REPORT

Former Mobil Dunedin Terminal - 199 Fryatt Street, Dunedin

Closure Report

Submitted to:

Mobil Oil New Zealand Limited

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Submitted by:

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Site Closure Outcomes

Mobil Oil New Zealand Limited (Mobil) commissioned this Closure Report with the purpose of establishing that no further action is required for the Former Mobil Dunedin Terminal.

Objectives

The objectives of this Closure Report are to:

- Summarise the understanding of the nature and extent of site-related impacts.
- Assess the stability of both Light Non-Aqueous Phase Liquid (LNAPL) and the associated dissolved phase impacts to groundwater.
- Assess potential risk to both on-site and off-site receptors (human health and the environment).

The outcomes of the assessment are summarised below.

LNAPL Extent and Stability

LNAPL is present in monitoring wells located across the southern half of the site, specifically the southern part of the former tank compound, drum filling site and tanker wagon fill station. The LNAPL consists predominately of diesel with some petrol. Given the heterogeneous nature of the fill, it is likely that the LNAPL does not comprise one single continuous layer. Rather it is present as a series of smaller discontinuous LNAPL pockets with varying LNAPL saturations.

Overall the lateral extent of LNAPL appears be contracting over time. This is supported by the apparent reduction in LNAPL thickness at many locations over the past decade. LNAPL bail down testing at the site indicates low LNAPL transmissivity, low recoverability and low mobility. The LNAPL is not considered to be mobile and does not pose a risk of migration towards or discharge into Otago Harbour.

Dissolved Phase Contaminant Plume Stability

An assessment of the stability of the dissolved phase hydrocarbon impacts can be made using trend analysis, estimates of the plume velocity, attenuation rates and predicted plume lengths. The stability of dissolved phase hydrocarbon impacts is summarised as follows:

- Concentrations of ethylbenzene, C_{10}-C_{14} TPH and naphthalene, which are considered to be the key indicators of the dissolved phase petroleum hydrocarbon contamination, indicate that overall there has been a decreasing trend over the past decade.
- Assessment of the ethylbenzene and naphthalene attenuation rates indicate that the dissolved phase contamination does not extend further than 40 m downgradient of the leading edge of the LNAPL.
- Given the decreasing trend and the relatively short extent for these the dissolved phase contaminants, they are unlikely to migrate beyond their present locations and are not considered to pose a future risk to Otago Harbour.

Natural Source Zone Depletion (NSZD)

Shallow soil vapour sampling at the site has demonstrated the presence of methane and elevated carbon dioxide in conjunction with depletion of oxygen consistent with the NSZD conceptual model of the key vadose zone vapour processes. The trends in LNAPL distribution and thickness over time as well as the presence of these gases indicate that NSZD is occurring at this site and hence ongoing degradation of the LNAPL can be expected overtime.

Future Monitoring

Future ongoing monitoring is not considered to be warranted based on the following:

- The LNAPL mass is not considered to be mobile and poses no further risk of migration.
- The overall trend of a reduction of the lateral extent and thickness of LNAPL.
- The dissolved phase contamination has and is continuing to attenuate. Concentrations adjacent to Otago Harbour are below the ANZECC (2000) trigger values.
- A clear trend of decreasing dissolved phase hydrocarbon concentrations which indicates that contamination is unlikely to pose a future risk to Otago Harbour.
- Soil vapour monitoring indicates no unacceptable risk to off-site commercial-industrial land-use.

An Environmental Management Plan (EMP) should be adopted to manage residual contamination for both potential on-site and off-site receptors and is described further in the following section.

Future Land Use and Management of Risks

The site is located in a commercial/industrial area of Dunedin. Based on the current understanding of soil and groundwater conditions at the site, the potential risks associated with the future commercial/industrial use of the site are anticipated to be:

- Workers undertaking sub-surface excavation works or working within underground voids both on site and off site in the area of Fryatt Street have a potential exposure risk to petroleum hydrocarbon vapours and dermal contact/ ingestion. Appropriate health and safety controls should be in place to manage risk to workers associated with sub surface excavations.
- Ensuring soil and groundwater disturbed during earthworks is appropriately managed to mitigate risks to human health and the environment and is disposed to an appropriately licensed disposal facility.
- Intrusion of soil vapour to indoor air in buildings constructed over areas of residual LNAPL. Risks to indoor air can be managed through appropriate consideration in building design such as ventilation or use of a vapour barrier depending on the building use and location with respect to the groundwater impacts.

Potential risks to current and potential future on-site and off-site receptors should be addressed through an EMP to be developed in consultation with key stakeholders.

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1.0 INTRODUCTION

1.1 Purpose

Mobil Oil New Zealand Limited (Mobil) ceased operation of its former Dunedin Terminal (the site) in 1995 and decommissioned the facility between 1995 and 2007. Mobil has continued to lease the site following decommissioning. Mobil has progressively undertaken environmental site assessment (ESA) works at the terminal, both on site and off site, commencing in 1992.

The ESA works have been undertaken in a step wise and sequential manner to assess the nature and extent of impacts associated with the historical bulk storage of petroleum hydrocarbons. The initial investigations focused on establishing the nature of on-site impacts to soil and groundwater. Recent investigations have focused on assessing the extent of residual Light Non-Aqueous Phase Liquid (LNAPL) and characterising the presence, stability and attenuation of dissolved phase hydrocarbons both on and off site.

The ESA works undertaken to date form the basis for development of a robust conceptual site model (CSM) and provide a detailed understanding of the extent of residual impacts to soil, groundwater and soil vapour and the associated risks to human health and the environment. The time-series of the ESA data also provides for a detailed understanding of the stability and attenuation of residual LNAPL and dissolved phase hydrocarbons. While active remediation has not been undertaken, the CSM developed for the site supports a position that risks to human health associated with residual petroleum hydrocarbon impacts are able to be managed on the basis of continued commercial/industrial use of the site. Further, natural attenuation processes are acting to degrade residual petroleum hydrocarbon impacts such that there is not considered to be unacceptable risks to the environment.

On the basis of the ESA works undertaken to date, Mobil commissioned Golder Associates (NZ) Limited (Golder) to prepare this Closure Report with the purpose of establishing that no further action is required. Further, this Closure Report provides the basis for establishing that risks to human health can be managed through regulatory controls and that on-going monitoring is not necessary.

1.2 Objectives

The objectives of this Closure Report are to:

- Summarise the understanding of the nature and extent of site-related impacts
- Assess the stability of both LNAPL and the associated dissolved phase hydrocarbons.
- Assess potential risk to off-site receptors (human health and the environment).

1.3 Methodology and Scope of Work

To address the objectives, the following scope of work was undertaken:

- Summarise pertinent information derived from the many studies undertaken at the site and surrounding areas to identify the following:
  - The history of industrial activity at the site (Section 2.2) and surrounding properties, including potentially contaminating activities and land uses (Section 2.3).
  - The environmental setting at the site and surrounding properties (Section 2.4).
- Summarise the decommissioning activities (Section 3.1) and sequence of ESA works undertaken between 1995 and 2017 (Section 3.2).

- Compilation and integration of ESA investigation data, including:
  - The inferred sources, nature and extent of contamination, including the various media affected by the contamination, is further discussed in Sections 4.2 (soil) 4.3 (soil vapour), and 4.4 (groundwater).
  - An assessment of LNAPL extent and mobility (Section 4.4.2)
  - An analysis of trends in concentration of contaminants of interest (Section 4.4.3).
  - An assessment of the fate and transport of key contaminants including derivation of degradation half-lives (Section 5.3).
  - An evaluation of the available site data for indicators of hydrocarbon degradation and the potential for Natural Source Zone Depletion (NSZD) to be occurring (Section 6.0).
  - The potential health and environmental risks for off-site receptors which the identified contamination is inferred to pose, is further discussed in Section 7.0.

2.0 SITE DESCRIPTION AND ENVIRONMENTAL SETTING

2.1 Site Description and Layout

The site is located at 199 Fryatt Street within an industrial area approximately 1.5 km from central Dunedin (Figure 1). The site covers an area of 1.12 ha and is bounded by Halsey Street to the south-west, Jutland Street to the north-west, Akaroa Street to the north-east and Fryatt Street to the south-east. The site is located approximately 60 m from the Otago Harbour. A summary of relevant site information is provided in Table 1.

Table 1: Site details.

Site address	199 Fryatt Street, Dunedin
Legal description	Sections 27-34 and 52-59, DP 3536.
Site area	1.12 ha
Co-ordinates (NZTM)	1407362 E, 4916984 N.
Regulatory authorities	Dunedin City Council (DCC) Otago Regional Council (ORC)
Zoning	'Port 2' under Dunedin City District Plan (2006) and 'Industrial Port' under Dunedin City Proposed Second Generation Plan (2018).
Land owner	Chalmers Properties Limited (on behalf of Port of Otago Limited (POL)).
Current status	Vacant.
Proposed future use	Continued commercial/industrial use associated operated by POL.

Currently, the site comprises a predominantly grassed vacant block of land, with concrete building foundations present in the southern corner of the site. Elements associated with former Mobil operations remaining on site include (Figure 2):

- Tank pads of the five former above ground storage tanks (ASTs).
- An earth bund, approximately 1.5 m in height, which formed the perimeter to the main bulk tank compound.
- Four fire hydrants and water lines associated with the former fire suppression system.
- Two separators formerly referred to as Separator 1 and Separator 3. Separator 1, a four-chamber separator, is in the eastern corner of the site and was connected to the stormwater system that collected water from the tank compound. Separator 3, a three-chamber separator, is located midway along the Halsey Street (south-west) boundary. The source of water received by Separator 3 is not known. Separator 2, formerly located in the southern corner of the site, was not observed during site works and is assumed to have been removed.
- A set of decommissioned fuel lines are visible next to Separator 3 on the Halsey Street boundary. These pipelines historically connected the site to a tanker wagon fill station located on the property south across Halsey Street. These lines are reportedly concrete slurry filled (PDP 2007).
- Historically a railway line ran along the south-eastern boundary (parallel to Fryatt Street), with a former rail siding servicing the terminal entering the south-eastern margin of the site. It is unknown when Mobil ceased using the rail siding. The railway lines were still present in a 1977 historical aerial photograph, however, appear to have been removed by 1985. The rail siding was used for distribution of product from the site to smaller regional depots via rail.

LEGEND

Site boundary

NOTES
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3. Schematic only, not to be interpreted as an engineering design or construction drawing.

0 25 50 METRES

REFERENCE SCALE: 1:1,000 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
SITE LOCATION

CONSULTANT: GOLDER

YYYY-MM-DD	2019-11-04
PREPARED	AE
REVIEW	AS
APPROVED	ST

PROJECT NO.	REPORT	REV.	FIGURE
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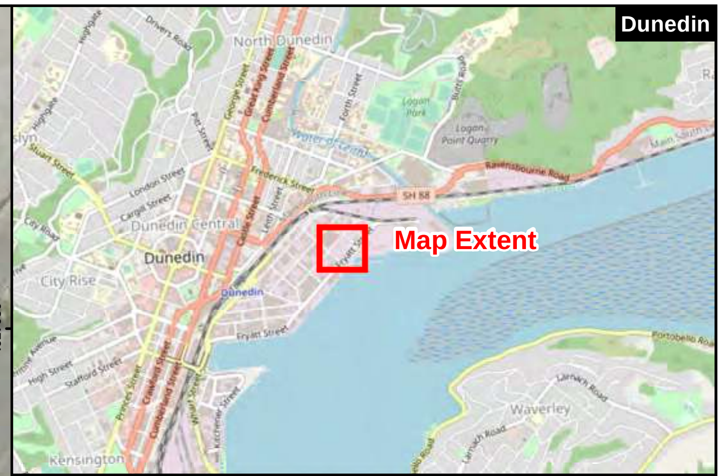

LEGEND

- Site boundary
- Sanitary sewer
- Stormwater
- Interceptor
- Electrical (de-energised)
- Hydrant line (de-energised)
- Unknown
- Stormwater
- Sump (1m diameter)
- Historic fuel lines
- Existing bund
- Concrete pad / surface structure

NOTES

1. Aerial: LINZ and Eagle Technology, CC-BY-3.0-NZ.
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3. Schematic only, not to be interpreted as an engineering design or construction drawing.

0 25 50 METRES

REFERENCE SCALE: 1:700 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
CURRENT SITE LAYOUT

CONSULTANT		
GOLDER	YYYY-MM-DD	2019-11-04
	PREPARED	AE
	REVIEW	AS
	APPROVED	ST

PROJECT NO.	REPORT	REV.	FIGURE
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2.2 Site History

Mobil has previously commissioned preliminary site investigations (PSIs) to document an assessment of historical land use activities undertaken as part of its operations at its former Dunedin Terminal (PDP 2007, PDP 2009). Mobil's terminal operations were split between two adjoining properties:

- The subject site which was principally used as a bulk fuel tank compound and associated operations.
- A neighboring property (located west of Halsey Street at 197 Fryatt Street) used for offices, warehousing, tanker wagon filling, bulk storage of lubricants, drum filling/reconditioning and drum storage.

The site operated from the mid to late 1920s to 1995. It was progressively decommissioned between 1995 and 2007 and based on the condition of the site at the time of these ESA works has remained vacant since decommissioning.

Fuels were delivered in bulk to the site either by ship via two above ground wharf lines (running from the Oil Wharf located 70 m to the south-east of the site) that entered the south corner of the site (with a small length of the wharf lines running underground by the Fryatt Street boundary), or via a rail car loading/unloading facility located along the south site boundary. A diesel bunker line was also located with the wharf lines which supplied diesel to the Oil Wharf. Fuels and lubricants were hard piped from the site to the neighbouring Halsey Street facility via fuel lines that passed under Halsey Street (PDP 2007).

A large bunded tank compound occupied the central and eastern parts of the site and some of the western site area (as shown in Figure 3). This compound contained up to seven large bulk storage tanks (ranging between 436,000 L and 4,695,000 L) storing petrol, diesel, kerosene and slops. This tank compound occupied at least 80 % of the site area. The tank compound also contained several smaller vertical and horizontal tanks (located in the western area of the tank compound) which are believed to have stored kerosene, slops, white spirit, turpentine, dry cleaning fluid (believed to be Stoddard Solvent (a white spirit)) and fuel additive (PDP 2007).

The western part of the site appears to have principally comprised various pump manifolds that serviced both properties/facilities. A small tanker wagon fill station was in the south-east area of the site before being relocated on the Halsey Street site sometime in the 1940s and 1950s. Drum storage occurred in the north-west corner of the site and drum filling is believed to have occurred close to the midway point of the site's western boundary (PDP 2007).

2.3 Adjacent Land Uses

The site is in an industrial area of Dunedin and surrounded by commercial/industrial land uses. A summary of land uses surrounding the site are indicated on Figure 1 and summarised in Table 2.

Table 2: Surrounding land use.

Direction	Land use
North-east (across Akaroa Street)	Bulk fuel storage terminal operated by Z Energy Limited (Z Energy).
South-east (across Fryatt Street)	Fulton Hogan Limited bitumen plant and HarbourCold cold store facility.
South-west (across Halsey Street)	Northern Southland Transport Holding Limited.
North-west (across Jutland Street)	Commercial properties (Tulloch Transport Company, Reillys Towage & Salvage).

LEGEND

Site boundary

Tanks

AST, removed

Above Ground Services

Fire Hydrant

Power Substation

Overhead Power

Fuel Pipeline

Underground Services

Dewatering Line

Product Pipeline (slurry filled)

Vacuum Recovery Pipeline

Vapour Conservation Pipeline

Chevron Pipeline

Historical Offsite Fuel Transfer Pipelines to Tanker Wagon Fill Stand

Power

Sewer

Stormwater

Water

Telephone

Fibre Optic

Gas

Drainage

Manhole

Water Draw Off Sump

Sump

Boundaries

Corrugated Steel Fence

Wire Mesh Fence

Boundary of Lease Area

Earth Bund Wall, existing

Earth Bund Wall, historical

NOTES

1. Aerial: LINZ and Eagle Technology, CC-BY-3.0-NZ.
2. Map image: © OpenStreetMap (and) contributors, CC-BY-SA
3. Schematic only, not to be interpreted as an engineering design or construction drawing.
4. Base plan and legend from Figure 2B in PDP (2013).

0 25 50
METRES

REFERENCE SCALE: 1:700 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
SITE LAYOUT PRE-DECOMMISSIONING

CONSULTANT

GOLDER

YYYY-MM-DD	2019-11-04
PREPARED	AE
REVIEW	AS
APPROVED	ST

PROJECT NO.	REPORT	REV.	FIGURE
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2.4 Environmental Setting

2.4.1 Topography

The site and surrounding areas has been reclaimed (refer Section 2.4.4) and is located on flat land with an elevation of the site and immediate surrounds ranges at approximately 103.5 MRL.

2.4.2 Hydrology

The nearest surface water body is Otago Harbour which is located approximately 60 m to the south-east of the site across Fryatt Street. The site is located adjacent to the upper harbour basin which comprises a highly modified environment as a result of reclamation, road works and dredging activities (URS-Opus 2011). The upper Otago Harbour basin receives stormwater discharges from the greater Dunedin urban area which includes a range of mixed recreational and commercial land use activities. URS-Opus (2011) notes that tidal range in Otago Harbour is approximately 2.2 m with estimates of harbour flushing times ranging from four to 15 days.

2.4.3 Underground services

2.4.3.1 On Site

With exception to the underground services mentioned in Section 2.1 and indicated on Figure 2, there are no other known underground services present on the site.

2.4.3.2 Off Site

A network of underground services is present in the streets adjacent to the site (Figure 2) and include:

- Shallow telecommunication and water services likely to be installed above the shallow groundwater table.
- Two stormwater lines beneath Halsey Street along the south-west of the site. DCC's Geographic Information System[1] (GIS) shows the stormwater lines to be 1,950 mm and 1,300 mm in diameter with invert levels of 99.893 m RL (2.36 m below ground level (m bgl)) at Jutland Street and 99.829 m RL (2.94 m bgl) at Fryatt Street. The stormwater lines form part of the stormwater system that receives stormwater from the wider Dunedin City and discharge to Otago Harbour beneath the HarbourCold facility.
- A stormwater line beneath Akaroa Street and Fryatt Street to the north-east of the site. DCC's GIS shows the stormwater pipe is 225 mm in diameter with an invert level of 101.954 m RL (1.0 m bgl) adjacent to the Z Energy bulk fuel terminal in Akaroa Street. The pipe increases to 300 mm in diameter with an invert level of 101.204 m RL (1.67 m bgl) beneath Fryatt Street. Available plans (URS New Zealand Limited (URS) 2012) indicate that this line receives stormwater from the bulk fuel storage terminal located to the north-east of the site and discharges to Otago Harbour between the Fulton Hogan bitumen plant and the HarbourCold facility.
- A sewer line beneath Akaroa Street and Jutland Street. The pipe is 225 mm in diameter with invert levels of 101.091 m RL (1.70 m bgl) at the intersection of Akaroa Street and Fryatt Street, 100.588 m RL (2.63 m bgl) at the intersection of Akaroa Street and Jutland Street and 99.924 m RL (2.95 m bgl) at the intersection of Halsey Street and Jutland Street. The sewer pipe pumps sewage along Halsey Street away from Otago Harbour and connects to a main trunk sewer approximately 400 m north-west of the site.

[1] https://www.dunedin.govt.nz/do-it-online/maps-and-photos/water-services-map-and-wws-work-in-progress

- Two sewer lines are present beneath Halsey Street to the south of the site. The first, a 300 mm diameter pipe runs from Fryatt Street with an invert level of 100.341 m RL (2.49 m bgl) and connects to the 225 mm diameter pipe from Jutland Street. The second is a 300 mm pipe with invert levels of 100.658 m RL (1.93 m bgl) at the intersection of Fryatt Street and Halsey Street and 100.286 m RL (2.59 m bgl) at the intersection of Halsey Street and Jutland Street.

2.4.4 Geology

The site has been shown to be underlain by the following geological sequence:

- **Fill** comprising:
  - Gravel (sandy fine gravel) across the whole site predominately from surface to 0.7 m bgl, however the fill extends to depths up to 2 to 3 m bgl beneath and between former Tank 1 and Tank 8, and the southern corner of the site.
  - Sand (fine to medium coarse, often with shells and varying amounts of silt) with discontinuous layers of silt or gravels at varying thicknesses underlies the gravel fill unit. This sand unit extends to between 4.5 and 5 m bgl.
- Marine sediments – Clayey silt and silty clay between 4.5 m and about 8.0 m bgl. Competent material (possibly bedrock) was encountered below about 8 m bgl.

2.4.5 Hydrogeology

Key hydrogeological findings from the supplementary ESA works undertaken at the site (Golder, 2019) are summarised in Table 3.

Table 3: Summary of site hydrogeology.

Aspect	Description
Depth to groundwater	A shallow unconfined aquifer system is present within the fill material, with groundwater present at depths between approximately 0.45 m and 3.0 m bgl based on data collected between November 2015 and April 2017 (Golder 2019). Average depth to groundwater has ranged between 1.61 m btoc (June 2016) and 1.75 m btoc (November 2015) over this period. Groundwater levels are typically lower (up to 0.5 m) in monitoring wells located closer to Otago Harbour than those located in the centre or north-west of the site
Groundwater elevations	Measured groundwater elevations have ranged between: ■ 100.115 m RL (BHA) and 101.875 m RL (BH26) in November 2015 ■ 100.475 m RL (BH29) and 102.654 m RL (BH23) (June 2016). ■ 100.801 m RL (BH46) and 102.852 m RL (BH56) in April 2017.
Inferred flow direction	Groundwater flow in the unconfined aquifer is typically in a south-easterly direction toward Otago Harbour (Golder 2019).
Tidal response	The shallow groundwater system in the area of Fryatt Street and in close proximity to the harbour shows evidence of tidal influence (up to 0.23 m), while little or no tidal influence was noted within the confines of the site (maximum ~ 0.002 m).

Aspect	Description
Salinity	Electrical conductivity has ranged from 400 µS/cm to 2,009 µS/cm (Golder 2019).
Redox Conditions	Groundwater reported slightly to moderately negative redox conditions and low dissolved oxygen (Golder 2019).
Hydraulic conductivity (K)	Previous hydraulic testing of the shallow strata indicated hydraulic conductivity values in the range 0.4 m/d to 2.2 m/d (PDP 2012).
Effective porosity (θ_e)	Estimated to range from 5 % to 10 % based on values reported from over 100 tracer tests in unconsolidated sand and gravel aquifers (Suthersan et al 2016)
Hydraulic gradient (i)	The groundwater gradient across the site is in the order of 0.004 to 0.006 metres per metre (m/m).
Estimated groundwater flow velocity	~ 90 m/year (assuming upper value of K ~ 2 m/d, i = 006, θ_e ~5 %)

2.4.6 Groundwater sensitivity

The Ministry for the Environment (MfE 2011a) provides criteria for assessing groundwater sensitivity at petroleum hydrocarbon impacted sites (Table 4). An aquifer is defined as sensitive when either all the first three criteria are met, or the fourth criterion is met.

Table 4: Groundwater sensitivity assessment.

Criteria	Assessment
The aquifer is not artesian or confined; and	**Yes** The site stratigraphy comprises sand and silt deposits that form an unconfined aquifer.
The aquifer is expected to be less than 10 m below the potential suspected source of contamination; and	**Yes** Groundwater has been measured in the unconfined aquifer at depths between 1.3 and 3.0 m bgl in groundwater monitoring wells on the site.
The aquifer is of quality, appropriate for use, can yield water at a useful rate and is in an area where extraction and use of groundwater may be reasonably foreseen; or	**No** The site is located in an area of Dunedin consisting of reclaimed land with a long history (>100 years) of commercial/industrial use. This history combined with the close proximity to the harbour means it is extremely unlikely that shallow groundwater will be extracted for beneficial use.
The source of contamination is less than 100 m from a sensitive surface water body	**Yes** The Otago Harbour is located approximately 60 m from the site.

Although the site is located within 60 m of Otago Harbour, the shallow aquifer would be classified as **not sensitive** with respect to abstractive use and with respect to environmental discharges for the following reasons:

- No registered groundwater abstractions for potable, irrigation or stockwater use purposes are located within 1.5 km of the site with registered wells mainly used monitoring or geological investigation purposes (PDP 2013).

