill Fluid: **N/A**

Drill Method	Sample Interval	PID (ppm)	Sample ID	Legend	Classification	USC DESCRIPTION OF STRATA	Moisture	Depth (m)
					CL	Saturated and mixed materials. Silty CLAY, brown		0
NND					CL	Sandy CLAY; low plasticity, soft, brownish yellow (10YR 6/3), sand well graded, fine to coarse grained with trace calcareous nodules	W	1
	⋈		MW348_1.4-1.5 No odour					
					CALC	Calcareous band; white, hard	D	
	⋈		MW348_1.9-2.0 Sweet hydrocarbon odour		CL	Silty CLAY; moderate plasticity, firm, light brownish grey (10YR 6/2) with brownish yellow mottling (10YR 6/6) (~30%), trace sand	D/M	2
	⋈		MW348_2.4-2.5		SC	Clayey SAND; fine to medium grained, moderately graded with silty clay matrix as above	W	
	⋈		MW348_2.9-3.0 Strong sweet hydrocarbon odour Negative hydrophobic dye test Water at 3.36m			Sand content decreasing, becoming Sandy CLAY		3
					CALC	Calcareous band; hard, gravel and nodules in light grey (10YR 7/2), Sandy CLAY matrix	D	
	⋈		MW348_3.4-3.5 QC01 and QC02 Strong sweet hydrocarbon odour Negative hydrophobic dye test		CL	Silty Sandy CLAY; moderate plasticity, stiff, grey (10YR 6/2) with brownish yellow (10YR 6/3) mottling (~15%) Brownish yellow mottles becoming sandy Black to dark grey hydrocarbon staining evident in sandy material from 3.4-3.8m	M	4
	⋈		MW348_3.9-4.0			Wet	W	
						Becoming brownish yellow with grey mottling		
	⋈		MW348_4.9-5.0					5
						Becoming stiff with reduced moisture and sand content, grey	M	
Sonic					CALC	Calcareous band		
	⋈		MW348_5.9-6.0		CL	Silty CLAY; some sand content, moderate plasticity, stiff, grey (10YR 6/2) with brownish yellow (10YR 6/3) mottling (~15%) End of hole at 6.0m	M	6

WELL CONSTRUCTION DETAILS



MONITORING WELL MW349

URS Australia Pty Ltd
Level 6, 1 Southbank Boulevard, Southbank VIC 3006
Phone 8699 7500
Fax 8699 7550

Drilling Contractor: **South Western Drilling**

Project Name: **Plume 2 Drilling September 2015**

Project No.: **43514142**

Client: **Viva Energy Australia**

Location: **Geelong Refinery**

Logged By:	**MR**	Bore Size:	**120 mm**	Relative Level (PVC)	**5.02 mRL**
Checked By:	**KAP**	Total Depth:	**6.00 m**	Coordinates:	**270999.47 mE**
Date Started:	**15-9-15**	Casing Size:	**50 mm**		**5782935.79 mN**
Date Finished:	**16-9-15**			Permit No:	**N/A**