- Unregistered potable abstractions are considered unlikely given the proximity of Otago Harbour (low groundwater quality) and the presence of a reticulated supply in the vicinity of the site.
- Otago Harbour is a large water body and would facilitate significant dilution. MfE (2011a) guidance notes that where "*the receiving water body facilitates significant dilution of groundwater discharged into it (large river systems, coastal water), sites within 100 metres of a surface water are unlikely to affect the surface water quality significantly, unless free phase hydrocarbons* [LNAPL] *is present and migrating off-site. Frequently, dilution rates in the order of 1000:1 following discharge of groundwater to surface water, resulting in contaminant concentrations less than criteria for the protection of aquatic ecosystems in the surface water after dilution, even when high dissolved phase concentrations are present. Under these conditions, some minor impact on the aquatic ecosystem within the dilution or mixing zone may occur*."
- Previous ESA works have not documented the presence of LNAPL in monitoring wells installed immediately adjacent to Otago Harbour (Golder 2019, PDP 2011, 2013).

3.0 PREVIOUS WORKS

3.1 Summary of Decommissioning Works

Terminal operations ceased in 1995 with decommissioning works undertaken between 1995 and 2007.

PDP (2007) documents that by 2007, the site comprised a decommissioned tank farm with a former terminal office, workshop, storage shed, pump area and a pipe manifold presented toward the southern end of the site. The tank farm was defined by a grass covered clay bund (1.5 m high) with ground surfaces across the tank farm comprising a combination of dirt and grass. Surface cover across the southern area of the site (outside of the tank farm bund) consisted mainly of concrete.

A number of the bulk tanks were present on site during a site inspection in August 2007. These were subsequently removed from site in November 2007 (Table 5). The bulk tanks had been decommissioned in 1995 with fuel lines connected to the tanks and tank manhole coverings also removed at this time.

Table 5: Summary of bulk storage tanks and decommissioning dates.

Tank	Product	Capacity	Date removed
Tank 1	91 octane petrol 96 octane petrol Diesel	1,144,000	Empty in 1995 and removed in November 2007
Tank 2	Diesel	1,135,000	Between 1988 and 2000
Tank 3	Slops	Unknown	Between 1978 and 1988
Tank 4	Turpentine and kerosene	Unknown	Between 1978 and 1988
Tank 5	96 octane petrol	4,695,000	Empty in 1995 and removed in November 2007
Tank 7	91 octane petrol	1,135,000	Between 1988 and 2000
Tank 8	91 octane petrol 96 octane petrol Diesel	2,115,600	Empty in 1995 and removed in November 2007
Tank 10	Slops	Unknown	Empty in 1995 and removed in November 2007
Tank 11	Unknown	Unknown	
Tank 12	White spirits	Unknown	
Tank	Additive	10,000	November 2007
Tank	Kerosene	45,400	Between 1978 and 1988

Notes: Data from Table 2 in PDP (2007).

3.2 Summary of Investigation Works

Mobil has progressively undertaken a significant amount of ESA works at the site commencing in 1992 to assess soil and groundwater quality associated with its occupation of the property. A number of investigations have been undertaken at the site. The timeline for the ESA works and scope of each investigation are summarised in Table 6.

Based on a review of the historical ESA works, the following key potential sources of contamination have been identified:

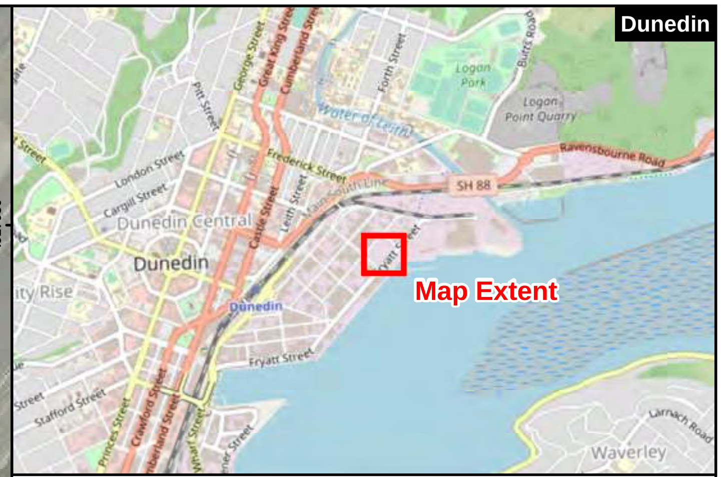
- Bulk storage ASTs – 13 ASTs principally storing leaded and unleaded petrol, diesel, slops, turpentine, kerosene and white spirits (Stoddard Solvent). According to PDP (2007), lubricants were not stored on site.
- Rail car loading/unloading rack along the south-east site boundary.
- Drum storage in the north-west corner of the site and drum filling midway along the west area of the site.
- Small tanker wagon fill station in the west area of the site.

The investigation locations for these historical ESA works are shown on Figure 4.

Table 6: Timeline and summary of historical investigations.

Report date	Scope of ESA works
September 1992 and July 1994 (PDP 1992, 1994a, 1994b)	Installation of 18 groundwater monitoring wells (BH1 to BH18), the drilling of 22 shallow (to ~1.5 m bgl) soil bores and the collection of soil and groundwater samples. Soil samples were analysed for total petroleum hydrocarbons (TPH) and lead (organic and inorganic). Groundwater samples were analysed for TPH and inorganic lead.
March to June 1995 (PDP 1995)	LNAPL recovery pumping trial. Three water/LNAPL recovery wells (R1-R3) were installed to recover water and LNAPL. Between 13 m^3 and 21 m^3 per day (approximately 813 m^3 in total) of water was pumped from the recovery wells to Tank 10 with overflow discharging to Tank 1. The trial recovered approximately 80 L of LNAPL.
December 2007 (PDP 2007)	Phase 1 ESA comprising a desktop information review and site visit to understand the site's operational history.
September 2011 (PDP 2011)	Drilling of 96 soil bores (88 on site and eight off site) based on a 12 m x 12 m grid spacing. Installation of 22 on-site groundwater monitoring wells (BH19 to BH40) and 10 off-site groundwater monitoring wells (BH41 to BH50) with associated soil and groundwater sampling. Groundwater sampling of 24 on-site and four off-site (BH44, BH45, BH48 and BH50) groundwater monitoring wells. Samples were not collected from on-site wells BH20, BH1, BHA and BHB and off-site wells BH43, BH46, BH47 and BH49 due to the presence of measurable LNAPL. Collection of LNAPL sample from BH43 for identification purposes. LNAPL bail-down test on monitoring well BH43 to assess LNAPL recoverability.
July 2012 (PDP 2012)	Groundwater monitoring of 28 on-site (BH1, BH19-BH42, BHA, BHB and BHC) and eight off-site (BH43-BH50) monitoring wells. Analysis of samples for dissolved lead (field filtered), total petroleum hydrocarbons (TPH), individual BTEX (benzene, toluene, ethylbenzene and total xylenes) compounds and polycyclic aromatic hydrocarbons (PAHs). Samples from six monitoring wells (BH21, BH23, BH28, BH37, BH40 and BH50) analysed for geochemical parameters including nitrate-nitrogen, sulphate, dissolved iron and dissolved manganese). LNAPL bail-down tests performed at BH29, BH31 and BH35. Hydraulic testing (slug tests) performed at BH19, BH30 and BH37.
October 2013 (PDP 2013)	Installation of three additional off-site groundwater monitoring wells (BH51, BH52 and BH53) and a nested soil vapour bore (SV1_S and SV1_D) adjacent to an off-site property (HarbourCold).

Report date	Scope of ESA works
	Sampling of 11 off-site (BH43, BH44, BH45, BH46, BH47, BH48, BH49, BH50, BH51, BH52 and BH53) groundwater monitoring wells. Samples were not collected from BH46, and BH47 due to the presence of measurable LNAPL. Sampling of shallow off-site soil vapour bore (SV1_S). LNAPL removed from the monitoring wells with measurable LNAPL thicknesses (BH1, BH24, BH25, BH29, BH31, BH33, BH35, BH46, BH47, BHA and BHB). An approximate total of 18L of LNAPL was removed from the monitoring wells.
December 2013 and August 2014 (Golder 2014)	Gauging of 39 monitoring wells BH1, BH19 to BH53 and BHA, BHB and BHC in December 2013 and June 2014. Sampling of wells BH42, BH43, BH44, BH45, BH48, BH50, BH51, BH52 and BH53 in December 2013 with analysis for TPH, BTEX and PAHs. Sampling of wells BH48, BH49, BH50, BH51, BH52 and BH53 in June 2014 with analysis for TPH, BTEX, PAHs and dissolved lead. Sampling of shallow off-site soil vapour bore (SV1_S) in December 2013 and June 2014.
November 2014 (Golder 2019)	Installation of seven off-site monitoring wells along Fryatt Street (BH54 to BH58 and BH60) and Halsey Street (BH59). Installation of pressure transducers in two transects of monitoring wells. One transect comprised monitoring wells BH45, BH21, BH22 and BH23 and the second comprised monitoring wells BH53, BH40, BH38 and BH37.
May 2015 (Golder 2015)	Gauging of 23 on-site (BH1, BH19 to BH40, BHA-BHC) and 20 off-site (BH41 to BH60) monitoring wells. Sampling of 18 off-site (BH41 to BH60) monitoring wells for TPH, BTEX and PAHs.
November 2015 (Golder 2019)	Gauging of 23 on-site (BH1, BH19 to BH40, BHA-BHC) and 20 off-site (BH41 to BH60) monitoring wells Sampling of 18 off-site (BH41 to BH49, BH51 to BH56, BH58, BH59) monitoring wells for TPH, BTEX and PAHs.
December 2015 (Golder 2019)	Direct push investigation using laser induced fluorescence (LIF) technology was undertaken to assist with evaluating the lateral and vertical extent of the LNAPL. Cone penetrometer testing (CPT) at four locations.
March 2016 (Golder 2019)	Excavation of 13 test pits across the site to validate the findings of the LIF investigation. Sampling of off-site shallow soil vapour bore (SV1_S).
June-July 2016 (Golder 2019)	Gauging of 25 on-site (BH19 to BH40, BHA to BHC) and 20 off-site (BH41 to BH60) monitoring wells. Sampling of 14 off-site (BH41 to BH45, BH48, BH51 to BH55, BH58 to BH60) monitoring wells. Samples not collected at BH46, BH47 and BH57 due to measurable LNAPL. Monitoring well BH50 recorded as dry. Installation and sampling of three on-site soil vapour bores (SV2, SV3, and SV4). The soil vapour bores were installed at 1.0 m bgl toward the southern corner of the site adjacent to Fryatt Street with soil vapour well SV4 installed centrally in the western half of the site between former AST4 and AST5. LNAPL bail-down testing on monitoring well BH25.
April 2017 (Golder 2018)	Gauging of 24 on-site (BH1, BH19 to BH40, BHA to BHC) and 19 off-site (BH41 to BH60) on-site and 15 off-site groundwater monitoring wells. Groundwater sampling of 15 off-site groundwater monitoring wells (BH41 to BH45, BH48, BH49, BH51 to BH54, BH56, BH58 to BH60). Sampling of one off-site soil vapour bore (SV1_S) and three on-site soil vapour bores (SV2, SV3 and SV4).



LEGEND

- Site boundary
- Groundwater monitoring wells
- Soil bores
- Soil vapour well

NOTES

1. Aerial: LINZ and Eagle Technology, CC-BY-3.0-NZ.
2. Map image: © OpenStreetMap (and) contributors, CC-BY-SA
3. Schematic only, not to be interpreted as an engineering design or construction drawing.
4. Site layout derived from Figure 2C in PDP (2011).

0 20 40
METRES

REFERENCE SCALE: 1:700 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
HISTORICAL ESA SAMPLING LOCATIONS AND MONITORING

CONSULTANT
GOLDER

YYYY-MM-DD	2019-10-04
PREPARED	AE
REVIEW	AS
APPROVED	ST

PROJECT NO.	REPORT	REV.	FIGURE
1792933	003	1	4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM A3

LEGEND

- Site boundary
- Soil vapour wells
- Test pit locations
- LIF locations
- LIF / CPT locations
- Groundwater monitoring wells
- Electrical (de-energised)
- Hydrant line (de-energised)
- Unknown
- Stormwater (remaining)
- Stormwater (isolated)
- Historic fuel lines
- Concrete pad / surface structure

NOTES

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3. Schematic only, not to be interpreted as an engineering design or construction drawing.

0 20 40
METRES

REFERENCE SCALE: 1:700 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
SUPPLEMENTARY ESA SAMPLING LOCATIONS AND MONITORING WELLS

CONSULTANT

GOLDER

YYYY-MM-DD	2019-11-04
PREPARED	AE
REVIEW	AS
APPROVED	ST

PROJECT NO.	REPORT	REV.	FIGURE
1792933	003	1	5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM A3
25mm
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4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 Overview

This section summarised the nature and extent of contamination associated with petroleum hydrocarbon storage at the site with a primary focus on LNAPL and dissolved phase impacts including an assessment of stability and trends. On-site soil and soil vapour impacts are briefly summarised, and more detailed discussion of the on-site impacted media is provided in Golder (2019).

4.2 Soil

Golder (2019) presented an assessment of the nature and extent of on-site soil impacts associated with historical bulk fuel storage activities at the site. Petroleum hydrocarbon concentrations in soil exceeded MfE (2011a) Tier 1 acceptance criteria for a commercial/industrial land use. Primarily these exceedances have been identified for C_7-C_9 TPH, C_{10}-C_{14} TPH and (total) xylenes and for specific criteria for the protection of excavation worker based on the inhalation pathway.

Evaluation of the soil quality data identifies that the bulk of the excavation worker exceedances are present in soils between 1.0 m and 4.0 m including in soils located below the groundwater table. The exceedances are primarily located in the former tank farm area to south-west of former Tank 5 and toward the southern corner of the site.

A limited number of exceedances of the indoor inhalation pathway, primarily for total xylenes were also identified. Exceedances of the indoor inhalation pathway were primarily located in samples collected at and below the groundwater table. As volatilisation is controlled by solubility, soil samples collected below the groundwater table cannot be used to assess vapour inhalation risk.

4.3 Soil Vapour

Golder (2019) presented the results and Tier 1 risk assessment for on-site and off-site soil vapour sampling. In summary, soil vapour samples have been collected from three on-site soil vapour bores installed across the southern and western areas of the site and one off-site soil vapour bore installed adjacent to the HarbourCold cold storage facility.

Soil vapour monitoring undertaken to date shows concentrations of the primary chemicals of interest (COIs), namely BTEX and naphthalene, in soil vapour on site are below MfE (2011a) target soil gas concentrations for the protection of indoor quality. The on-site soil vapour samples identified the presence of a range of petroleum hydrocarbon related compounds in addition to BTEX and naphthalene. The reported concentrations of these compounds, with the exception of 1,2,4-trimethylbenzene at soil vapour bore SV3 were below vapour intrusion screening criteria.

The presence of LNAPL in the south-west of the site is a source of soil vapour which may represent a risk to indoor air of newly constructed buildings where the LNAPL occurs. However, the risk to indoor air can be managed through appropriate consideration in building design such as ventilation or use of a vapour barrier, depending on the building use and location with respect to the groundwater impacts.

Monitoring of the shallow soil vapour bore located adjacent to the off-site HarbourCold facility identified the presence of BTEX and naphthalene at concentrations below MfE (2011a) target soil gas concentration for the protection of indoor air quality. This indicates a low probability of a vapour intrusion risk to off-site properties associated with the presence of off-site petroleum hydrocarbon impacts.

The three on-site soil vapour samples were also analysed for oxygen, methane and carbon dioxide (Table 7). Evidence of oxygen depletion and enriched concentrations (relative to atmospheric conditions) of methane and carbon dioxide were detected at vapour well SV3. Methane was not detected above the laboratory LOR at vapour bores SV2 and SV4. Carbon dioxide was present above atmospheric levels in vapour bores SV2 and SV3.

Table 7: Summary of atmospheric gases in on-site soil vapour monitoring wells.

Soil vapour bore	SV2		SV3		SV4	
Sample depth (m bgl)	1.0		1.0		1.0	
Sample date	2016	2017	2016	2017	2016	2017
Oxygen (Mole %)	18.5	17.0	< 0.2	< 0.2	15.8	8.46
Methane (µg/m^3)	< 0.12	< 0.1	6.05	1.66	< 0.1	< 0.1
Carbon dioxide (Mole %)	1.43	2.34	10.1	15.4	3.35	9.23

Note: m bgl – metres below ground level.

Of particular interest with respect to potential biodegradation of petroleum hydrocarbons, is the presence of methane at SV3 which confirms methanogenic conditions in the subsurface. At this location oxygen is completely depleted and the level of carbon dioxide indicative of hydrocarbon and methane oxidation is significant. Carbon dioxide is also reported at SV2 and SV3 with SV4 showing comparatively high rate of oxygen depletion.

4.4 Groundwater

4.4.1 Overview

Groundwater gauging and sampling has regularly been undertaken since 2011 and the historical data is tabulated and presented in Appendix A (groundwater and LNAPL levels) and Appendix B (groundwater quality). The nature and extent of LNAPL and dissolved phase impacts including stability and trend analysis is presented in the following sections.

4.4.2 LNAPL

4.4.2.1 LNAPL Apparent Thickness and Trends

The relevant historical LNAPL measurements and observations from gauging events is presented in Appendix A and the LNAPL thickness is summarised in Table 8. The maximum LNAPL thickness recorded in the most recent GME (April 2017) was 0.232 m (BH25) and in many wells was typically only several millimetres thick. Overall there appears to be a trend of decreasing thickness of LNAPL over time, considering water table fluctuations.

Table 8: Summary of recorded LNAPL thickness and observations.

Monitoring well	Aug 2009	Apr 2011	Apr 2012	Jul 2013	Dec 2013	Jun 2014	May 2015	Nov 2015	May 2016	Apr 2017
BH1	0.066	0.12	0.101	0.535	0.165	0.545	-	-	-	-
BH9	S	Well Destroyed								
BH15	G	Well Destroyed								
BH20	NI	0.003	0-0.09	-	-	-	-	-	-	-
BH22	NI	-	G	-	-	-	-	-	-	-
BH24	NI	S	G	0.757	0.321	0.431	-	0.14	0.002	0.004
BH25	NI	-	0.09	0.275	0.293	-	0.22	0.45	0.08	0.232
BH28	NI	-	G	-	-	-	-	-	-	-
BH29	NI	-	0.218	0.897	0.93	0.192	0.05	-	0.615	0.006
BH31	NI	S	0.172	-	0.14	-	-	0.01	0.034	G
BH33	NI	S	0.129	0.008	0.003	-	-	-	-	-
BH34	NI	S	S	G	-	-	-	-	-	-
BH35	NI	S	0.161	0.279	0.339	0.002	0.27	0.04	0.002	0.002
BH36	NI	S	G	-	S	S	0.04	0.01	0.02	0.003
BH43	NI	0.107	0.026	-	-	-	-	-	-	-
BH44	NI	G	S	-	-	-	-	-	-	-
BH46	NI	0.071	G	0.589	0.038	0.282	S	-	0.001	0.093
BH47	NI	0.069	0.003	0.251	0.141	0.53	S	-	0.001	0.01
BH48	NI	S	-	-	-	-	S	-	-	-
BH49	NI	0.002	G	-	S	-	S	-	-	-
BH57	NI						0.03	0.01	0.012	0.019
BHA	0.424	0.165	0.045	0.019	0.016	0.021	-	0.01	0.032	0.033
BHB	0.531	0.187	0.114	0.056	0.024	0.021	0.03	0.03	0.03	0.004
BHC	G	-	S	G	-	-	-	-	-	-

Notes: 'NI' denotes well not installed. 'G' denotes globules. 'S' denotes Sheen. '-' denotes LNAPL not present.

A plot of the LNAPL thickness versus the groundwater elevation for wells with measurable LNAPL in more than two GMEs is presented in Appendix C and selected hydrographs are presented in Figure 6 to Figure 9 inclusive. Whilst some wells such as BH29 (Figure 7) and BH35 (Figure 8) partially illustrate a classic response of increasing LNAPL thickness in response to a decrease in water levels this is not always apparent and in many instances there does not appear to be a relationship between apparent LNAPL thickness and water levels. This may be a function of the decreasing residual saturation of LNAPL in the subsurface overtime. Nonetheless, as noted above the general trend is that LNAPL has decreased in thickness at many locations since 2001 and this appears to be largely independent of the water table fluctuation.

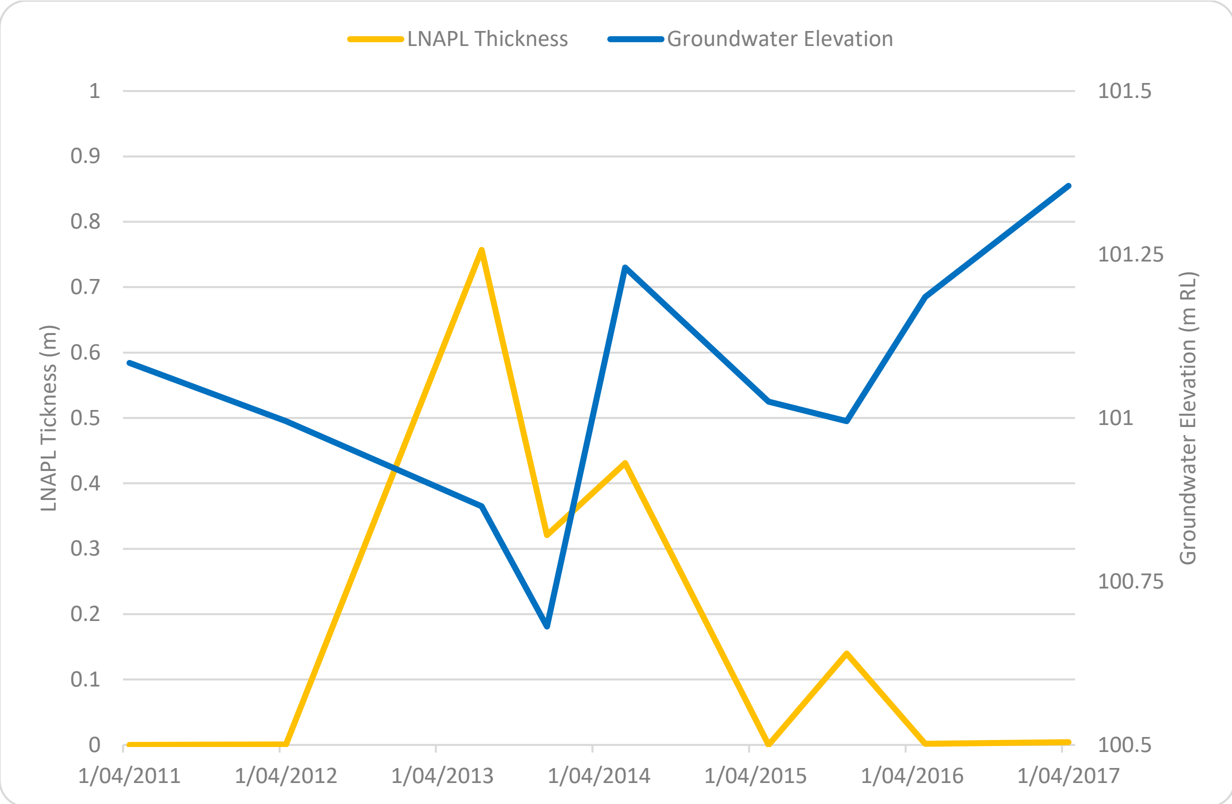


Figure 6: Hydrograph for monitoring well BH24.

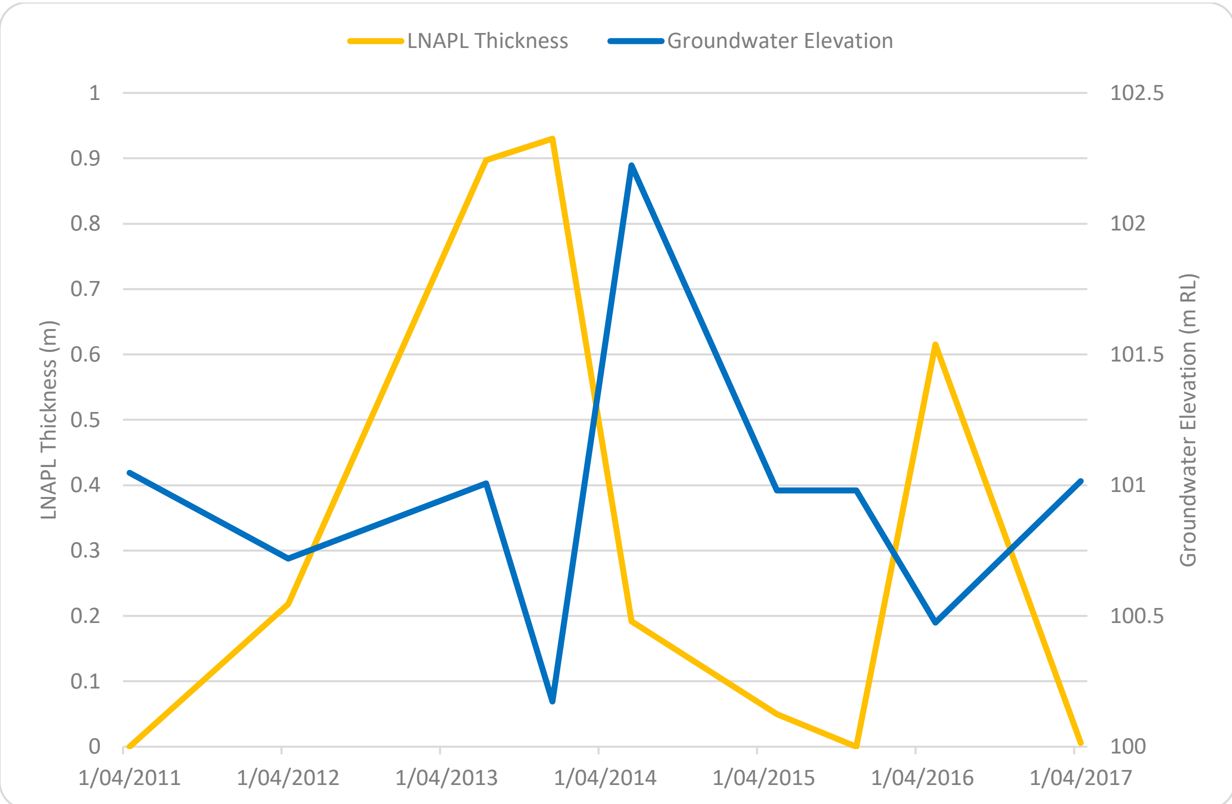


Figure 7: Hydrograph for monitoring well BH29.

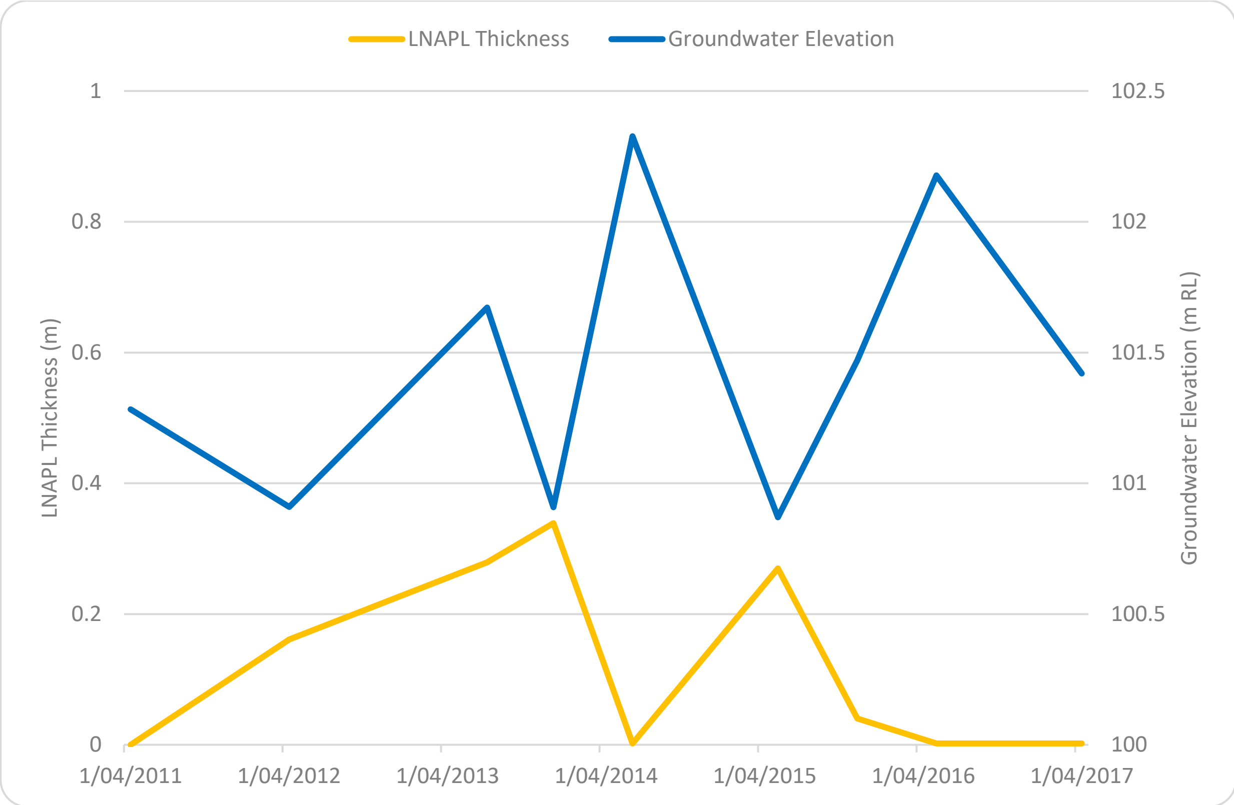


Figure 8: Hydrograph for monitoring well BH35.

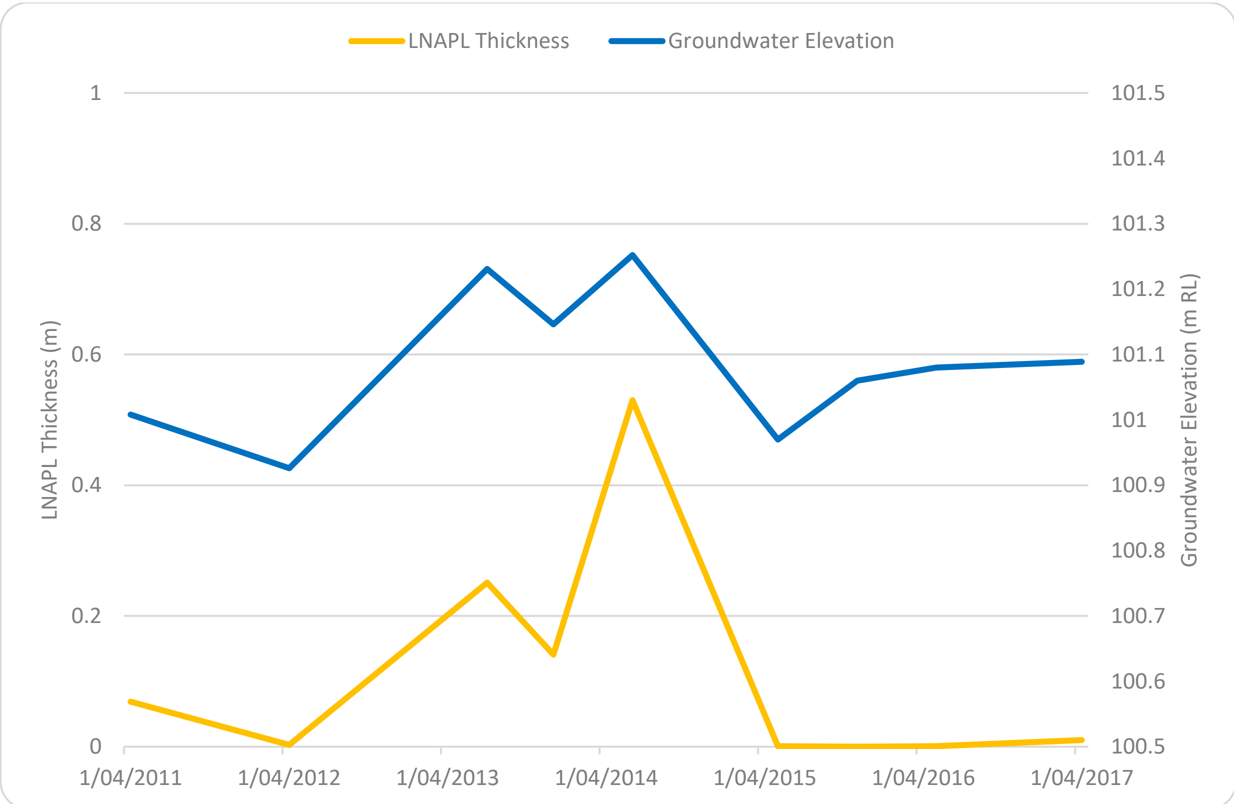


Figure 9: Hydrograph for monitoring well BH47.

4.4.2.2 LNAPL Spatial Extent

The most recent inferred extent of LNAPL based on measured apparent thickness in monitoring wells in the April 2017 GM is shown on Figure 14. Measurable LNAPL was detected in seven on-site wells (BH24, BH25, BH29, BH35, BH36, BHA and BHB) with globules observed in a further well (BH31). Measured in-well LNAPL thickness ranged between 0.002 m (BH35) and 0.232 m (BH25). LNAPL was recorded in three off-site wells located on Fryatt Street (BH46, BH47 and BH57) of very limited thickness ranging from 0.01 to 0.019 m.

The monitoring data indicates that LNAPL is present in a number of monitoring wells across the central and southern area of the site and in monitoring wells along the western side of Fryatt Street. This is consistent with the findings of the high resolution LIF investigation (Golder 2019) completed across the site (Figure 5). The LIF data is displayed for three cross-sections across the site (Figure 10, Figure 11 and Figure 12). The cross-sections show the LIF outputs across the site along with the summer and winter groundwater elevations. The cross-sections indicate that where LNAPL is present there is a smear zone of up to 1.5 m in thickness between the highest and lowest groundwater elevations recorded. The data indicates that LNAPL is not present below lowest groundwater elevations in 55 of the 59 locations, suggesting it is limited to the zone of water table fluctuations.

The presence of LNAPL on site corresponds primarily to the presence of petrol and diesel signatures in LIF locations in the south-east of the site in the area bound by former Tank 5 to the north, the southern extent of the tank farm and the Fryatt Street site boundary. Golder (2019) presented an assessment of the inferred hydrocarbon signature based on the LIF response and is shown on Figure 13.

However, whilst the LIF data has shown LNAPL to be present across most of the north-western portion of the site, LNAPL has not been recorded in many wells (BH27, BH28, BH30, BH32 and BH37) located across this area. This likely indicates a low residual saturation and mobility which prevents LNAPL entry into the well screen. This tends to be supported by the historical dissolved phase concentration data for these wells which clearly indicate petroleum hydrocarbon impacts are present.

4.4.2.3 LNAPL Mobility

Previous ESA work included the completion of LNAPL bail-down tests on monitoring wells BH29, BH31 and BH35 (PDP 2012). Based on the work undertaken, PDP (2012) noted that LNAPL recovery measured in the three wells was likely a function of drainage from the filter pack rather than the surrounding formation and considered that the LNAPL recovery would be limited. This supports the findings of LNAPL recovery works undertaken between April and June 2005 (PDP 1995).

The recovery trial utilised three recovery wells installed in the southern area of the site with the removal of liquids over a 53 period. PDP (1995) notes that the pumping rate fluctuated between 13,000 to 25,000 L per day. This suggests a total of between 689,000 L and 1,325,000 L of the liquid was pumped from the groundwater system during the trial period. PDP (1995) documents that LNAPL was observed in the pumped water after 14 days of operation with between 60 to 80 L of LNAPL maintained in the storage tank during the trial period. While the total volume of LNAPL recovered was not recorded, PDP (1995) estimated that the total volume of LNAPL recovered was “in the order of a few hundred litres”. This infers that the total volume of LNAPL recovered was in the order of 0.03 % of the total volume of liquid recovered.

Legend

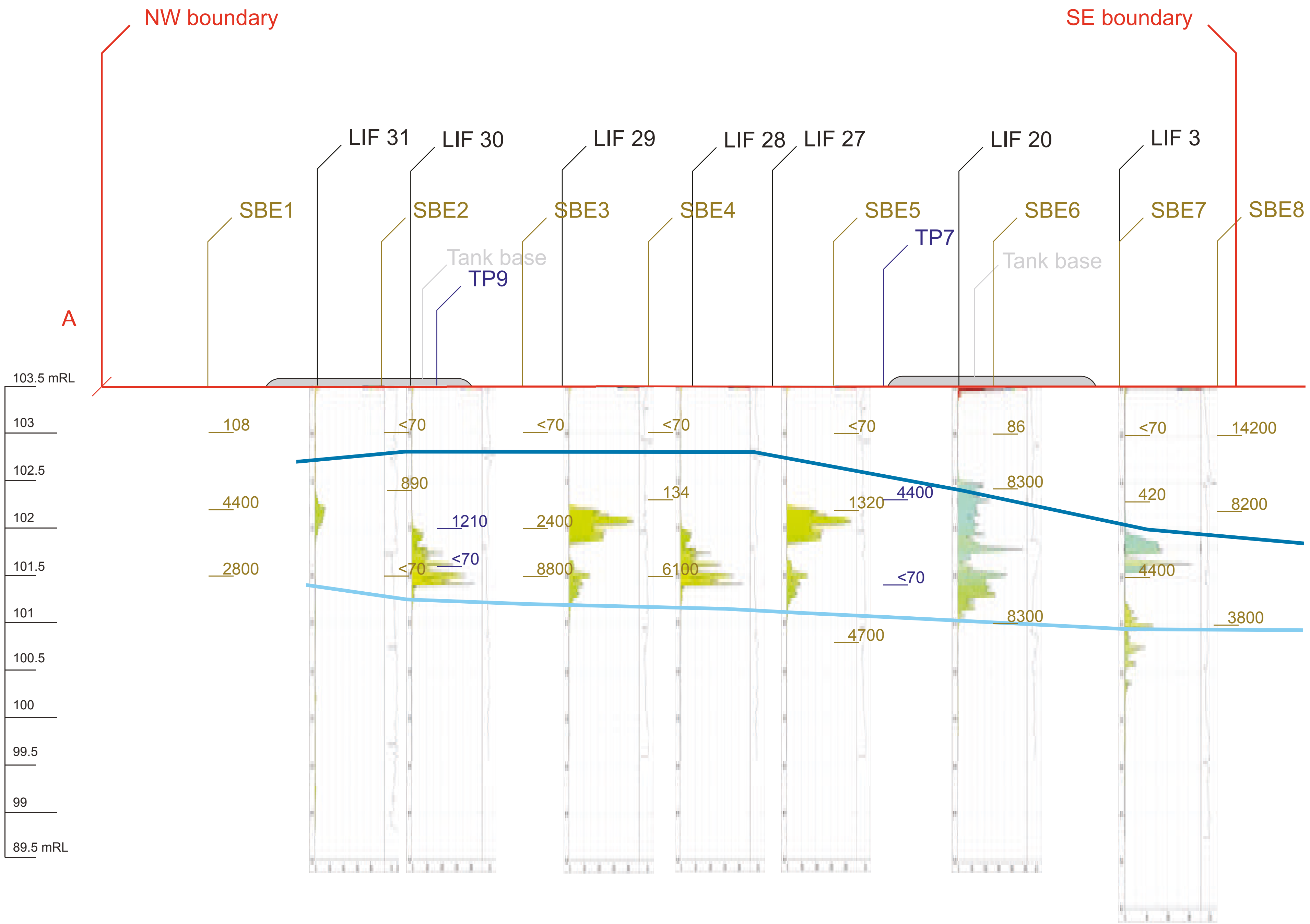
mRL Metres Reduced Levels

Groundwater elevation (June 2014)

Groundwater elevation (April 2012)

1890 C_7 - C_{36} TPH concentration (mg/kg) (PDP 2011)

<70 C_7 - C_{36} TPH concentration (mg/kg) (Golder 2015/2016)



1. Schematic only, not to be interpreted as an engineering design or construction drawing
2. Drawn by: AP Reviewed by: ST

GOLDER

TITLE LIF CROSS-SECTION A-A'

November 2019

PROJECT 1792933

10

S:\Graphics\Projects-Dynamics\2016\7405\1648460_MobilNZLtdDunedin_GRA\Apr19

Legend

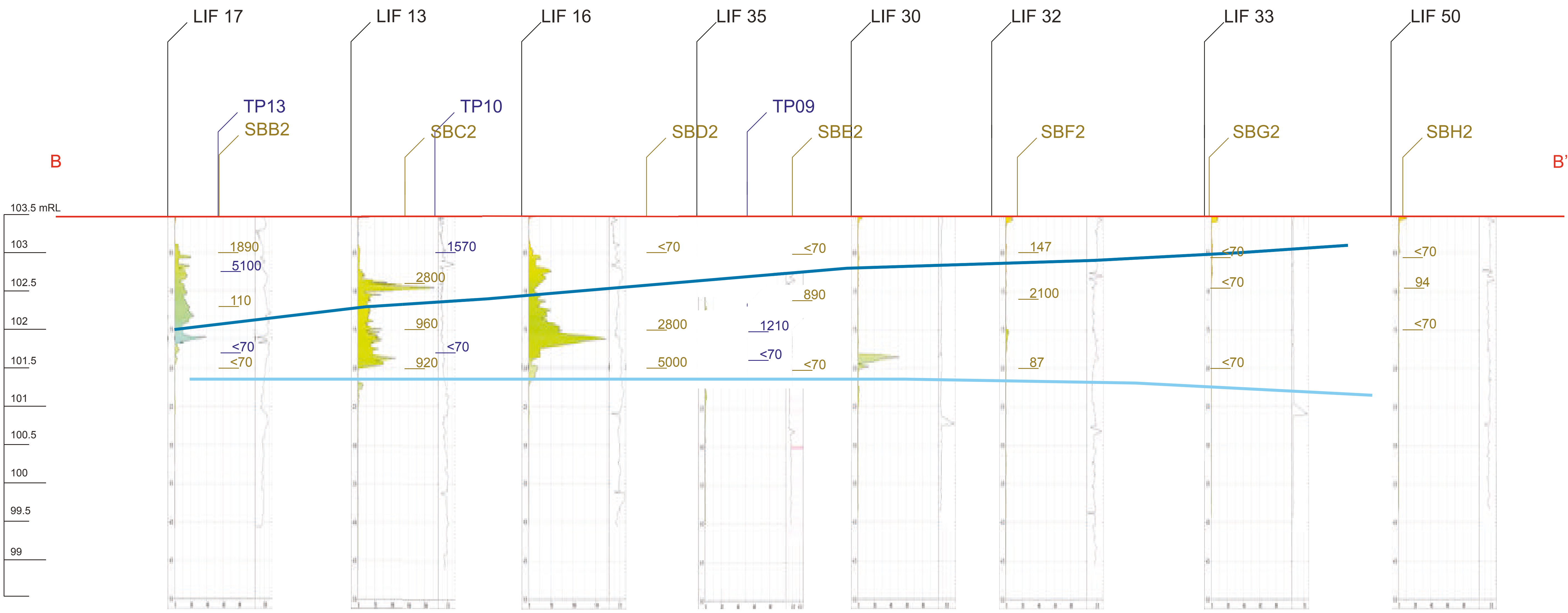
mRL Metres Reduced Levels

Groundwater elevation (June 2014)

Groundwater elevation (April 2012)

1890 C_7 - C_{36} TPH concentration (mg/kg) (PDP 2011)

5100 C_7 - C_{36} TPH concentration (mg/kg) (Golder 2015/2016)



1. Schematic only, not to be interpreted as an engineering design or construction drawing
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GOLDER

TITLE LIF CROSS-SECTION B-B'

November 2019

PROJECT 1792933

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Legend

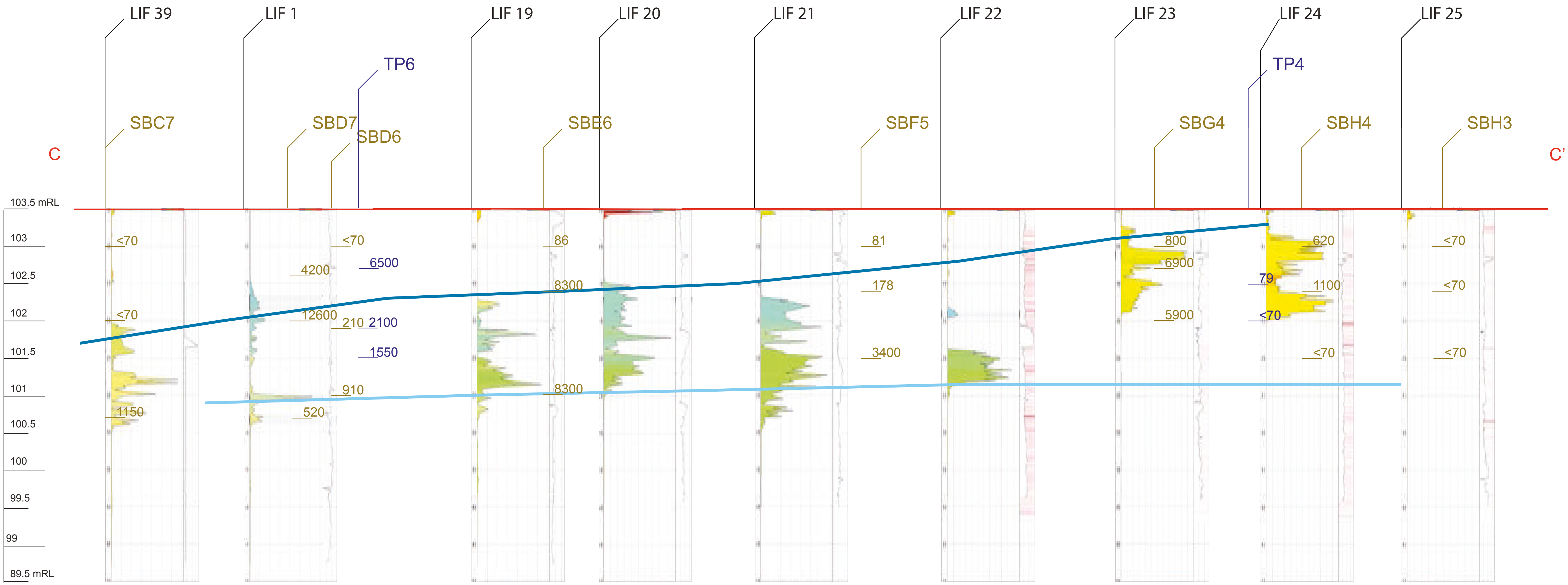
mRL Metres Reduced Levels

Groundwater elevation (June 2014)

Groundwater elevation (April 2012)

1890 C_7 - C_{36} TPH concentration (mg/kg) (PDP 2011)

6500 C_7 - C_{36} TPH concentration (mg/kg) (Golder 2015/2016)



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GOLDER

TITLE LIF CROSS-SECTION C-C'

November 2019

PROJECT 1792933

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LEGEND

- No petroleum hydrocarbon observed
- Diesel (0.5 - 2 mbgl)
- Diesel (1.5 - 2.5 mbgl)
- Heavy end hydrocarbon (0.5 - 1.5 mbgl)
- Petrol (1.0 - 1.8 mbgl)
- Diesel (2.0 - 3.0 mbgl)
- Variable (refer Table 17)
- Cross-section transects (refer Figure 10, Figure 11, Figure 12)
- Site boundary

NOTES

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2. Map image: © OpenStreetMap (and) contributors, CC-BY-SA
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0 10 20
METRES

REFERENCE SCALE: 1:600 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
INFERRED HYDROCARBON SIGNATURES FROM LIF DATA

CONSULTANT		
GOLDER	YYYY-MM-DD	2019-11-04
	PREPARED	AE
	REVIEW	AS
	APPROVED	ST

PROJECT NO.	REPORT	REV.	FIGURE
1792933	003	1	13

For more information regarding our GIS services/consultancy, please contact Reza Kalbasi (GIS Leader at Golder Associates NZ); rkalbasi@golder.co.nz

LEGEND

- Groundwater monitoring wells
- Monitoring wells April 2017 (LNAPL observed; thickness; m)
- Monitoring wells - not Mobil
- Inferred LNAPL extent
- Site boundary
- Concrete pad / surface structure

0 20 40

REFERENCE SCALE: 1:700 (at A3) METRES

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

NOTE(S)

1. AERIAL: LINZ AND EAGLE TECHNOLOGY, CC-BY-3.0-NZ.
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CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
INFERRED LNAPL EXTENT - APRIL 2017

CONSULTANT
GOLDER

YYYY-MM-DD	2019-11-04
PREPARED	AE
REVIEWED	JMM/AH
APPROVED	JMM/AH

PROJECT NO.	CONTROL	REV.	FIGURE
1792933	003	1	14

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

Golder (2019) reported on LNAPL bail-down test conducted on monitoring well BH25. Prior to the testing LNAPL thickness was measured at 0.28 m; 125 minutes after LNAPL had been removed LNAPL thickness was measured at only 0.006 m. Due to the slow LNAPL recovery it was not possible to estimate a NAPL transmissivity. However, the slow recovery does indicate a low NAPL transmissivity suggesting low recoverability and that LNAPL in vicinity of BH25 has a low mobility and/or there is limited LNAPL saturation in nearby soil. Elsewhere on and off site, the LNAPL head was at similar elevations as groundwater in the surrounding monitoring wells without LNAPL (indicative of negligible LNAPL gradient). These similar head levels as well as the low recoverability observed from BH25 and the minimal LNAPL thickness in other monitoring wells, indicates that the remaining LNAPL has low mobility.