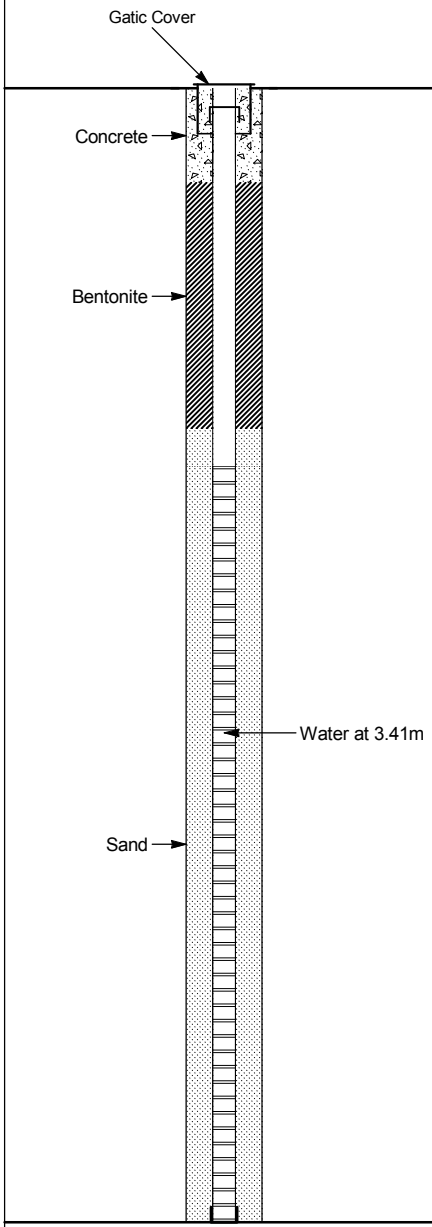
Drill Type: **Sonic Drill**

Drill Model: **SDC450**

Drill Fluid: **N/A**

Drill Method	Sample Interval PID (ppm)	Sample ID	Legend	Classification	USC DESCRIPTION OF STRATA	Moisture	Depth (m)
NDD	29.9	MW349_0.4-0.5 Sweet hydrocarbon odour		CL	Saturated and mixed material. Silty CLAY; brown		0
				CL	Sandy Silty CLAY; light yellowish brown (10YR 6/4), low plasticity, firm, sand well graded, fine to coarse grained with some calcareous nodules and gravel Becomes light grey (10YR 2/1)	D/M	1
	109	MW349_1.9-2.0			Sand content reducing, appearence of some grey mottling (10YR 5/1)		2
	812	Strong hydrobarbon odour Hydrophobic dye test negative			Becoming stiff and dry	D	
	1222	MW349_2.9-3.0 Very hard		CL	CORE LOSS Limited returns suggest Silty CLAY; low plasticity, soft, yellowish brown (10YR 6/4) mottling in grey (10YR 5/1) (Presumed hard material clogged bit at 3m and pushed soft material from 3-4m aside)	W	3
		Water gauged at 3.41 Very stong hydrocarbon odour Hydrophobic dye test negative					
	1258	MW349_3.9-4.0		CL	Sandy Silty CLAY; moderate plasticity, grey (10YR 5/1), poorly graded, fine grained sand and some calcareous nodules	M/W	4
	1388	Slight hydrocarbon odour		SC	Clayey SAND; poorly graded, fine grained with silty clay matrix, firm, yellowish brown (10YR 6/4) with grey (10YR 5/1) mottling	M/W	
	125	MW349_4.9-5.0		CALC	Calcareous layer	D	5
				SC	Clayey SAND; poorly graded, fine grained with silty clay matrix, firm, yellowish brown (10YR 6/4) with grey (10YR 5/1) mottling	M/W	
Sonic	52.2	No odour		CL	CLAY; moderate plasticity, stiff, grey (10YR 5/1)		
	10.0	MW349_5.9-6.0					6
					End of hole at 6.0m		

WELL CONSTRUCTION DETAILS



WELL MW348-MW351.GPJ WCC_AUS.GDT 4/12/15

MONITORING WELL MW350

URS Australia Pty Ltd
Level 6, 1 Southbank Boulevard, Southbank VIC 3006
Phone 8699 7500
Fax 8699 7550

Drilling Contractor: **South Western Drilling**

Project Name: **Plume 2 Drilling September 2015**

Project No.: **43514142**

Client: **Viva Energy Australia**

Location: **Geelong Refinery**

Logged By:	**MR**	Bore Size:	**120 mm**	Relative Level (PVC)	**4.32 mRL**
Checked By:	**KAP**	Total Depth:	**6.00 m**	Coordinates:	**271042.92 mE**
Date Started:	**17-9-15**	Casing Size:	**50 mm**		**5782891.60 mN**
Date Finished:	**17-9-15**			Permit No:	**N/A**