4.4.2.4 LNAPL Stability

The LNAPL stability can also be assessed by examining the inferred lateral extent overtime. Figure 15 presents the inferred LNAPL distribution from April 2011 through to December 2013 whilst Figure 16 presents the distribution from June 2014 to June 2016. In comparison with the current distribution (Figure 14) the overall the footprint (based on the apparent LNAPL thickness) is similar indicating LNAPL across the central and southern area of the site and in monitoring wells along the western side of Fryatt Street.

One exception is the presence of LNAPL in the north-eastern corner of the site in 2011 and 2012 (BH42, BH43 and BH44), which is inferred to be attributed to an offsite source (URS 2012). This LNAPL impact has not been observed in these wells since 2012 and dissolved phase concentrations of hydrocarbons are very low, not indicative of the presence of LNAPL.

Whilst some variation in the lateral extent of LNAPL is possibly a function of fluctuations in the water table, overall the lateral extent appears be contracting over time, and is supported by the apparent reduction in LNAPL thickness at many locations.

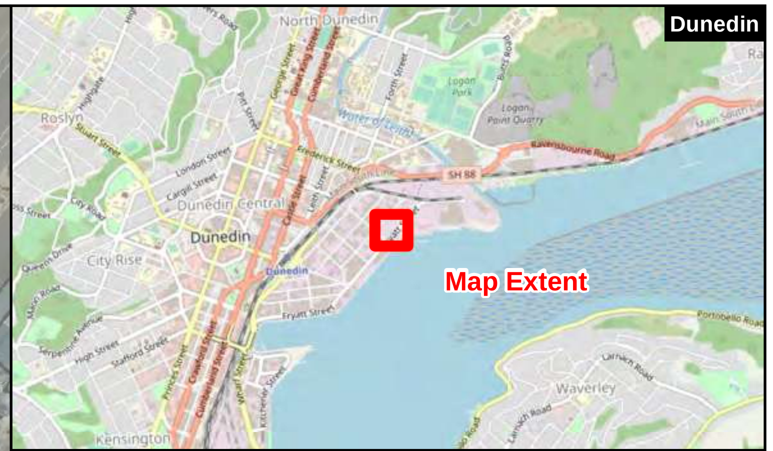
Based on lateral and thickness trends in the LNAPL distribution, the LNAPL mass is considered to be stable and is not moving laterally off site towards Otago Harbour. This conclusion is further supported by the bail down testing of LNAPL which has been completed at the site (refer Section 4.4.2.3) which indicates that the LNAPL has a low recoverability and mobility.

4.4.3 Distribution of dissolved phase petroleum hydrocarbons

The most recent GME was conducted in April 2017 and the groundwater quality data is presented in Appendix B. The monitoring was focussed on the off-site wells and the results for key COI that define the dissolved phase impacts from LNAPL are summarised in Table 9.

The data shows that with the exception of a six monitoring wells (BH41, BH42, BH49, BH51, BH52 and BH56), dissolved phase hydrocarbon concentrations were below the ANZECC (2000) trigger values for protection of aquatic ecosystems. The highest concentrations were generally in wells in close proximity to the inferred LNAPL distribution (MW41 and MW49) and monitoring wells immediately adjacent to Otago Harbour (BH53 and BH54) were below the relevant criteria (Figure 17).

Overall the distribution of dissolved phase hydrocarbons suggests that they have, and are continuing to attenuate with increasing distance from the LNAPL source. This is discussed further in Section 5.0.



LEGEND

- Groundwater monitoring wells
- Monitoring wells (LNAPL observed; thickness; m)
- Monitoring wells - not Mobil
- Inferred LNAPL extent
- Site boundary
- Concrete pad / surface structure

S Denotes sheen observed during well pumping
G Denotes globules present in the well

0 20 40

REFERENCE SCALE: 1:1,500 (at A3) METRES

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

NOTE(S)

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4. SITE LAYOUT DERIVED FROM PDP FIGURE 3D.

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

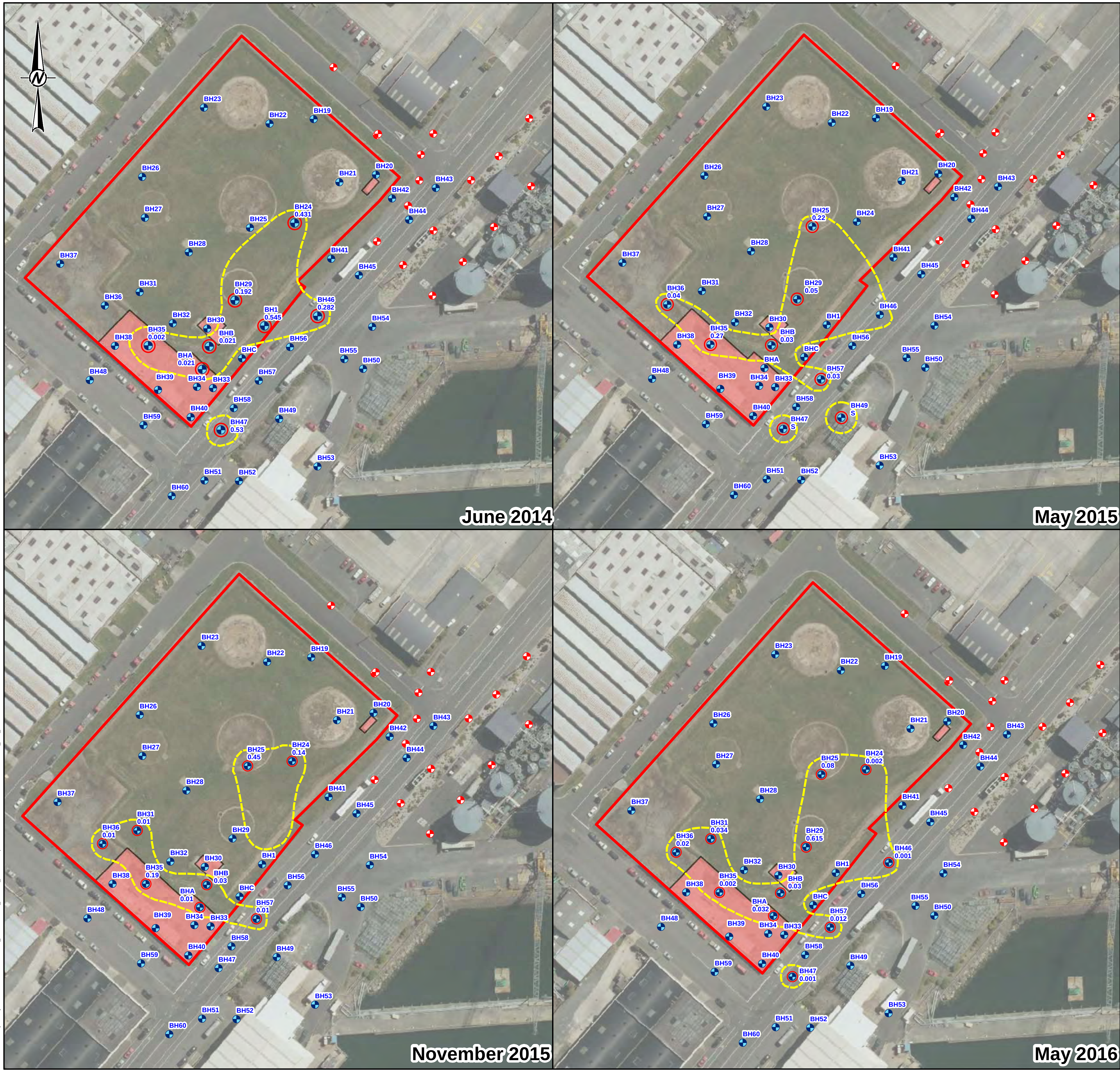
TITLE
INFERRED LNAPL EXTENT - APRIL 2011 TO DECEMBER 2013

CONSULTANT		
GOLDER	YYYY-MM-DD	2019-11-04
	PREPARED	AE
	REVIEWED	JMM/AH
	APPROVED	JMM/AH

PROJECT NO.	CONTROL	REV.	FIGURE
1792933	003	1	15

PATH: K:\GIS\Projects-Dynamics\2017\7405\1792933_MobilOilNZLtd_Dunedin_terminal\MapDocuments\003-R\1792933-003-R-RevC-F02_A3L_GIS.mxd PRINTED ON: 2019-04-09 AT 2:32:18 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25mm
0



LEGEND

- Groundwater monitoring wells
- Monitoring wells (LNAPL observed; thickness; m)
- Monitoring wells - not Mobil
- inferred LNAPL extent
- Site boundary
- Concrete pad / surface structure

S Denotes sheen obesrved during well pumping
G Denotes globules present in the well

0 20 40

REFERENCE SCALE: 1:1,500 (at A3) METRES

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

NOTE(S)

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CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
INFERRED LNAPL EXTENT - JUNE 2014 TO JUNE 2016

CONSULTANT

GOLDER

YYYY-MM-DD	2019-11-04
PREPARED	AE
REVIEWED	JMM/AH
APPROVED	JMM/AH

PROJECT NO.	CONTROL	REV.	FIGURE
1792933	003	1	16

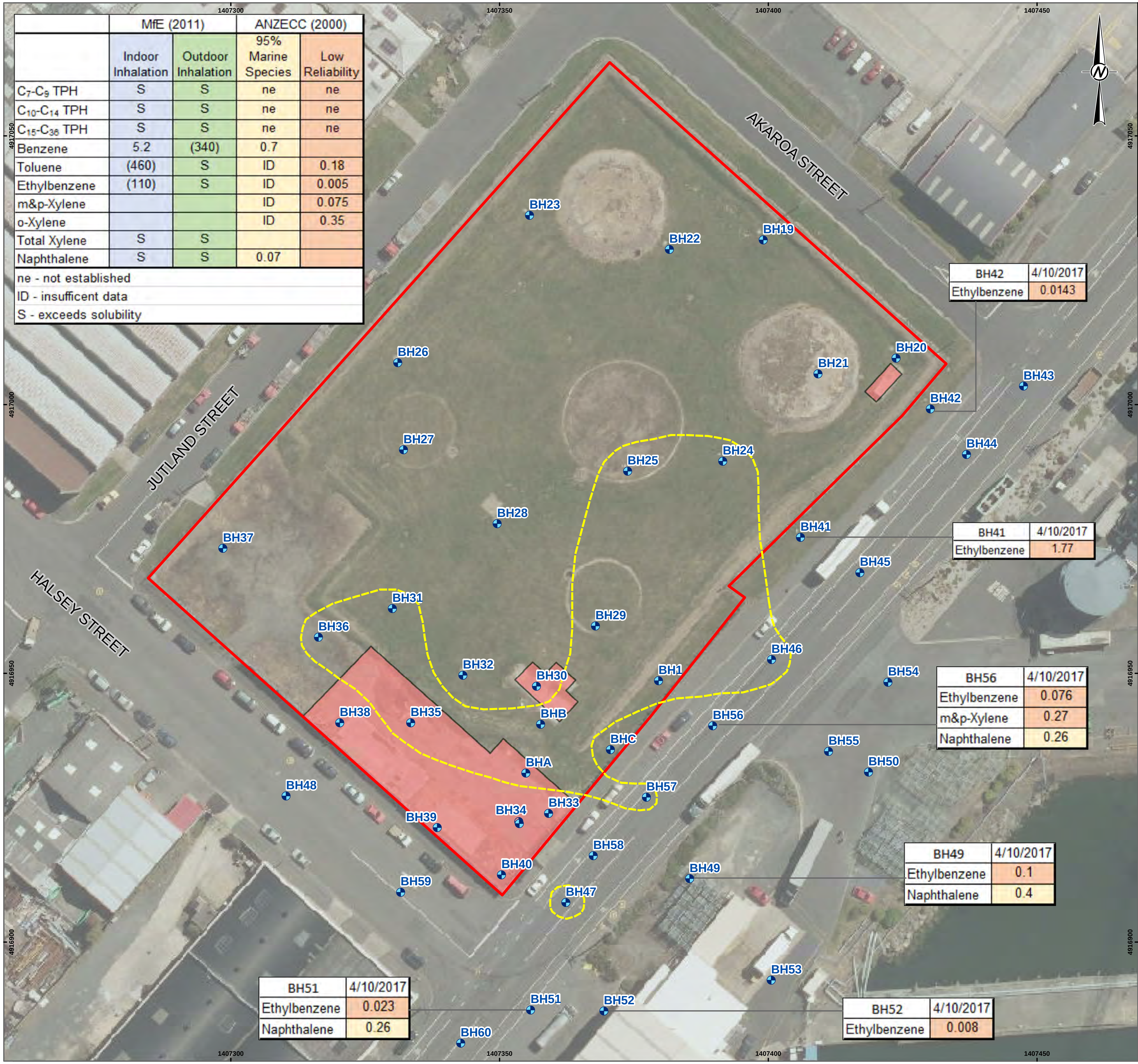
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

25mm

Table 9: Summary of concentrations for key COIs in off-site groundwater monitoring wells – April 2017.

Monitoring well	TPH			BTEX					PAHs
	C_7-C_9	C_{10}-C_{14}	C_{15}-C_{36}	Benzene	Toluene	Ethylbenzene	m&p-Xylene	o-Xylene	Naphthalene
ANZECC (2000) [1]	ne	ne	ne	0.7	0.18*	0.005*	0.075*	0.35*	0.07
BH41	3.4	1.0	< 0.4	0.0183	0.0033	**1.77**	**1.20**	0.0047	0.0146
BH42	0.24	< 0.2	< 0.4	0.0021	0.0042	**0.0143**	0.062	0.0057	0.0013
BH43	< 0.06	< 0.2	< 0.4	< 0.001	< 0.001	< 0.001	< 0.002	< 0.001	< 0.0005
BH44	< 0.06	< 0.2	< 0.4	< 0.001	< 0.001	< 0.001	0.003	< 0.001	< 0.0005
BH45	0.15	< 0.2	< 0.4	0.009	< 0.001	< 0.001	0.022	< 0.001	0.0128
BH46	LNAPL								
BH47	LNAPL								
BH48	0.07	0.9	< 0.4	< 0.001	< 0.001	< 0.001	< 0.002	< 0.001	0.0007
BH49	2.1	3.1	< 0.4	0.0104	< 0.001	**0.100**	0.039	< 0.001	**0.40**
BH50	Not Sampled (Dry)								
BH51	0.91	1.7	< 0.4	0.0183	0.0013	**0.023**	< 0.002	< 0.001	**0.26**
BH52	0.58	1.5	< 0.4	0.0025	< 0.001	**0.008**	0.062	< 0.001	0.030
BH53	0.27	0.3	< 0.4	< 0.001	< 0.001	< 0.001	< 0.002	< 0.001	< 0.0005
BH54	< 0.06	< 0.2	< 0.4	< 0.0010	< 0.001	< 0.001	< 0.002	< 0.001	< 0.0005
BH56	1.50	2.2	1.1	0.22	0.0022	**0.076**	**0.27**	< 0.001	**0.26**
BH57	LNAPL								
BH58	0.45	1.2	0.6	0.032	< 0.001	0.002	< 0.002	< 0.001	0.039
BH59	0.11	< 0.2	< 0.4	< 0.001	< 0.001	< 0.001	< 0.002	< 0.001	< 0.0005
BH60	< 0.06	< 0.2	< 0.4	< 0.001	< 0.001	< 0.001	< 0.002	< 0.001	< 0.0005

Notes: [1] ANZECC (2000) trigger values for protection of 95 % marine species. '*' denotes low reliability trigger values. Bold values denote exceedance of ANZECC (2000) trigger values.



	MfE (2011)		ANZECC (2000)	
	Indoor Inhalation	Outdoor Inhalation	95% Marine Species	Low Reliability
C_7-C_9 TPH	S	S	ne	ne
C_{10}-C_{14} TPH	S	S	ne	ne
C_{15}-C_{36} TPH	S	S	ne	ne
Benzene	5.2	(340)	0.7	
Toluene	(460)	S	ID	0.18
Ethylbenzene	(110)	S	ID	0.005
m&p-Xylene			ID	0.075
o-Xylene			ID	0.35
Total Xylene	S	S		
Naphthalene	S	S	0.07	

ne - not established
ID - insufficient data
S - exceeds solubility

BH42	4/10/2017
Ethylbenzene	0.0143

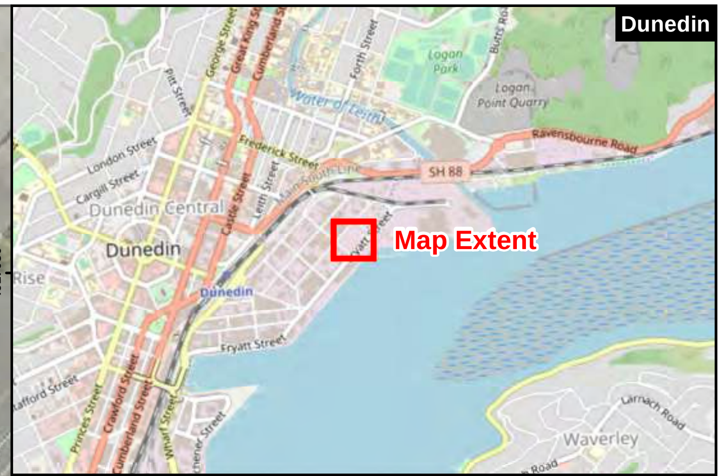
BH41	4/10/2017
Ethylbenzene	1.77

BH56	4/10/2017
Ethylbenzene	0.076
m&p-Xylene	0.27
Naphthalene	0.26

BH49	4/10/2017
Ethylbenzene	0.1
Naphthalene	0.4

BH51	4/10/2017
Ethylbenzene	0.023
Naphthalene	0.26

BH52	4/10/2017
Ethylbenzene	0.008



LEGEND

- Groundwater monitoring wells
- Inferred LNAPL extent
- Site boundary
- Concrete pad / surface structure

0 20 40
METRES

REFERENCE SCALE: 1:700 (at A3)
PROJECTION: NZGD 2000 New Zealand Transverse Mercator

NOTES

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3. Schematic only, not to be interpreted as an engineering design or construction drawing.
4. Shading represents exceedance of Tier 1 acceptance criteria.
5. Concentrations expressed in mg/L.

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
GROUNDWATER EXCEEDANCES - APRIL 2017

CONSULTANT
GOLDER

YYYY-MM-DD	2019-11-04
PREPARED	AE
REVIEW	AE
APPROVED	AH

PROJECT NO.	REPORT	REV.	FIGURE
1792933	003	1	17

4.4.4 Dissolved phase hydrocarbon concentration trends

An assessment of trends in petroleum hydrocarbon concentrations was undertaken using the GSI Mann-Kendall Toolkit (GSI Environmental 2012). The GSI Mann-Kendall Toolkit utilizes the methodology for statistical analysis of concentration trends that was initially incorporated in the MAROS software (Aziz et al., 2003; AFCEE, 2004). The Mann-Kendall test for trend analysis, as coded in the GSI Mann-Kendall Toolkit, relies on three statistical metrics (Aziz et al. 2003), as follows:

- The ‘S’ Statistic: Indicates whether concentration trend vs. time is generally decreasing (negative S value) or increasing (positive S value).
- The Confidence Factor (CF): The CF value modifies the S Statistic calculation to indicate the degree of confidence in the trend result, as in ‘Decreasing” vs. “Probably Decreasing” or “Increasing” vs. “Probably Increasing.” Additionally, if the confidence factor is quite low, due either to considerable variability in concentrations vs. time or little change in concentrations vs. time, the CF is used to apply a preliminary “No Trend” classification, pending consideration of the COV.
- The Coefficient of Variation (COV): The COV is used to distinguish between a “No Trend” result (significant scatter in concentration trend vs. time) and a “Stable” result (limited variability in concentration vs. time) for datasets with no significant increasing or decreasing trend (e.g. low CF).

Ethylbenzene, C_{10}-C_{14} TPH and naphthalene were selected as COI for analysis as these represent the primary indicators of petroleum hydrocarbon impacts associated with LNAPL present at the site. The analysis requires at least four independent sampling events per well to calculate a trend. Monitoring wells with measurable LNAPL have been excluded from analysis.

Concentration versus time plots for 12 key off-site monitoring wells with sufficient data are presented in Figure 18 (ethylbenzene), Figure 19 (C_{10}-C_{14} TPH) and Figure 20 (naphthalene). Worksheets which include the statistical analysis are provided in Appendix D. The trend analysis for each compound is summarised in Table 10.

The Mann-Kendall trend analysis concluded that there were no increasing trends for any of the COI and as a whole, the analysis suggests that dissolved petroleum hydrocarbons have decreased in concentration at relevant locations across the off-site area over the past decade (Figure 21, Figure 22, Figure 23 and Figure 24). More importantly the concentration of these compounds in monitoring wells adjacent to Otago Harbour are below the ANZECC (2000) trigger values.

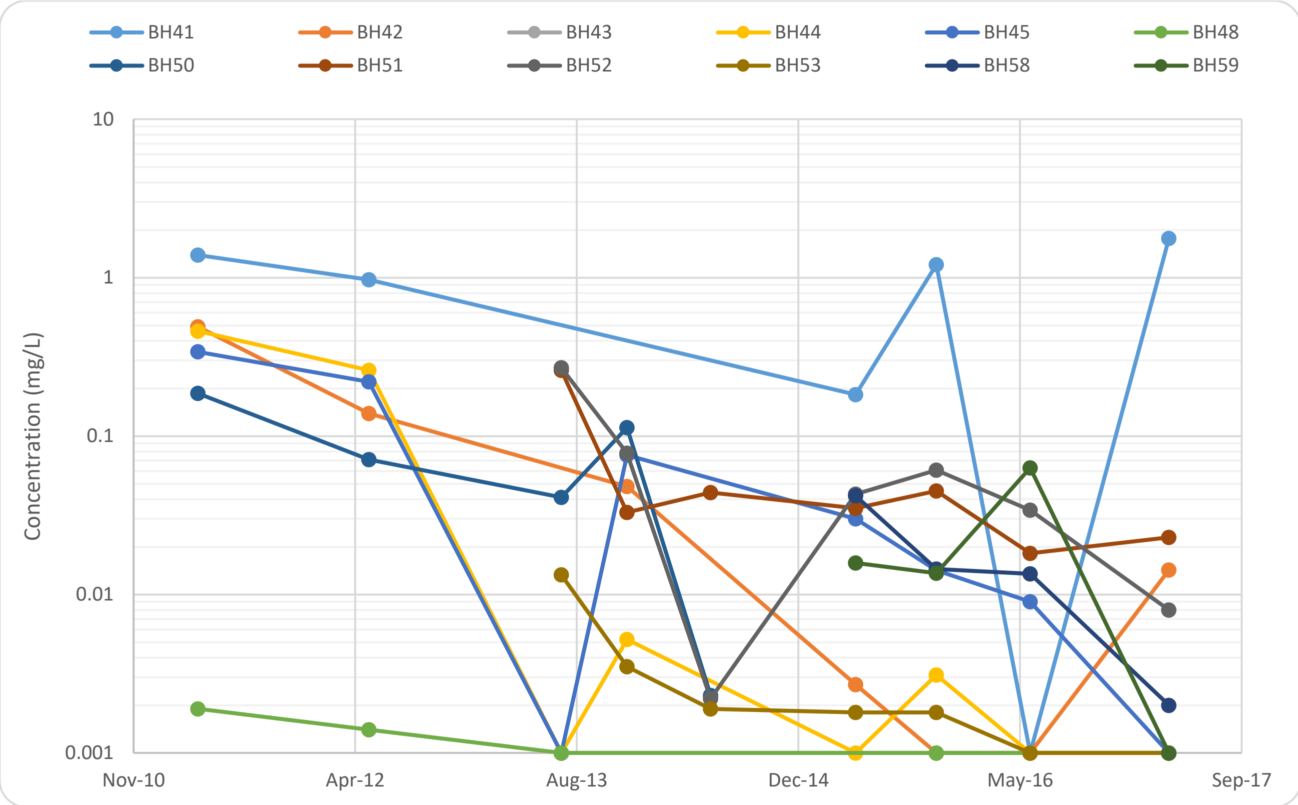


Figure 18: Ethylbenzene concentration versus time.

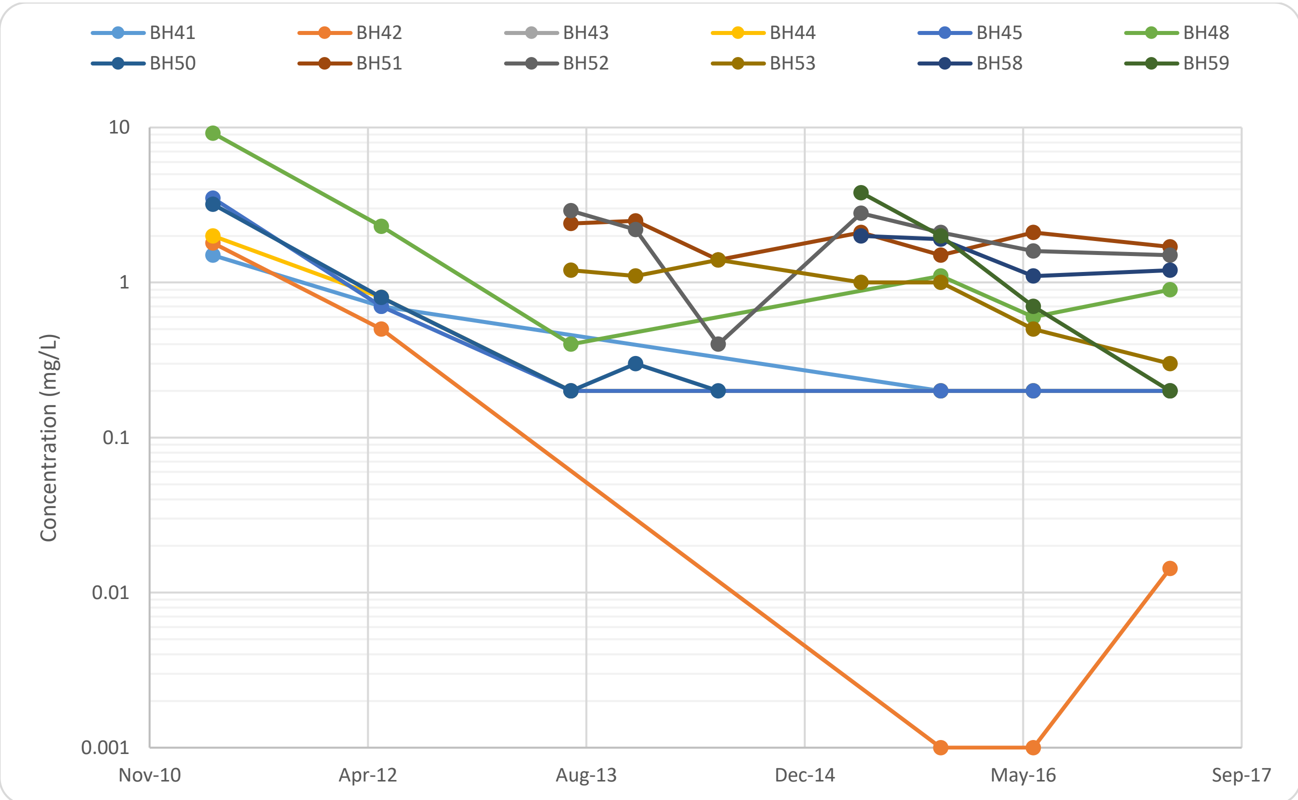


Figure 19: C_{10}-C_{14} TPH concentration versus time.

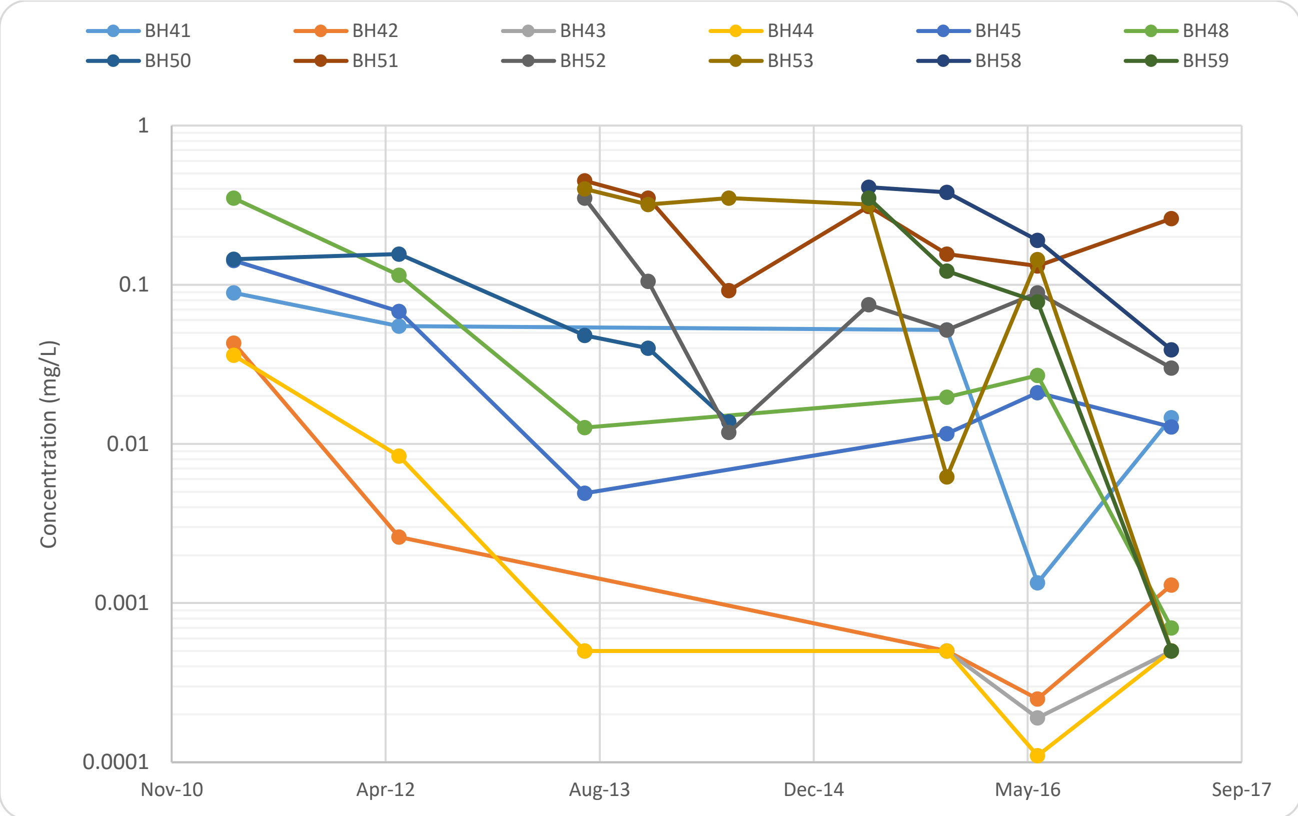
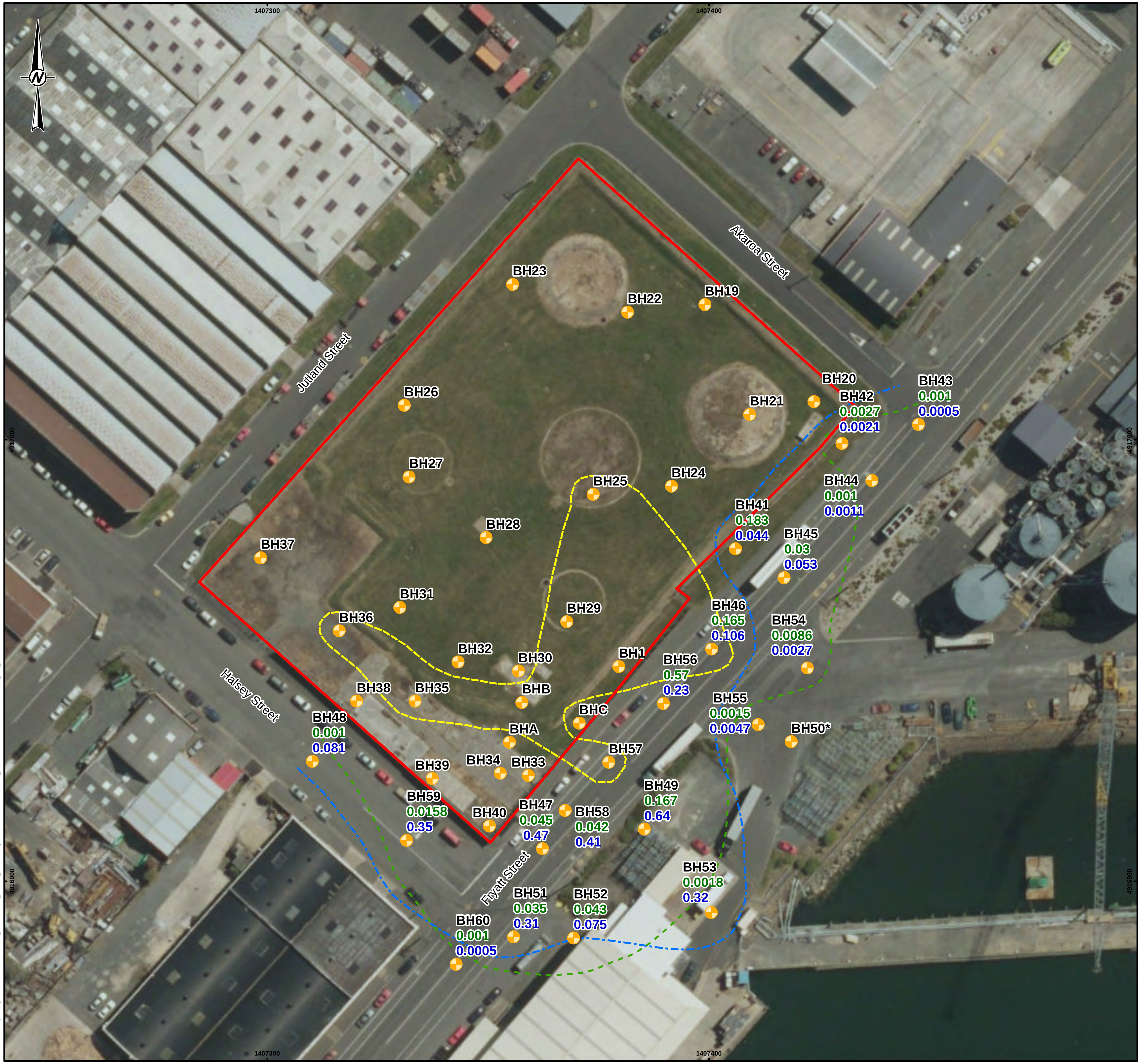


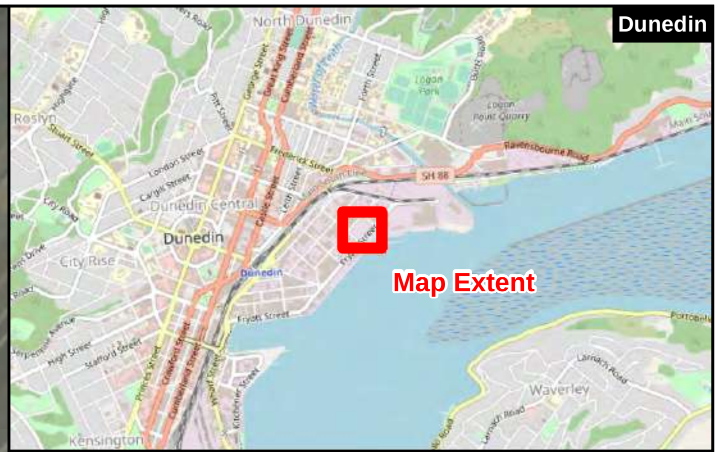
Figure 20: Naphthalene concentration versus time.

Table 10: Summary of Mann-Kendall statistical analysis.

Well	Ethylbenzene	C_{10}-C_{14} TPH	Naphthalene
BH41	Stable	Probably Decreasing	Decreasing
BH42	Decreasing	No Trend	No Trend
BH43*	Stable	Stable	Stable
BH44	Decreasing	Probably Decreasing	Decreasing
BH45	Decreasing	Probably Decreasing	No Trend
BH48	Probably Decreasing	No Trend	Probably Decreasing
BH50	Stable	Probably Decreasing	Decreasing
BH51	No Trend	Stable	Stable
BH52	Probably Decreasing	Probably Decreasing	No Trend
BH53	Decreasing	Decreasing	Decreasing
BH58	Decreasing	Stable	Decreasing
BH59	No Trend	Decreasing	Decreasing

Note: * Most of the results were below the LOR and the LOR values were used for the trend analysis.





LEGEND

- Site boundary
- Monitoring well
  - Ethylbenzene concentration
  - Napthalene concentration
- Ethylbenzene (0.005 mg/L)
- Napthalene (0.07 mg/L)
- Inferred LNAPL extent

0 30 60

METRES

REFERENCE SCALE: 1:850 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

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4. CONTOURS REPRESENT ANZECC (2000) TRIGGER VALUES FOR 95% OF MARINE SPECIES.
5. CONTOURS BASED ON OFF-SITE DISSOLVED CONCENTRATIONS.
6. * WELL NOT SAMPLED.

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
INFERRED DISSOLVED PHASE HYDROCARBON EXTENT - MAY 2015

CONSULTANT

GOLDER

MM-DD-YYYY	11/1/2019
PREPARED	AE
REVIEWED	ZM
APPROVED	AH

PROJECT NO.	CONTROL	REV.	FIGURE
1792933	003-R	1	21

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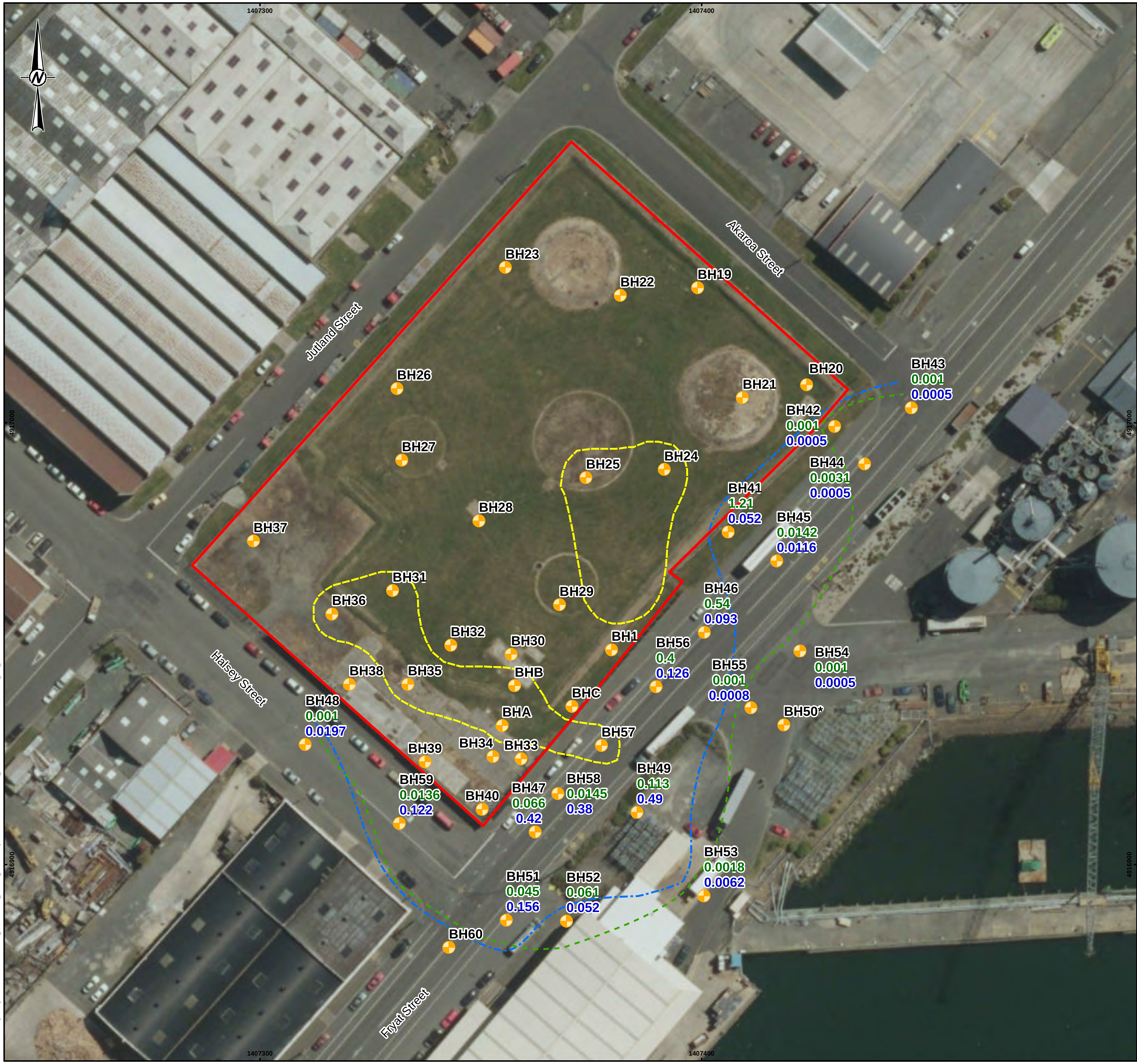

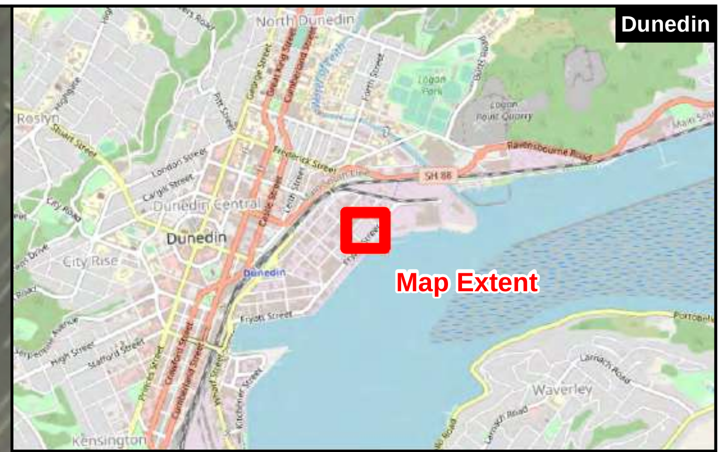

LEGEND

- Site boundary
- Monitoring well
  - Ethylbenzene concentration
  - Napthalene concentration
- Ethylbenzene (0.005 mg/L)
- Napthalene (0.07 mg/L)
- Inferred LNAPL extent

0 30 60

REFERENCE SCALE: 1:850 (at A3) METRES

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

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5. CONTOURS BASED ON OFF-SITE DISSOLVED CONCENTRATIONS.
6. * WELL NOT SAMPLED.

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MOBIL OIL NEW ZEALAND LIMITED

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FORMER MOBIL DUNEDIN TERMINAL

TITLE
INFERRED DISSOLVED PHASE HYDROCARBON EXTENT - NOVEMBER 2015

CONSULTANT

GOLDER

MM-DD-YYYY	11/04/2019
PREPARED	AE
REVIEWED	ZM
APPROVED	AH

PROJECT NO.	CONTROL	REV.	FIGURE
1792933	003-R	1	22

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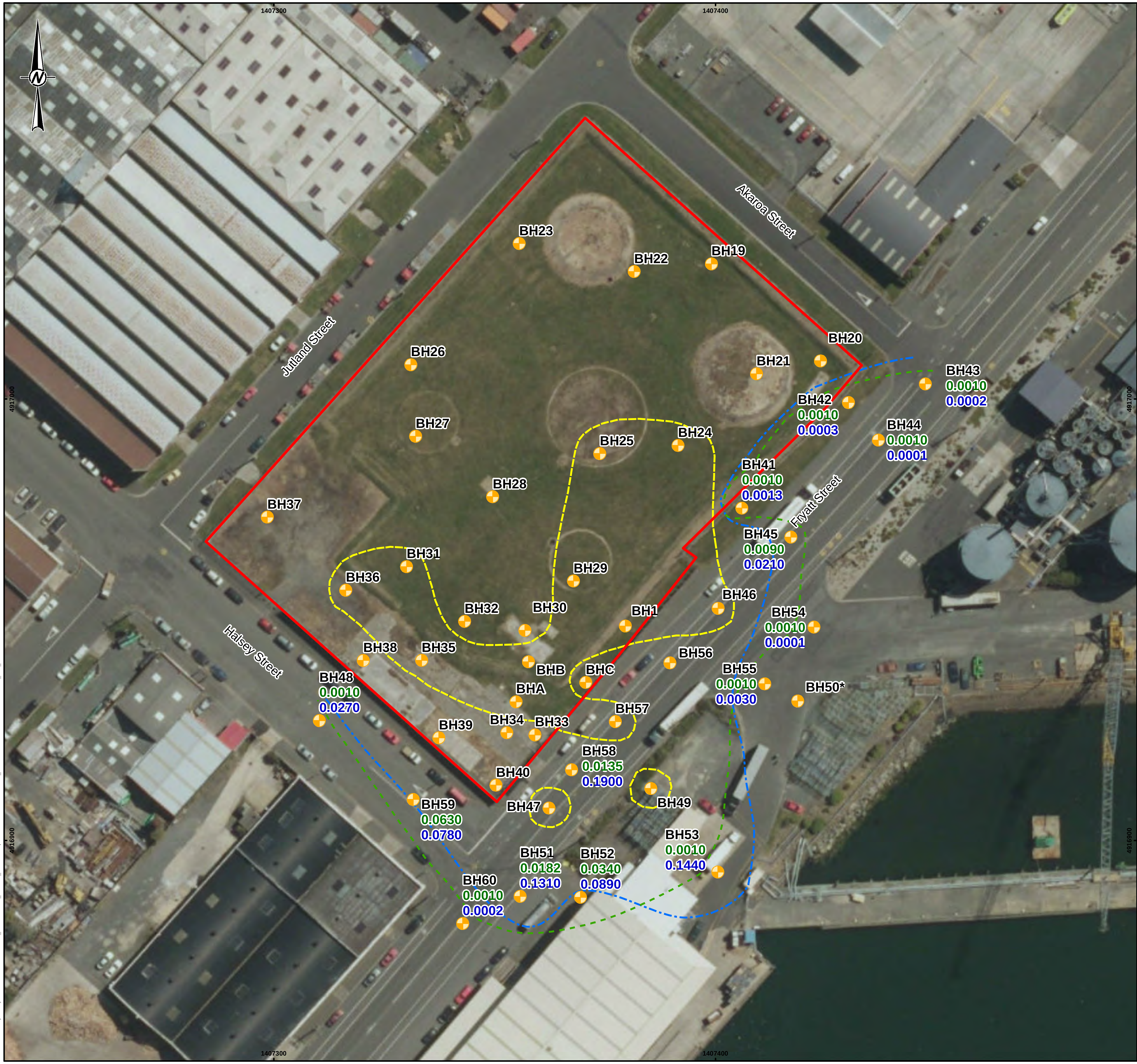

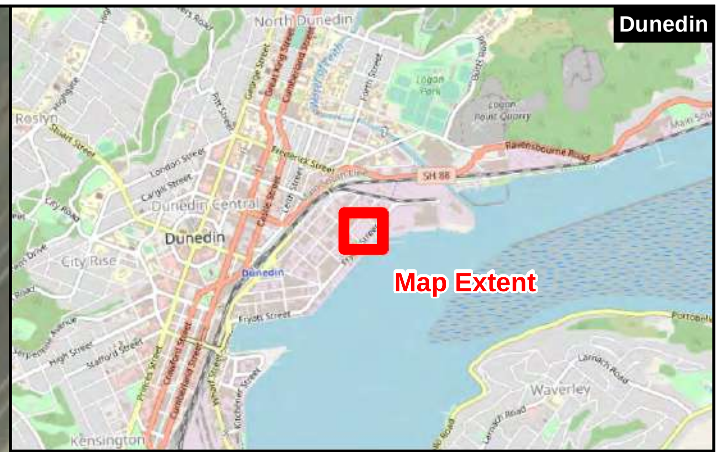

LEGEND

- Site boundary
- Monitoring well
  - Ethylbenzene concentration
  - Napthalene concentration
- Ethylbenzene (0.005 mg/L)
- Napthalene (0.07 mg/L)
- Inferred LNAPL extent

0 20 40 METRES

REFERENCE SCALE: 1:850 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

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5. CONTOURS BASED ON OFF-SITE DISSOLVED CONCENTRATIONS.
6. * WELL NOT SAMPLED.