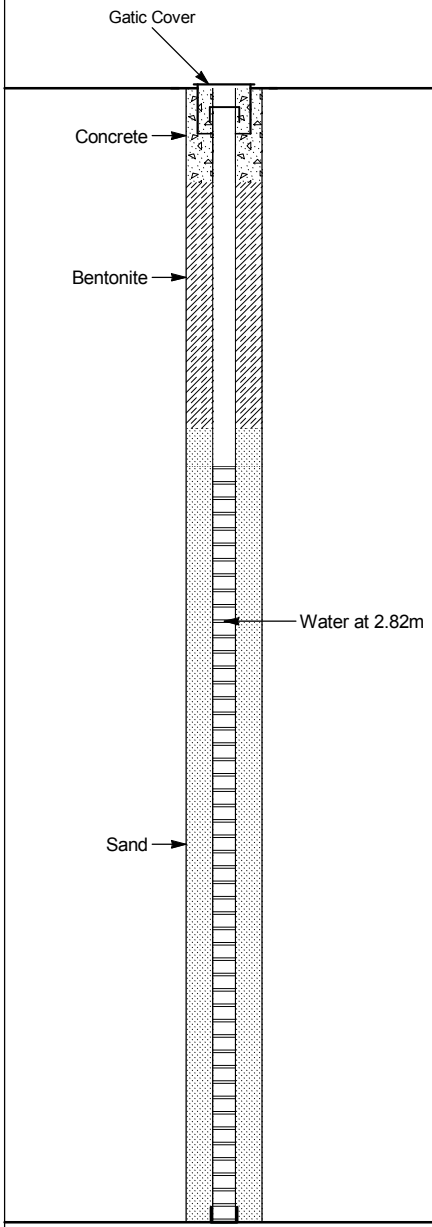
Drill Type: **Push Tube/Soild Stem**

Drill Model: **Geoprobe 7730**

Drill Fluid: **N/A**

Drill Method	Sample Interval	PID (ppm)	Sample ID	Legend	Classification	USC DESCRIPTION OF STRATA	Moisture	Depth (m)
						Topsoil; Silty CLAY, dark greyish brown (10YR 3/2), low plasticity, fine tree roots	M	0
Hand Auger		0.0	MW350_0.4-0.5 No odour		CL	Silty CLAY; moderate plasticity, light brownish grey (10YR 6/2), uniform colour and density from 0.4-1.2m	M	
		0.0	MW350_0.9-1.0 No odour					1
		0.0	No odour					
		0.0	MW350_1.9-2.0 No odour		CALC	Calcareous band; light grey-white (10YR 4/2) nodules and gravel in silty clay matrix. Silty CLAY component increases with depth	D/M	2
		0.0	No odour		CL	Silty CLAY; moderate plasticity, dark greyish brown (10YR 4/2), stiff with some calcareous nodules (~5-10%)	M	
		0.0	MW350_2.9-3.0 No odour			Becoming greenish grey (GLEY 15/1)		3
		0.0	MW350_3.4-3.5 No odour			Becoming grey (10YR 5/1) with no calcareous nodules from 3.6m		
		0.0	MW350_3.9-4.0 No odour			Trace calcareous gravels from 4.0-4.4m (~5%)		4
		0.0	MW350_4.4-4.5 No odour		CL	Silty Sandy CLAY; moderate plasticity, firm, brownish yellow (10YR 6/8) with grey (10YR 6/1) mottling with poorly graded fine grained sand	M	
Push Tube/Solid Stem Auger		0.0	MW350_4.9-5.0 No odour					5
					CALC	Calcareous band	D/M	
					CL	Silty Sandy CLAY; moderate plasticity, firm, brownish yellow (10YR 6/8) with grey (10YR 6/1) mottling with poorly graded fine sand	M	
					CALC	Calcareous band	D/M	
		0.0	MW350_5.9-6.0 No odour		CL	Silty Sandy CLAY; moderate plasticity, soft, brownish yellow (10YR 6/8) with poorly graded fine sand	M	6

WELL CONSTRUCTION DETAILS



Remarks: End of hole at 6.0m

MONITORING WELL MW351

URS Australia Pty Ltd
Level 6, 1 Southbank Boulevard, Southbank VIC 3006
Phone 8699 7500
Fax 8699 7550

Drilling Contractor: **South Western Drilling**	Project Name: **Plume 2 Drilling September 2015**	Client: **Viva Energy Australia**	
	Project No.: **43514142**	Location: **Geelong Refinery**	
Logged By: **MR**	Bore Size: **120 mm**	Relative Level (PVC) **5.02 mRL**	Drill Type: **Push Tube/Soild Stem**
Checked By: **KAP**	Total Depth: **6.00 m**	Coordinates: **271046.32 mE**	Drill Model: **Geoprobe 7730**
Date Started: **17-9-15**	Casing Size: **50 mm**	**5782968.74 mN**	Drill Fluid: **N/A**
Date Finished: **17-9-15**		Permit No: **N/A**	

Drill Method	Sample Interval PID (ppm)	Sample ID	Legend	Classification	USC DESCRIPTION OF STRATA	Moisture	Depth (m)
					Topsoil; Silty CLAY, moderate plasticity, very dark greyish brown (10YR 6/2), tree roots	D/M	0
Hand auger	0.0	MW351_0.4-0.5 No odour		CL	Silty CLAY; moderate plasticity, stiff, light brownish grey (10YR 6/2)	M	
	0.0	MW351_0.9-1.0 No odour					1
				CALC	10mm calcareous band	D	
	0.0	MW351_1.4-1.5 No odour		CALC	10mm calcareous band	D	
				CALC	Calcareous band; light grey-white (10YR 7/1), calcareous nodules and gravel in silty clay matrix, increasing silty clay with depth	D	
	0.0	MW351_1.9-2.0 No odour		CL	Silty CLAY; moderate plasticity, stiff, light grey (10YR 7/1), soft and crumbly from 1.9-2.4m	D/M	2
	0.0	MW351_2.4-2.5 No odour			Becoming stiff		
				CALC	Hard calcareous band	D	
				CL	Silty CLAY; moderate plasticity, stiff, light grey (10YR 7/1), soft and crumbly from 1.9-2.4m	D/M	
	0.0	MW351_2.9-3.0 No odour		CL	Sandy Silty CLAY; moderate plasticity, stiff, pale brown (10YR 7/3)	M	3
					Hard band (dry silty clay); yellow brown (10YR 5/2)	D	
	0.0	MW351_3.4-3.5 No odour			Becoming greyish brown (10YR 5/2)	M	
				CALC	Becoming greenish grey (GLEY 5/1)		
				CL	Calcareous band		
	0.0	MW351_3.9-4.0 No odour			Sandy Silty CLAY; moderate plasticity, firm, greenish grey (GLEY 15/1) with yellowish brown (10YR 6/8) mottling		4
	0.0	MW351_4.4-5.4 No odour			Sand content increasing		
				SM	Silty SAND; poorly graded, fine grained with silty clay matrix, light brownish grey (10YR 6/8) mottling		
	0.0	MW351_4.9-5.0 No odour		CALC	50mm calcareous band		5
				CL	Sandy Silty CLAY; moderate plasticity, firm, greenish grey (GLEY 15/1) with yellowish brown (10YR 6/8) mottling		
Push Tube/Solid Stem Auger	0.0	MW351_5.9-6.0 No odour		CALC	Calcareous band		6
					End of hole at 6.0m		

WELL CONSTRUCTION DETAILS