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
INFERRED DISSOLVED PHASE HYDROCARBON EXTENT - JUNE 2016

CONSULTANT
GOLDER

MM-DD-YYYY	11/04/2019
PREPARED	AE
REVIEWED	ZM
APPROVED	AH

PROJECT NO.	CONTROL	REV.	FIGURE
1792933	003-R	1	23

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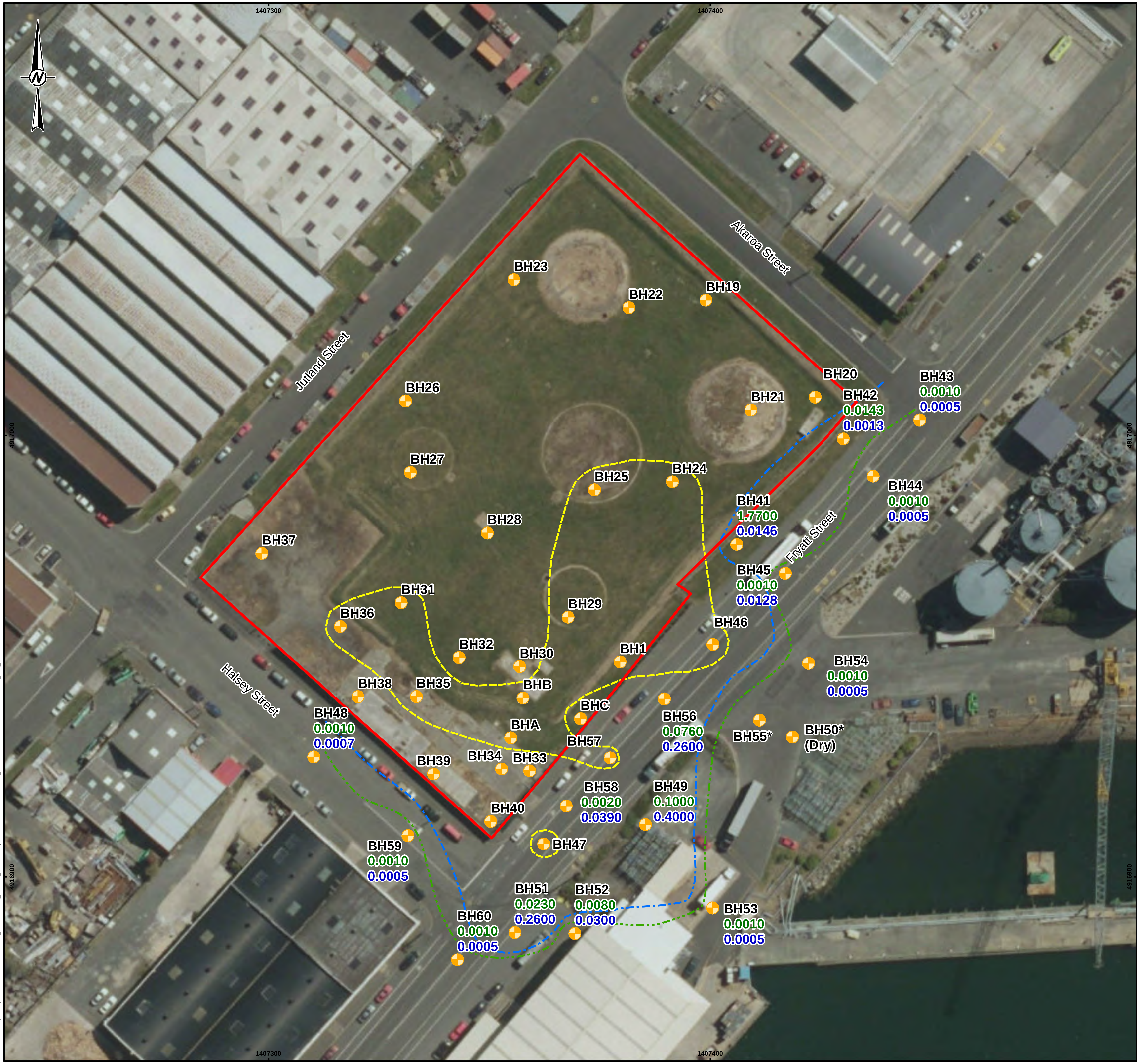

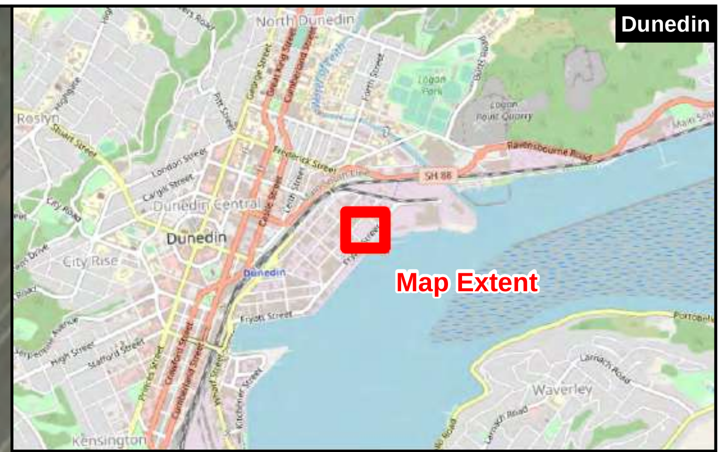

LEGEND

- Site boundary
- Monitoring well
  - Ethylbenzene concentration
  - Napthalene concentration
- Ethylbenzene (0.005 mg/L)
- Napthalene (0.07 mg/L)
- Inferred LNAPL extent

0 20 40

METRES

REFERENCE SCALE: 1:850 (at A3)

PROJECTION: NZGD 2000 New Zealand Transverse Mercator

NOTE(S)

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5. CONTOURS BASED ON OFF-SITE DISSOLVED CONCENTRATIONS.
6. * WELL NOT SAMPLED.

CLIENT
MOBIL OIL NEW ZEALAND LIMITED

PROJECT
FORMER MOBIL DUNEDIN TERMINAL

TITLE
INFERRED DISSOLVED PHASE HYDROCARBON EXTENT - APRIL 2017

CONSULTANT
GOLDER

MM-DD-YYYY	11/04/2019
PREPARED	AE
REVIEWED	ZM
APPROVED	AH

PROJECT NO.	CONTROL	REV.	FIGURE
1792933	003-R	1	24

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5.0 FATE AND TRANSPORT

5.1 Overview

Contaminant fate and transport considers several processes that occur in the saturated and unsaturated zones. Within groundwater, the processes of advection, diffusion, dispersion, sorption, volatilisation and degradation control the movement of contaminants in the aquifer. Within the unsaturated zone, similar processes may occur, however, transport is largely governed by diffusion, and is discussed in more detail in Section 6.0.

The fate and transport of the primary contaminants of interest, petroleum hydrocarbons are provided within this section.

5.2 Degradation Processes in Groundwater

Degradation processes in the subsurface may result from the reaction with other chemicals, enzymes or geochemical conditions. Generally, these are considered as abiotic or biodegradation processes. The rate of degradation and degradation pathway will vary with the specific chemical properties, physical properties, microbes and geochemistry.

Groundwater investigations have included the collection of data to enable a qualitative assessment of potential biodegradation processes for the COI.

A number of International technical guidance documents have been published for the assessment of natural attenuation of various compounds for petroleum hydrocarbons (AFCEE 2004, Newell et al. 1996, Wiedemeier et al. 1999). The framework underpinning each of the various guidance documents is the identification of various lines of evidence that can be used to estimate natural attenuation, and includes:

- **Primary evidence:** Historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points.
- **Secondary evidence:** Hydrogeologic and geochemical data that can be used to demonstrate indirectly the type(s) of natural attenuation processes active at the site, and the rate at which such processes reduce contaminant concentrations.
- **Tertiary evidence:** Data from field or microcosm studies (conducted in or with actual contaminated site media) which directly demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern.

5.2.1 Primary evidence

As indicated in Section 4.4.4, the historic trends of ethylbenzene and naphthalene, representative of petroleum hydrocarbon impacts, in most monitoring wells where there is sufficient historical data appear to be decreasing and as a whole, the statistical analysis would suggest that petroleum hydrocarbon contamination (as represented by these indicators) has been decreasing in concentration at relevant locations across the site over the past decade.

Similarly, as discussed in Section 4.4.2 the overall lateral extent and thickness of LNAPL appears to have diminished overtime. This is likely a function of ongoing biodegradation of the LNAPL mass and is discussed further in Section 6.0.

5.2.2 Secondary evidence of degradation

Petroleum hydrocarbons are most efficiently biodegraded under aerobic conditions. However, these contaminants may also be effectively biodegraded under anoxic or anaerobic condition using electron acceptors such as nitrate, ferrous iron, sulfate and carbon dioxide (or acetate) in reducing environments. Anaerobic degradation processes are likely occurring within central portions of the petroleum hydrocarbon impacted areas on the site, which suggested predominantly anaerobic reducing aquifer conditions (refer Section 2.4.5).

This is also supported by the soil vapour data (primarily vapour bore SV2 located over the main area of residual LNAPL) which indicates methanogenic conditions are present. Studies have indicated that the anaerobic biodegradation of petroleum hydrocarbons often accounts for greater than 90 % of the dissolved phase hydrocarbon mass degraded (Wiedemeier et al. 1999). At the edges of the plume, conditions will transition from anaerobic to aerobic condition given the shallow nature of the groundwater and the unconfined conditions. Aerobic degradations rates are typically an order of magnitude greater and serve to control the migration of the leading-edge of the dissolved phase hydrocarbon plume.

Another key line of evidence is the extent of the dissolved phase plume from the zone of observed LNAPL. Where this extent is small, i.e. tens of metres it indicates conditions conducive of biodegradation and attenuation. In other words, dissolved phase hydrocarbons from the LNAPL source are being readily degraded within a short distance along the groundwater flow path. The monitoring data indicates that the spatial extent of dissolved phase impacts related to petroleum hydrocarbons is relatively small and does not extend far downgradient from areas where LNAPL is present, i.e. typically 30 metres. This indicates a high degree of attenuation is occurring, most likely as a function of biodegradation. This is discussed further in the following section.

5.3 Dissolved Phase Plume Attenuation

Decreasing petroleum hydrocarbon concentrations along inferred groundwater flow paths imply that some form of attenuation is occurring, that is, there is a decrease in the concentration of dissolved phase contaminants with distance from the source. USEPA guidance on the calculation and use of first order attenuation rate constants (Newell et al. 2002) notes that a bulk attenuation rate (k) can be derived from a concentration (natural log) versus distance plots. The bulk attenuation rate constant incorporates all attenuation parameters (sorption, dispersion, degradation, dilution and volatilisation) for dissolved constituents after they leave the source.

The bulk attenuation rate (k) is calculated as follows:

$$k = \frac{\Delta S}{Vc}$$

Where k = bulk attenuation rate (yr^{-1})

ΔS = slope of the exponential regression of the concentration v distance plot (m^{-1})

Vc = contaminant velocity (m/yr)

As noted by Newel et al (2002), attenuation rate calculations can be affected by uncertainties from a number of sources, such as the design of the monitoring network, seasonal variations, sampling methods, laboratory analysis and the heterogeneity in most groundwater plumes. The uncertainties applicable to the site are likely around the monitoring well network, e.g. the distance between wells, and the heterogeneity of the groundwater plume. Monitoring data collected to date indicates that seasonal variations are minimal. Sampling methods and laboratory analytical methods have been consistent at the site for several years.

There is a reasonable network of monitoring wells located along and in proximity to inferred groundwater flow paths and the LNAPL source. A transect was selected near the south western corner of the site which includes the following monitoring wells:

- BH33 – This well is located within the inferred LNAPL extent and has generally recorded the presence of LNAPL, but occasionally has recorded no measurable LNAPL and has groundwater sampled for assessment of dissolved phase impacts, considered to be representative of LNAPL dissolution in source zone.
- BH58 – located on Fryatt Street and considered to be in near proximity to LNAPL as adjacent wells (BH47 and BH57) have typically recorded presence of LNAPL on Fryatt Street.
- BH53 – located adjacent to Otago Harbour (HabourCold Storage) and one of the furthest wells from inferred LNAPL extent.

The transect locations and monitoring wells used to assess the bulk attenuation rate constant are shown on Figure 25.

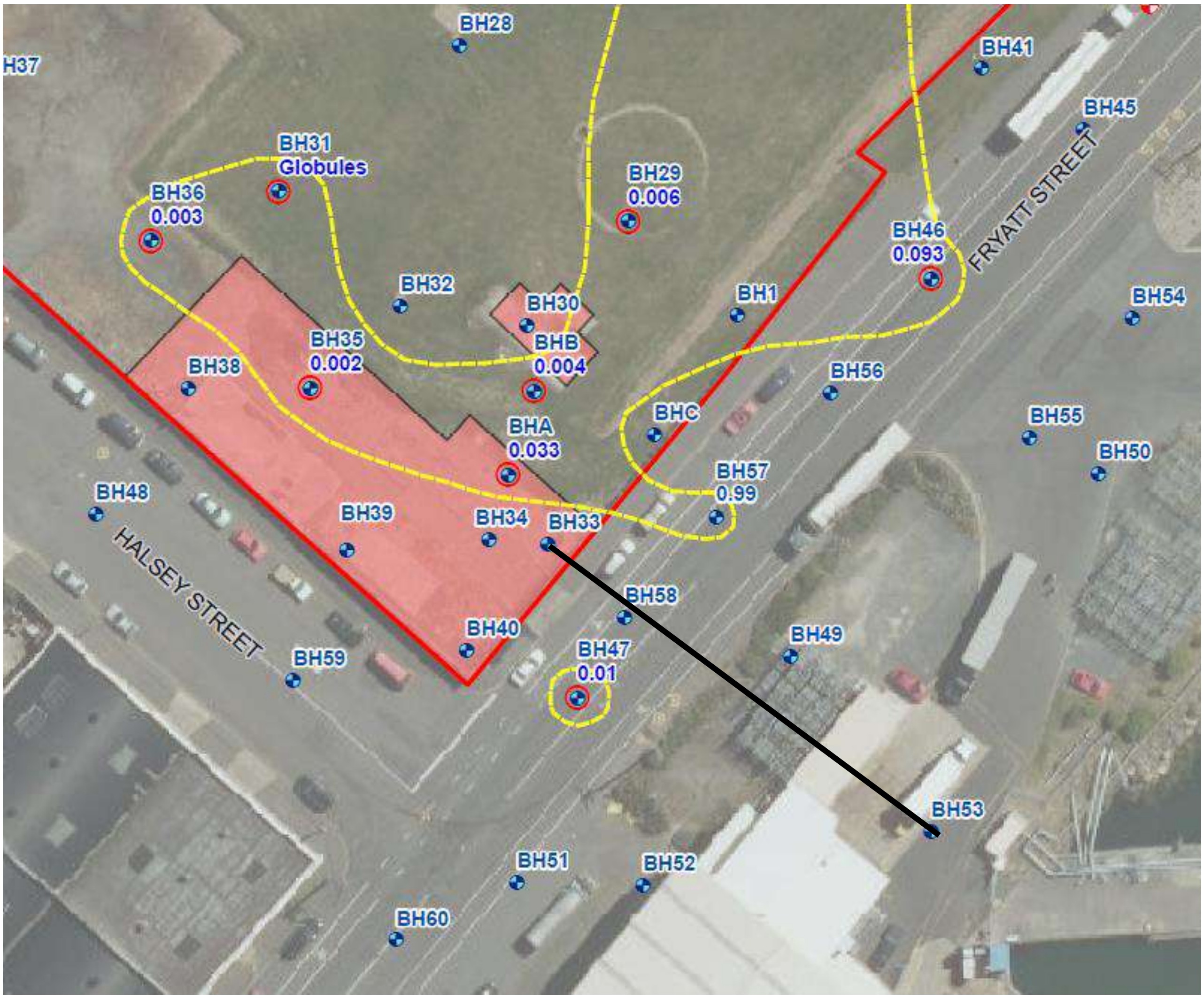

Figure 25: Transect location and monitoring wells used for natural attenuation rate assessment. Transect defined by black line. Inferred extent of LNAPL in April 2017 defined by yellow line.

Historical data from each of the monitoring wells in the transect were used to assess the bulk attenuation rate constant using concentration versus distance plots. A plot of concentration versus distance for the key contaminants ethylbenzene and naphthalene is presented on Figure 26 and Figure 27 respectively. In order to assess the length that the contaminant plume will travel before it attenuates to a specific concentration (conservatively assumed to be ANZECC (2000) 95 % trigger value), the relevant criteria has also been shown. In each instance, the data appears to fit a first order rate constant with a high regression coefficient (R^2) ranging from approximately 0.99 (ethylbenzene) to approximately 0.98 (naphthalene).

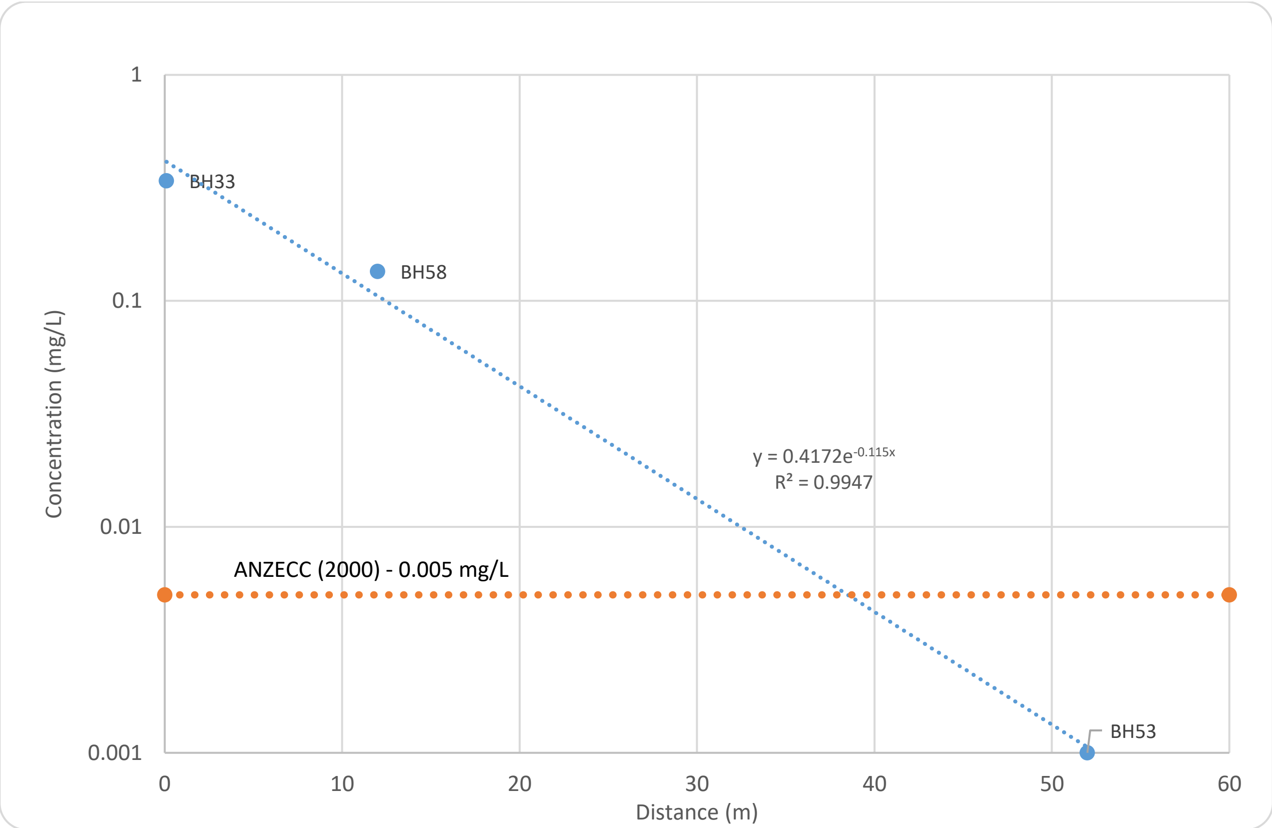

Figure 26: Ethylbenzene concentration versus distance.

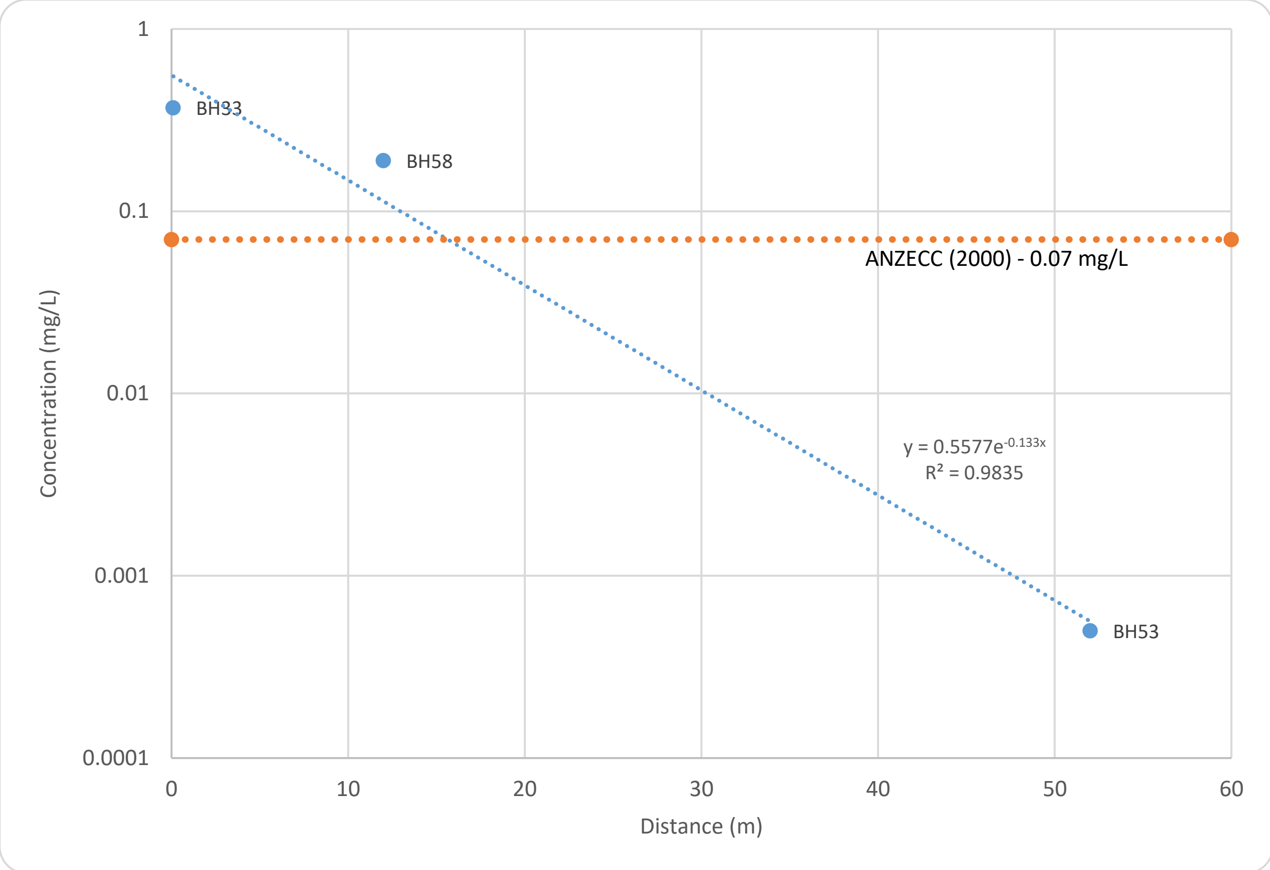

Figure 27: Naphthalene concentration versus distance.

The estimated "plume length" based on the relevant data for each of the selected contaminants is summarised on Table 11. It is estimated that ethylbenzene contamination sourced from the site which exceeds the ANZECC (2000) trigger value may extend up to 40 m downgradient of the leading edge of the LNAPL and is a function of having a much lower threshold trigger value than naphthalene.

Table 11: Estimated length of key petroleum hydrocarbon impacts based on concentration versus distance regression.

Contaminant	Estimated plume length (m)	Regression slope
Ethylbenzene	40	-0.115
Naphthalene	15	-0.133

In order to calculate a bulk attenuation rate constant (and in turn the half-life), an estimate of the plume migration rate is required. The rate of plume migration can be estimated from the groundwater seepage velocity and an estimate of the retardation factor (R_f) based on the following equation and the parameters outlined in Table 12:

$$Rf = \frac{Vgw}{Vc} = 1 + \frac{\rho b}{\eta} Kd$$

Table 12: Parameters for calculation of retardation factor and estimate of contaminant velocity.

Parameter	Description	Units	Source/Details
R_f	Retardation factor	Dimensionless	Calculated based on equation above
K_{oc}	Water/organic carbon partition coefficient	L/kg	Literature. USEPA (1995) – 250 mL/g for ethylbenzene and 933 for naphthalene
f_{oc}	Fraction of organic carbon	%	*f_{oc} = total organic carbon (TOC) in %/100* Aquifer conservatively assumed to have relatively low organic carbon in the order of ~ 0.25 %
K_d	Distribution coefficient	L/kg	Calculated. $K_d = K_{oc}. f_{oc}$.
η_t	Porosity (total)	Dimensionless	Estimated based on lithology ~ 30 %.
ρ_b	Bulk density	kg/m^3	Estimated – assumed to be ~ 1.8 g/cm^3 measure from site soil samples
V_{gw}	Groundwater seepage velocity	m/year	Calculated. $V_{gw} = K.i/\eta_e$ ~ 90 m/year (refer Section 2.4)
V_c	Contaminant velocity	m/year	Calculated. $V_c = V_{gw}/R_f$

Based on the parameters presented in Table 12, the bulk attenuation rate and corresponding half-live for ethylbenzene and naphthalene is summarised in Table 13.

Table 13: Estimated bulk attenuation rates and half-lives for key COIs.

Section	Retardation factor	Contaminant velocity (m/year)	Bulk attenuation rate (per year)	Half-life (months)
Ethylbenzene	4.75	18.5	2.12	3.9
Naphthalene	15	6	0.78	10.7

As noted above, the bulk attenuation rate constant incorporates all attenuation parameters (sorption, dispersion, degradation, dilution and volatilisation) for dissolved constituents after they leave the source. Since the fraction of organic carbon in the aquifer is assumed to be very low, the main mechanism for attenuation of petroleum hydrocarbons is considered to be a function of biodegradation, largely under anaerobic aquifer conditions within the plume, and primarily by methanogenesis.

Based on the concentration versus distance plot for ethylbenzene which has the lowest threshold criteria for protection of aquatic ecosystem, the impacts do not appear likely to extend further than 40 m downgradient of the LNAPL source. This is consistent with findings reported by Weidermeier et al (1999) of statistical studies conducted in California and Texas using data from nearly 2000 petroleum sites, which concluded that between 80 and 90 percent of petroleum hydrocarbon plumes are stable or receding and are less than 80 m long.

The estimated ethylbenzene bulk attenuation rate/half-life of 3.9 months (~120 days) is consistent with the rate constants for BTEX compounds as reported by Rifai and Newell (2001) which noted that typical values for half-life was in the order of 70 to 700 days. The relatively short bulk attenuation rate/half-life indicates that petroleum hydrocarbons are effectively attenuated resulting in relatively short plume lengths which are largely constrained to short distances from where LNAPL is present and the dissolved phase plumes are unlikely to discharge to Otago Harbour.

6.0 NATURAL SOURCE ZONE DEPLETION (NSZD)

6.1 Overview

As noted in Section 4.3 there is some data collected from soil vapour monitoring which clearly indicates that key natural biodegradation processes of the LNAPL mass are occurring. This is termed natural source zone depletion (NSZD). The following sections presents an overview of NSZD including relevant guidance documents, conceptual model of the key vadose zone vapour processes. Using the NSZD rates published from a large number of international studies, an indicative range of potential LNAPL depletion is provided for the Former Dunedin Terminal.

6.2 NSZD Guidance Documents

Natural source zone depletion (NSZD) is emerging as an important remediation approach for petroleum hydrocarbon sites. In recent years, rapid advances have been made with NSZD as documented in a large body of research. This research has been synthesised into various documents which provide guidance for application of NSZD for site characterisation and remediation and include:

- Golder (2016). *Toolkits for Evaluation of Monitored Natural Attenuation and Natural Source Zone Depletion*. https://csapsociety.bc.ca/members/professional-development/technical-studies/
- API (2017). *Quantification of Vapor Phase-related Natural Source Zone Depletion Processes*.
- ITRC (2018). LNAPL-3: *LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies.* https://lnapl-3.itrcweb.org/
- CRC CARE (2018). *Technical Measurement Guidance for LNAPL Natural Source Zone Depletion*. https://www.crccare.com/publications/technical-reports/technical-reports

6.3 Paradigm Shift from MNA to NSZD

The widespread acceptance of natural processes being important in hydrocarbon attenuation started in the early 1990s (Newell et al. 1996; Wiedemeier et al. 1999), where monitored natural attenuation (MNA) was recognised as playing a key role in dissolved plume stability (as discussed in Section 5.3). These hydrocarbon source zone mass balance models incorrectly assumed that hydrocarbon mass removal fully accounted for the mass discharge of aqueous phase electron acceptors entering, and soluble by-products (ferrous iron and dissolved methane) leaving saturated LNAPL source zones. This focus on the horizontal flux of reaction constituents in the saturated zone led to the conclusion that LNAPL source zones biodegraded at a rate of only a few 10s to 100s of litres of LNAPL depletion.

A large number of researchers over past decade have focussed on the model where methanogenesis coupled with transport of gases (methane, carbon dioxide, and volatile organic compounds) through the vadose zone is recognised as the primary mass-loss mechanism. The research indicates that this typically accounts for more than 90 % of LNAPL mass loss.

Some key aspects of the paradigm shift from MNA to NSZD include:

- Depletion of LNAPL body not just dissolved phase constituents.
- All LNAPL constituents are biodegraded, including short-chain aromatics (BTEX) and long-chain alkanes.
- NSZD rates are in the order of 100s to 1000s L/hectare/year.

6.4 NSZD Conceptual Model

Garg et al (2017) presented a NSZD conceptual model, based on Irianni-Renno et al. (2016) and is shown in Figure 28.

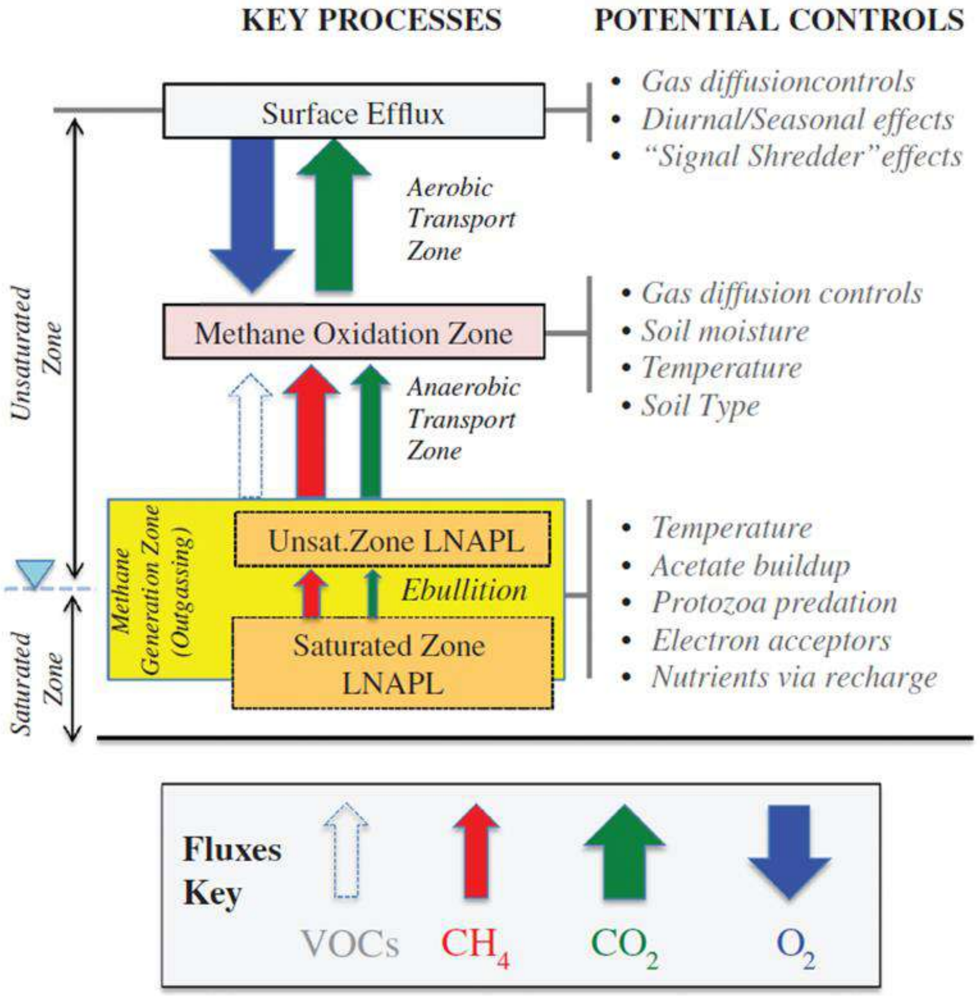

Figure 28: Vapour transport related processes (Garg et al. 2017).

Three distinct zones can be defined for their key role in the overall NSZD process:

- Methane Generation Zone
  - Significant methanogenesis which results in direct outgassing and ebullition of methane and carbon dioxide.
- Methane Oxidation Zone (methanotrophic zone)
  - Methane and carbon dioxide migrate upward through the vadose zone (principally by diffusion) to a relatively thin reaction zone where most or all of the methane and VOCs (if present) are oxidized to carbon dioxide.

- Aerobic Transport Zone
  - Oxygen diffuses toward the methane oxidation zone, and the produced carbon dioxide diffuses upward through the unsaturated zone and can be measured as a surface efflux of carbon dioxide.
  - If the shallow vadose zone is also contaminated and utilises more oxygen than that necessary to fully oxidise the methane from the methane production zone, methane efflux could occur.

As discussed in Section 4.3, shallow soil vapour sampling at the site has demonstrated the presence of methane and elevated carbon dioxide in conjunction with depletion of oxygen consistent with the NSZD conceptual mode presented above.

NSZD is likely occurring across the entire LNAPL footprint at the site. The trends in reducing LNAPL distribution and thickness over time as well as the presence of these gases indicate that NSZD is occurring at this site and hence ongoing degradation of the LNAPL can be expected overtime.

7.0 POTENTIAL FUTURE RISK, MONITORING AND MANAGEMENT

7.1 Potentially Complete Source-Pathway-Receptor Linkage

An exposure pathway describes the course a chemical or physical agent takes from the site source to the exposed receptor and generally includes the following elements:

- A source and mechanism of chemical release.
- A retention or transport medium (or media where chemicals are transferred between media).
- A point of potential human or ecological contact with the contaminated medium.
- An exposure route (e.g., ingestion, inhalation) at the point of exposure.

Golder (2019) presented a Conceptual Site Model (CSM) which include an assessment of Source-Pathway-Receptor linkages and identified the following potentially complete exposure pathways, for site derived contamination.

Human health

- On-site inhalation of petroleum hydrocarbon vapours during excavation works in shallow soils and/or close to the groundwater table undertaken in central and southern areas of the site, likely to be associated with LNAPL and soil impacts.
- Off-site inhalation of petroleum hydrocarbon vapours during deep excavation works, particularly those that intersect the groundwater along Fryatt Street adjacent to the site.
- Occupiers of poorly ventilated workspaces located across the southern half of the site via the vapour intrusion pathway due to the presence LNAPL.

Environment

- Migration of impacted groundwater from the site towards Otago Harbour and associated marine ecosystems.

Based on the additional assessment documented in this Closure Report these receptors remain valid. No other potentially complete source-pathway-receptor linkages are considered to exist.

7.2 Current and Potential Future Risks

7.2.1 Human health

The site is located in a commercial/industrial area of Dunedin. Based on the current understanding of soil and groundwater conditions at the site, the potential risks associated with the future commercial/industrial use of the site are anticipated to be:

- Workers undertaking sub-surface excavation works or working within underground voids both on site and off site in the area of Fryatt Street have a potential exposure risk to petroleum hydrocarbon vapours and dermal contact/ ingestion. Appropriate health and safety controls should be in place to manage risk to workers associated with sub surface excavations.
- Ensuring soil and groundwater disturbed during earthworks is appropriately managed to mitigate risks to human health and the environment and is disposed to an appropriately licensed disposal facility.

- Intrusion of soil vapour to indoor air in buildings constructed over areas of residual LNAPL. Risks to indoor air can be managed through appropriate consideration in building design such as ventilation or use of a vapour barrier depending on the building use and location with respect to the groundwater impacts.

The use of soil and groundwater management best practices at the site should enable the site to operate as a continued commercial/industrial land use designation with minimal limitations to normal operation of the site. Future buildings may need to be considered the use of a vapour barrier to limit the potential for vapour migration from sub-surface soils and groundwater into indoor air.

7.2.2 Environment

Overall the lateral extent of LNAPL has contracted over time. This is supported by the apparent reduction in LNAPL thickness at many locations over the past decade, which indicates it is not mobile and does not pose a risk of migration towards or discharge into Otago Harbour. This is supported from testing of wells which indicate a low LNAPL transmissivity suggesting low recoverability and low mobility.

Several petroleum hydrocarbon compounds including ethylbenzene, m&p-xylene and naphthalene exceeded ANZECC (2000) trigger values for the protection of marine ecosystems in groundwater off site. However, these off-site locations are limited to only a portion of land extending from the southern end of the site, and the concentrations of these compounds in monitoring wells adjacent to Otago Harbour are below the ANZECC (2000) trigger values. More importantly the contaminants are being effectively attenuated through biodegradation of the dissolved phase hydrocarbons. The assessment of the attenuation and the estimate half-lives of key contaminant support the conclusion that the concentrations observed in the off-site groundwater are not likely to present a risk to the marine ecosystems in Otago Harbour.

An assessment of the dissolved phase contaminant trend indicate that the concentrations are stable or decreasing and will not pose a future risk to Otago Harbour.

7.3 Regulatory Context

7.3.1 Regional Plan – Waste for Otago

Otago Regional Council's (ORC) Regional Plan – Waste for Otago (Regional Plan - Waste) adopts the definition of a contaminated site as "*a site at which hazardous substances occur at concentrations above background levels and where assessment indicates it poses, or is likely to pose an immediate or long term hazard to human health or the environment*". As part of its approach to the management of contaminated land, the Regional Plan – Waste for Otago includes policies, objectives and rules with the intended purpose of ensuring contaminated sites are located and assessed, ensuring immediate and long-term protection of the environment from contaminated sites is achieved and new contaminated sites are not created.

The Regional Plan – Waste includes rules for the management of contaminated land with respect to the disturbance of contaminated sites and the discharge of:

- "hazardous waste into water",
- "hazardous waste onto or into land in circumstances that may result in that hazardous waste (or any other hazardous waste emanating as a result of natural processes from that hazardous waste) entering water"; or
- "hazardous waste into air at or from a contaminated site".

Under the Regional Plan – Waste, these activities are considered to require a discharge permit as a discretionary activity. The Regional Plan – Waste does not specify criteria to assess the effects of a discharge from a contaminated site. However, the Regional Plan – Waste refers to the ANZECC (1992) Guidelines for the Assessment and Management of Contaminated Sites as a basis for decision making on the management of contaminated sites and is focused on ensuring immediate and long-term protection of the environment.

Adoption of the ANZECC (1992) guidelines supports the implementation of a risk-based decision-making process for the management of contaminated land. The ANZECC (1992) guideline notes that a fundamental goal is to "*render a site acceptable and safe for continuation of its existing use*". Further it considers that where there is no threat to human health and the environment is not at risk, a management approach is acceptable particularly where further investment in site investigation and remediation will not result in a net benefit with respect to understanding and managing risks associated with residual contamination.

With respect to discharges to the environment, the groundwater quality data have been compared with trigger values for the protection of aquatic ecosystems (ANZECC 2000). Adoption of the ANZECC (2000) trigger values provides a conservative assessment in that it does not account for attenuation and dilution between the site and Otago Harbour. For assessment purposes, the 95 % trigger values are considered applicable as they have been derived for 'slightly to moderately' disturbed ecosystems, or where the ecosystem has been heavily disturbed, but it is aimed to reduce contamination so that the ecosystem can recover.

Groundwater quality data collected from the site, as outlined in this Closure Report, shows that hydrocarbon impacts have and continue to attenuate within approximately 30 m of the site boundary and that concentrations in the monitoring wells closest to Otago Harbour are below adopted ANZECC (2000) trigger values.

7.3.2 Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011

The assessment of risk to human health from contaminated soil is regulated by the Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (NES_{soil}). The NES_{soil} is enforced by territorial authorities, and:

- Sets a standard at which land is considered to pose a minimal risk to human health.
- Seeks to ensure that land affected by contaminants in soil is appropriately identified and assessed during development; and if necessary remediated, or the contaminants contained.

The NES_{soil} is applicable to a piece of land where an activity or industry described in the HAIL is, has or is more than likely to have been on it. Where applicable, the NES_{soil} permits and controls certain activities on land affected or potentially affected by contaminants, including soil disturbance, subdivision and change of land use. It does not apply to the site until one of these activities takes place.

The NES_{soil} outlines a framework for the adoption of applicable standards (regulation 7) for the assessment of contaminants in soil to protect human health. The framework adopts soil contaminants standards (SCS_{health}) for priority contaminants (derived using MfE's (2011b) methodology) and soil guideline values (SGVs) for non-priority contaminants selected using the hierarchy outlined in MfE (2011c) guidance. The framework also allows for the derivation of site-specific SGVs (following the methods and guidance presented in MfE (2011b)).

The NES_{soil} also outlines the consent activity status with respect to each of the activities managed by the NES_{soil}. The consent activity status is primarily based on the concentrations of contaminants in soil and whether they exceed an applicable standard.

The investigation data collected during the ESA works at the site have documented the presence of contaminants at concentrations that exceed SGVs for a commercial/industrial land use exposure scenario. Future disturbance, land use change or subdivision would require a land use consent as a restricted activity under regulation 10 of the NES_{soil}. A key requirement of an application for land use consent would be the preparation of an Environmental (Site) Management Plan to outline the methodology for the works and associated controls for the management of contaminants in soil and risks to human health and the environment.

7.4 Future Monitoring

Future ongoing monitoring is not considered to be warranted based on the following:

- The LNAPL mass is not considered to be mobile and poses no further risk of migration
- The overall trend in the apparent reduction of the lateral extent and thickness of LNAPL.
- The dissolved phase contamination has and is continuing to attenuate. Concentrations adjacent to Otago Harbour are below the ANZECC (2000) trigger values.
- A clear trend of decreasing dissolved phase hydrocarbon concentrations which indicates that contamination is unlikely to pose a future risk to Otago Harbour.
- Soil vapour monitoring indicates no unacceptable risk to off-site commercial-industrial land-use.

However, a management plan should be adopted to manage residual contamination for both potential on-site and off-site human receptors and is described further in the following section.

7.5 Site Management Plan

Potential risks to current and potential future on-site and off-site human receptors should be addressed through an Environmental Management Plan (EMP). The EMP should be developed in consultation with relevant stakeholders and include, but not be limited to the following:

- A clear statement on the purpose of EMP.
- An outline of the relevant parties.
- General site details.
- Summary of contamination risks.
- Site management protocols for **on-site** areas in relation to:
  - outline of controls (including health and safety aspects such as PPE requirements and workplace monitoring) for soil disturbance and disposal
  - outline of controls (including health and safety aspects such as PPE requirements and workplace monitoring) for groundwater management during excavations below the groundwater table, potential dewatering including disposal.
  - outline of potential controls around building construction with respect to addressing potential vapour intrusion risks.
- Site management protocols for **off-site** areas along Fryatt Street. These would include an outline of controls (including health and safety aspects such as PPE requirements and workplace monitoring) for soil disturbance and the management of groundwater during excavations below the water table and dewatering including disposal.

8.0 CONCLUSIONS

LNAPL Extent and Stability

LNAPL is present in several monitoring wells located across the southern half of the site, specifically the southern part of the former tank compound, drum filling site and tanker wagon fill station. The LNAPL consists predominately of diesel with some petrol. Given the heterogeneous nature of the fill, it is likely that the LNAPL does not comprise one single continuous layer. Rather, residual LNAPL is present as a series of smaller discontinuous LNAPL pockets with varying LNAPL saturations.

Overall the lateral extent of LNAPL appears to be contracting over time and is supported by the apparent reduction in LNAPL thickness at many locations over the past decade. This indicates the LNAPL is not mobile and does not pose a risk of migration towards or discharge into Otago Harbour. This is supported from testing of wells which indicates a low LNAPL transmissivity, low recoverability and low mobility.

Dissolved Phase Contaminant Plume Stability

An assessment of the stability of various dissolved phase contaminant plumes can be made using trend analysis, estimates of the plume velocity, attenuation rates and predicted plume lengths. The stability of dissolved phase plume is summarised as follows:

- The concentration trend for ethylbenzene, C_{10}-C_{14} TPH and naphthalene, which are considered to be the key indicators of the dissolved phase petroleum hydrocarbon contamination, indicate that overall concentrations have decreased over the past decade.
- The assessment the ethylbenzene and naphthalene attenuation rates indicate that the dissolved phase contamination does not extend further than 40 m downgradient of the leading edge of the LNAPL.

Therefore, given the decreasing trends and the relatively short extent of impacts, the dissolved phase hydrocarbons are unlikely to migrate beyond the current extent and are unlikely to pose a future risk to Otago Harbour.

Natural Source Zone Depletion (NSZD)

Shallow soil vapour sampling at the site has demonstrated the presence of methane and elevated carbon dioxide in conjunction with depletion of oxygen consistent with the NSZD conceptual model of the key vadose zone vapour processes. The trends in LNAPL distribution and thickness over time as well as the presence of these gases indicate that NSZD is occurring at this site and hence ongoing degradation of the LNAPL can be expected overtime.

Future Monitoring

Future ongoing monitoring is not considered to be warranted based on the following:

- The LNAPL mass is not considered to be mobile and poses no further risk of migration
- The overall trend in the apparent reduction of the lateral extent and thickness of LNAPL.
- The dissolved phase contamination has and is continuing to attenuate. Concentrations adjacent to Otago Harbour are below the ANZECC (2000) trigger values.
- A clear trend of decreasing dissolved phase hydrocarbon concentrations which indicates that contamination is unlikely to pose a future risk to Otago Harbour.
- Soil vapour monitoring indicates no unacceptable risk to off-site commercial-industrial land-use.

Future Land Use and Management of Risks

The site is located in a commercial/industrial area of Dunedin. Based on the current understanding of soil and groundwater conditions at the site, the potential risks associated with the future commercial/industrial use of the site are anticipated to be:

- Workers undertaking sub-surface excavation works or working within underground voids both on site and off site in the area of Fryatt Street have a potential exposure risk to petroleum hydrocarbon vapours and dermal contact/ ingestion. Appropriate health and safety controls should be in place to manage risk to workers associated with sub surface excavations.
- Ensuring soil and groundwater disturbed during earthworks is appropriately managed to mitigate risks to human health and the environment and is disposed to an appropriately licensed disposal facility.
- Intrusion of soil vapour to indoor air in buildings constructed over areas of residual LNAPL. Risks to indoor air can be managed through appropriate consideration in building design such as ventilation or use of a vapour barrier depending on the building use and location with respect to the groundwater impacts.

Potential risks to current and potential future on-site and off-site receptors should be addressed through an EMP.

9.0 LIMITATIONS

Your attention is drawn to the document, "Report Limitations", as attached (Appendix E). The statements presented in that document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks to which this report relates which are associated with this project. The document is not intended to exclude or otherwise limit the obligations necessarily imposed by law on Golder Associates (NZ) Limited, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

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APPENDIX A

Groundwater and LNAPL Monitoring Data

Mobil Oil New Zealand Limited
Former Mobil Dunedin Terminal

Monitoring Well	Total Depth of Well	Screen Interval	Top of Casing	Top of Screen	Bottom of Screen	10-Aug-09					11 April 2011					30 April 2012				
						Depth to LNAPL	Depth to Water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness	Depth to LNAPL	Depth to Water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness	Depth to LNAPL	Depth to Water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness
	m bgl	m bgl	m RL	m RL	m RL	m BTOC	m BTOC	m RL	m RL	m	m BTOC	m BTOC	m RL	m RL	m	m BTOC	m BTOC	m RL	m RL	m
BH1	3.0	0.6 - 3.0	103.03	102.43	100.03	2.036	2.102	100.994	100.928	0.066	2.005	2.125	101.025	100.905	0.12	2.139	2.24	100.891	100.79	0.101
BH9	3.1	0	Unknown			-	1.084	-	-	Sheen	Well Destroyed					Well Destroyed				
BH15	3.0	0.6 - 3.0	Unknown	0.6	3.0	-	1.881	-	-	Globules	Well Destroyed					Well Destroyed				
BH19	4.0	0.5 - 4.0	103.205	102.705	99.205	Not Installed					-	2.017	-	101.188	-	-	2.19	-	101.015	-
BH20	4.0	0.5 - 4.0	103.15	102.65	99.15	Not Installed					2.07	2.073	101.08	101.077	0.003	2.14	2.23	101.01	100.92	0.09
BH21	4.5	0.9 - 4.5	103.47			Not Installed					-	2.333	-	101.137	-	-	2.512	-	100.958	-
BH22	4.0	0.5 - 4.0	103.25	102.75	99.25	Not Installed					-	2.042	-	101.208	-	2.21	2.21	101.04	101.04	Globules
BH23	4.0	0.5 - 4.0	103.1	102.6	99.1	Not Installed					-	1.748	-	101.352	-	-	1.937	-	101.163	-
BH24	4.0	0.5 - 4.0	102.945	102.445	98.945	Not Installed					-	1.861	-	101.084	Sheen	1.95	1.95	100.995	100.995	Globules
BH25	4.0	0.5 - 4.0	102.855	102.355	98.855	Not Installed					-	1.59	-	101.265	-	1.285	1.375	101.57	101.48	0.09
BH26	4.0	0.5 - 4.0	103.045	102.545	99.045	Not Installed					-	1.505	-	101.54	-	-	1.577	-	101.468	-
BH27	4.0	0.5 - 4.0	102.925	102.425	98.925	Not Installed					-	1.376	-	101.549	Sheen	-	1.553	-	101.372	-
BH28	4.0	0.5 - 4.0	103.1	102.6	99.1	Not Installed					-	1.891	-	101.209	-	1.86	1.86	101.24	101.24	Globules
BH29	4.0	0.5 - 4.0	103.02	102.52	99.02	Not Installed					-	1.973	-	101.047	-	2.083	2.301	100.937	100.719	0.218
BH30	4.5	0.9 - 4.5	103.555	102.655	99.055	Not Installed					-	2.472	-	101.083	Sheen	-	2.568	-	100.987	-
BH31	4.0	0.5 - 4.0	103.055	102.555	99.055	Not Installed					-	1.657	-	101.398	Sheen	1.89	2.062	101.165	100.993	0.172
BH32	4.0	0.5 - 4.0	103.155	102.655	99.155	Not Installed					-	1.771	-	101.384	Sheen	-	2.033	-	101.122	-
BH33	4.0	0.5 - 4.0	102.645	102.145	98.645	Not Installed					-	1.61	-	101.035	Sheen	1.732	1.861	100.913	100.784	0.129
BH34	4.0	0.5 - 4.0	102.935	102.435	98.935	Not Installed					-	1.895	-	101.04	Sheen	-	2.04	-	100.895	Sheen
BH35	4.0	0.5 - 4.0	102.88	102.38	98.88	Not Installed					-	1.597	-	101.283	Sheen	1.809	1.97	101.071	100.91	0.161
BH36	4.0	0.5 - 4.0	103.12	102.62	99.12	Not Installed					-	1.506	-	101.614	Sheen	1.785	1.785	101.335	101.335	Globules
BH37	4.0	0.5 - 4.0	103.015	102.515	99.015	Not Installed					-	1.294	-	101.721	-	-	1.516	-	101.499	-
BH38	4.0	0.5 - 4.0	102.825	102.325	98.825	Not Installed					-	1.235	-	101.59	Sheen	-	1.396	-	101.429	-
BH39	4.0	0.5 - 4.0	103.06	102.56	99.06	Not Installed					-	1.689	-	101.371	Sheen	-	1.891	-	101.169	-
BH40	4.0	0.5 - 4.0	102.885	102.385	98.885	Not Installed					-	1.724	-	101.161	Sheen	-	1.911	-	100.974	-
BH41	4.0	0.5 - 4.0	102.875	102.375	98.875	Not Installed					-	1.883	-	100.992	-	-	2.011	-	100.864	-
BH42	4.0	0.5 - 4.0	102.7	102.2	98.7	Not Installed					-	1.687	-	101.013	Sheen	-	1.794	-	100.906	-
BH43	4.0	0.5 - 4.0	102.875	102.375	98.875	Not Installed					1.858	1.965	101.017	100.91	0.107	1.962	1.988	100.913	100.887	0.141
BH44	4.0	0.5 - 4.0	102.975	102.475	98.975	Not Installed					2.02	2.02	100.955	100.955	Globules	-	2.09	-	100.885	Sheen
BH45	4.0	0.5 - 4.0	103.14	102.64	99.14	Not Installed					-	2.201	-	100.939	-	-	2.284	-	100.856	-
BH46	4.0	0.5 - 4.0	103.01	102.51	99.01	Not Installed					2.046	2.117	100.964	100.893	0.071	2.159	2.159	100.851	100.851	0.009
BH47	4.0	0.5 - 4.0	102.75	102.25	98.75	Not Installed					1.673	1.742	101.077	101.008	0.069	1.821	1.824	100.929	100.926	0.038
BH48	4.0	0.5 - 4.0	102.71	102.21	98.71	Not Installed					-	1.178	-	101.532	Sheen		1.315	-	101.395	-
BH49	4.0	0.5 - 4.0	102.64	102.14	98.64	Not Installed					1.629	1.631	101.011	101.009	0.002	1.767	1.767	100.873	100.873	0.012
BH50	5.0	0.5 - 5.0	103.09	102.59	99.09	Not Installed					-	2.245	-	100.845	Sheen	-	2.29	-	100.8	-
BH51	4.0	0.5 - 4.0	102.656	102.156	98.656	Not Installed					Not Installed					Not Installed				
BH52	4.0	0.5 - 4.0	102.432	101.932	98.432	Not Installed					Not Installed					Not Installed				
BH53	5.0	0.5 - 5.0	103.072	102.572	98.072	Not Installed					Not Installed					Not Installed				
BH54	3.0		102.840	102.340	99.840	Not Installed					Not Installed					Not Installed				
BH55	3.0		102.765	102.265	99.765	Not Installed					Not Installed					Not Installed				
BH56	3.0		102.852	102.352	99.852	Not Installed					Not Installed					Not Installed				
BH57	3.0		102.770	102.270	99.770	Not Installed					Not Installed					Not Installed				
BH58	3.0		102.693	102.193	99.693	Not Installed					Not Installed					Not Installed				
BH59	3.0		102.625	102.125	99.625	Not Installed					Not Installed					Not Installed				
BH60	3.0		102.621	102.121	99.621	Not Installed					Not Installed					Not Installed				
BHA	5.2	2.5 - 5.19	103.095	100.595	97.905	2.751	3.175	100.344	99.92	0.424	2	2.165	101.095	100.93	0.165	2.19	2.235	100.905	100.86	0.045
BHB	5.1	2.5 - 5.10	103.32	100.82	98.22	2.765	3.296	100.555	100.024	0.531	2.232	2.419	101.088	100.901	0.187	2.407	2.521	100.913	100.799	0.114
BHC	5.2	2.5 - 5.18	102.91	100.41	97.73	-	2.9	-	100.01	-	-	1.883	-	101.027	-	-	2.03	-	100.88	Sheen

Notes:
Data collected prior to December 2013 reported by PDP (2013).
Data from December 2013 to 2017 collected by Golder.

Mobil Oil New Zealand Limited
Former Mobil Dunedin Terminal

Monitoring Well	Total Depth of Well	Screen Interval	Top of Casing	Top of Screen	Bottom of Screen	9 July 2013					4 December 2013					11 June 2014				
						Depth to LNAPL	Depth to Water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness	Depth to LNAPL	Depth to Water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness	Depth to LNAPL	Depth to Water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness
	m bgl	m bgl	m RL	m RL	m RL	m BTOC	m BTOC	m RL	m RL	m	m BTOC	m BTOC	m RL	m RL	m	m BTOC	m BTOC	m RL	m RL	m
BH1	3.0	0.6 - 3.0	103.03	102.43	100.03	1.58	2.115	101.45	100.915	0.535	2.051	2.216	100.979	100.814	0.165	1.573	2.118	101.457	100.912	0.545
BH9	3.1	0	Unknown			Well Destroyed					Well Destroyed					Well Destroyed				
BH15	3.0	0.6 - 3.0	Unknown	0.6	3.0	Well Destroyed					Well Destroyed					Well Destroyed				
BH19	4.0	0.5 - 4.0	103.205	102.705	99.205	-	1.617	-	101.588	-	-	2.177	-	101.028	-	-	1.518	-	101.687	-
BH20	4.0	0.5 - 4.0	103.15	102.65	99.15	-	1.703	-	101.447	-	-	2.226	-	100.924	-	-	1.692	-	101.458	-
BH21	4.5	0.9 - 4.5	103.47			-	1.004	-	102.466	-	-	2.495	-	100.975	-	-	1.065	-	102.405	-
BH22	4.0	0.5 - 4.0	103.25	102.75	99.25	-	0.76	-	102.49	-	-	2.093	-	101.157	-	-	0.294	-	102.956	-
BH23	4.0	0.5 - 4.0	103.1	102.6	99.1	-	0.395	-	102.705	-	-	1.912	-	101.188	-	-	0.329	-	102.771	-
BH24	4.0	0.5 - 4.0	102.945	102.445	98.945	1.323	2.08	101.622	100.865	0.757	1.943	2.264	101.002	100.681	0.321	1.284	1.715	101.661	101.23	0.431
BH25	4.0	0.5 - 4.0	102.855	102.355	98.855	0.289	0.564	102.566	102.291	0.275	1.546	1.839	101.309	101.016	0.293	-	-	-	-	-
BH26	4.0	0.5 - 4.0	103.045	102.545	99.045	-	0.633	-	102.412	-	-	1.369	-	101.676	-	-	0.494	-	102.551	-
BH27	4.0	0.5 - 4.0	102.925	102.425	98.925	-	0.44	-	102.485	-	-	1.445	-	101.48	-	-	0.197	-	102.728	-
BH28	4.0	0.5 - 4.0	103.1	102.6	99.1	-	0.673	-	102.427	-	-	1.514	-	101.586	-	-	0.268	-	102.832	-
BH29	4.0	0.5 - 4.0	103.02	102.52	99.02	1.116	2.013	101.904	101.007	0.897	1.917	2.847	101.103	100.173	0.93	0.605	0.797	102.415	102.223	0.192
BH30	4.5	0.9 - 4.5	103.555	102.655	99.055	-	1.327	-	102.228	-	-	2.437		101.118	-	-	1.062	-	102.493	-
BH31	4.0	0.5 - 4.0	103.055	102.555	99.055	0.925	0.953	102.13	102.102	-	1.589	1.729	101.466	101.326	0.14	-	0.592	-	102.463	-
BH32	4.0	0.5 - 4.0	103.155	102.655	99.155	-	0.874	-	102.281	-	-	1.894		101.261	-	-	0.44	-	102.715	-
BH33	4.0	0.5 - 4.0	102.645	102.145	98.645	1.073	1.081	101.572	101.564	0.008	1.66	1.663	100.985	100.982	0.003	-	0.823	-	101.822	-
BH34	4.0	0.5 - 4.0	102.935	102.435	98.935	1.401	1.401	101.534	101.534	Globules	-	1.808		101.127	-	-	1.165	-	101.77	-
BH35	4.0	0.5 - 4.0	102.88	102.38	98.88	0.929	1.208	101.951	101.672	0.279	1.633	1.972	101.247	100.908	0.339	0.551	0.553	102.329	102.327	0.002
BH36	4.0	0.5 - 4.0	103.12	102.62	99.12	-	1.077	-	102.043		1.624	1.624	101.496	101.496	Sheen	0.958	0.958	102.162	102.162	Sheen
BH37	4.0	0.5 - 4.0	103.015	102.515	99.015	-	0.923	-	102.092	-	-	1.394	-	101.621	-	-	0.696	-	102.319	-
BH38	4.0	0.5 - 4.0	102.825	102.325	98.825	-	0.781	-	102.044	-	-	1.294	-	101.531	-	-	0.573	-	102.252	-
BH39	4.0	0.5 - 4.0	103.06	102.56	99.06	-	1.193	-	101.867	-	-	1.705	-	101.355	-	-	0.949	-	102.111	-
BH40	4.0	0.5 - 4.0	102.885	102.385	98.885	-	1.176	-	101.709	-	-	1.62	-	101.265	-	-	0.84	-	102.045	-
BH41	4.0	0.5 - 4.0	102.875	102.375	98.875	-	1.591	-	101.284	-	-	2.207	-	100.668	-	-	1.577	-	101.298	-
BH42	4.0	0.5 - 4.0	102.7	102.2	98.7	-	1.224	-	101.476	-	-	1.791	-	100.909	-	-	1.331	-	101.369	-
BH43	4.0	0.5 - 4.0	102.875	102.375	98.875	-	1.139	-	101.736	-	-	1.454	-	101.421	-	-	1.178	-	101.697	-
BH44	4.0	0.5 - 4.0	102.975	102.475	98.975	-	1.59	-	101.385	-	-	2.091	-	100.884	-	-	1.723	-	101.252	-
BH45	4.0	0.5 - 4.0	103.14	102.64	99.14	-	1.867	-	101.273	-	-	2.268	-	100.872	-	-	1.883	-	101.257	-
BH46	4.0	0.5 - 4.0	103.01	102.51	99.01	1.65	2.239	101.36	100.771	0.589	2.11	2.148	100.9	100.862	0.038	1.766	2.048	101.244	100.962	0.282
BH47	4.0	0.5 - 4.0	102.75	102.25	98.75	1.268	1.519	101.482	101.231	0.251	1.463	1.604	101.287	101.146	0.141	0.968	1.498	101.782	101.252	0.53
BH48	4.0	0.5 - 4.0	102.71	102.21	98.71	-	0.945	-	101.765	-		1.187		101.523			0.84	-	101.87	-
BH49	4.0	0.5 - 4.0	102.64	102.14	98.64	-	1.252	-	101.388	-	1.527	1.527	101.113	101.113	Sheen		1.073	-	101.567	-
BH50	5.0	0.5 - 5.0	103.09	102.59	99.09	-	1.853	-	101.237	-	-	2.112	-	100.978	-	-	1.834	-	101.256	-
BH51	4.0	0.5 - 4.0	102.656	102.156	98.656	-	1.295	-	101.361	-	-	1.316	-	101.34	-	-	0.949	-	101.707	-
BH52	4.0	0.5 - 4.0	102.432	101.932	98.432	-	1.154	-	101.278	-	-	1.06	-	101.372	-	-	0.605	-	101.827	-
BH53	5.0	0.5 - 5.0	103.072	102.572	98.072	-	2.057	-	101.015	-	-	2.258	-	100.814	-	-	2.067	-	101.005	-
BH54	3.0		102.840	102.340	99.840	Not Installed					Not Installed					Not Installed				
BH55	3.0		102.765	102.265	99.765	Not Installed					Not Installed					Not Installed				
BH56	3.0		102.852	102.352	99.852	Not Installed					Not Installed					Not Installed				
BH57	3.0		102.770	102.270	99.770	Not Installed					Not Installed					Not Installed				
BH58	3.0		102.693	102.193	99.693	Not Installed					Not Installed					Not Installed				
BH59	3.0		102.625	102.125	99.625	Not Installed					Not Installed					Not Installed				
BH60	3.0		102.621	102.121	99.621	Not Installed					Not Installed					Not Installed				
BHA	5.2	2.5 - 5.19	103.095	100.595	97.905	1.676	1.695	101.419	101.4	0.019	2.074	2.09	101.021	101.005	0.016	1.654	1.675	101.441	101.42	0.021
BHB	5.1	2.5 - 5.10	103.32	100.82	98.22	1.905	1.961	101.415	101.359	0.056	2.317	2.341	101.003	100.979	0.024	1.906	1.927	101.414	101.393	0.021
BHC	5.2	2.5 - 5.18	102.91	100.41	97.73	1.517	1.517	101.393	101.393	Globules	-	1.926	-	100.984	-	-	1.55	-	101.36	-

Notes:
Data collected prior to December 2013 reported by PDP (2013).
Data from December 2013 to 2017 collected by Golder.

Groundwater Monitoring Data

Monitoring Well	Total Depth of Well	Screen Interval	Top of Casing	Top of Screen	Bottom of Screen	7 May 2015					2 November 2015					3 May 2016				
						Depth to LNAPL	Depth to water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness	Depth to LNAPL	Depth to water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness	Depth to LNAPL	Depth to water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness
	m bgl	m bgl	m RL	m RL	m RL	m BTOC	m BTOC	m RL	m RL	m	m BTOC	m BTOC	m RL	m RL	m	m BTOC	m BTOC	m RL	m RL	m
BH1	3.0	0.6 - 3.0	103.03	102.43	100.03	-	-	-	-	-	-	-	-	-	-					
BH9	3.1	0	Unknown			Well Destroyed					Well Destroyed									
BH15	3.0	0.6 - 3.0	Unknown	0.6	3.0	Well Destroyed					Well Destroyed									
BH19	4.0	0.5 - 4.0	103.205	102.705	99.205	-	2.14	-	101.065	-	-	2.06	-	101.145	-	-	1.987	-	101.218	-
BH20	4.0	0.5 - 4.0	103.15	102.65	99.15	-	2.16	-	100.99	-	-	2.08	-	101.07	-	-	2.067	-	101.083	-
BH21	4.5	0.9 - 4.5	103.47			-	2.45	-	101.02	-	-	2.35	-	101.12	-	-	1.111	-	102.359	-
BH22	4.0	0.5 - 4.0	103.25	102.75	99.25	-	2.14	-	101.11	-	-	1.865	-	101.385	-	-	1.150	-	102.100	-
BH23	4.0	0.5 - 4.0	103.1	102.6	99.1	-	1.28	-	101.82	-	-	1.6	-	101.5	-	-	0.446	-	102.654	-
BH24	4.0	0.5 - 4.0	102.945	102.445	98.945	-	1.92	-	101.025	-	1.81	1.95	101.135	100.995	0.14	1.758	1.76	101.187	101.185	0.002
BH25	4.0	0.5 - 4.0	102.855	102.355	98.855	1.57	1.79	101.285	101.065	0.22	1.15	1.6	101.705	101.255	0.45	0.614	0.694	102.241	102.161	0.08
BH26	4.0	0.5 - 4.0	103.045	102.545	99.045	-	1.82	-	101.225	-	-	1.17	-	101.875	-	-	1.115	-	101.93	-
BH27	4.0	0.5 - 4.0	102.925	102.425	98.925	-	1.25	-	101.675	-	-	1.65	-	101.275	-	-	1.309	-	101.616	-
BH28	4.0	0.5 - 4.0	103.1	102.6	99.1	-	1.99	-	101.11	-	-	1.39	-	101.71	-	-	1.528	-	101.572	-
BH29	4.0	0.5 - 4.0	103.02	102.52	99.02	1.99	2.04	101.03	100.98	0.05	-	2.04	-	100.98	-	1.93	2.545	101.09	100.475	0.615
BH30	4.5	0.9 - 4.5	103.555	102.655	99.055	-	2.15	-	101.405	-	-	2.33	-	101.225	-	-	2.129	-	101.426	-
BH31	4.0	0.5 - 4.0	103.055	102.555	99.055	-	1.79	-	101.265	-	1.44	1.45	101.615	101.605	0.01	1.656	1.69	101.399	101.365	0.034
BH32	4.0	0.5 - 4.0	103.155	102.655	99.155	-	2.03	-	101.125	-	-	1.3	-	101.855	-	-	0.907	-	102.248	-
BH33	4.0	0.5 - 4.0	102.645	102.145	98.645	-	1.65	-	100.995	-	-	1.46	-	101.185	-	-	1.185	-	101.46	-
BH34	4.0	0.5 - 4.0	102.935	102.435	98.935	-	1.93	-	101.005	-	-	1.75	-	101.185	-	-	1.865	-	101.07	-
BH35	4.0	0.5 - 4.0	102.88	102.38	98.88	1.74	2.01	101.14	100.87	0.27	1.37	1.41	101.51	101.47	0.04	0.700	0.702	102.18	102.178	0.002
BH36	4.0	0.5 - 4.0	103.12	102.62	99.12	1.8	1.84	101.32	101.28	0.04	1.46	1.47	101.66	101.65	0.01	1.63	1.65	101.49	101.47	0.02
BH37	4.0	0.5 - 4.0	103.015	102.515	99.015	-	1.62	-	101.395	-	-	1.78	-	101.235	-	-	1.088	-	101.927	-
BH38	4.0	0.5 - 4.0	102.825	102.325	98.825	-	1.42	-	101.405	-	-	1.08	-	101.745	-	-	0.726	-	102.099	-
BH39	4.0	0.5 - 4.0	103.06	102.56	99.06	-	1.89	-	101.17	-	-	1.58	-	101.48	-	-	1.429	-	101.631	-
BH40	4.0	0.5 - 4.0	102.885	102.385	98.885	-	1.81	-	101.075	-	-	1.43	-	101.455	-	-	1.221	-	101.664	-
BH41	4.0	0.5 - 4.0	102.875	102.375	98.875	-	1.97	-	100.905	-	-	1.95	-	100.925	-	-	1.992	-	100.883	-
BH42	4.0	0.5 - 4.0	102.7	102.2	98.7	-	1.75	-	100.95	-	-	1.73	-	100.97	-	-	1.663	-	101.037	-
BH43	4.0	0.5 - 4.0	102.875	102.375	98.875	-	1.4	-	101.475	-	-	1.42	-	101.455	-	-	1.299	-	101.576	-
BH44	4.0	0.5 - 4.0	102.975	102.475	98.975	-	2.05	-	100.925	-	-	2.05	-	100.925	-	-	1.983	-	100.992	-
BH45	4.0	0.5 - 4.0	103.14	102.64	99.14	-	2.24	-	100.9	-	-	2.02	-	101.12	-	-	2.219	-	100.921	-
BH46	4.0	0.5 - 4.0	103.01	102.51	99.01	Sheen	2.1	-	100.91	-	-	2.07	-	100.94	-	2.115	2.116	100.895	100.894	0.001
BH47	4.0	0.5 - 4.0	102.75	102.25	98.75	Sheen	1.78	-	100.97	-	-	1.69	-	101.06	-	1.669	1.67	101.081	101.08	0.001
BH48	4.0	0.5 - 4.0	102.71	102.21	98.71	Sheen	3.97	-	98.74	-	-	1.13	-	101.58	-	-	1.165	-	101.545	-
BH49	4.0	0.5 - 4.0	102.64	102.14	98.64	Sheen	1.72	-	100.92	-	-	1.63	-	101.01	-	-	1.582	-	101.058	-
BH50	5.0	0.5 - 5.0	103.09	102.59	99.09	Silted					Dry					Dry				
BH51	4.0	0.5 - 4.0	102.656	102.156	98.656	Sheen	1.69	-	100.966	-	-	1.61	-	101.046	-	-	1.575	-	101.081	-
BH52	4.0	0.5 - 4.0	102.432	101.932	98.432	-	1.49	-	100.942	-	-	1.35	-	101.082	-	-	1.306	-	101.126	-
BH53	5.0	0.5 - 5.0	103.072	102.572	98.072	-	2.34	-	100.732	-	-	2.32	-	100.752	-	-	2.375	-	100.697	-
BH54	3.0		102.840	102.340	99.840	-	2.05	-	100.79	-	-	2.02	-	100.82	-	-	2.123	-	100.717	-
BH55	3.0		102.765	102.265	99.765	-	1.95	-	100.815	-	-	1.9	-	100.865	-	-	1.961	-	100.804	-
BH56	3.0		102.852	102.352	99.852	-	2.03	-	100.822	-	-	1.89	-	100.962	-	-	1.976	-	100.876	
BH57	3.0		102.770	102.270	99.770	1.92	1.95	100.85	100.82	0.03	1.8	1.81	100.970	100.96	0.01	1.841	1.853	100.929	100.917	0.012
BH58	3.0		102.693	102.193	99.693	-	1.82	-	100.873	-	-	1.66	-	101.033	-	-	1.703	-	100.99	-
BH59	3.0		102.625	102.125	99.625	-	1.56	-	101.065	-	-	1.34	-	101.285	-	-	1.47	-	101.155	-
BH60	3.0		102.621	102.121	99.621	-	1.58	-	101.041	-	-	1.51	-	101.111	-	-	1.885	-	100.736	-
BHA	5.2	2.5 - 5.19	103.095	100.595	97.905	-	2.14	-	100.955	-	2.97	2.98	100.125	100.115	0.01	2.11	2.142	100.985	100.953	0.032
BHB	5.1	2.5 - 5.10	103.32	100.82	98.22	2.39	2.42	100.93	100.9	0.03	2.25	2.28	101.070	101.04	0.03	2.375	2.405	100.945	100.915	0.03
BHC	5.2	2.5 - 5.18	102.91	100.41	97.73	-	1.98	-	100.93	-	-	1.88	-	101.03	-	-	1.985	-	100.925	-

Notes:
Data collected prior to December 2013 reported by PDP (2013).
Data from December 2013 to 2017 collected by Golder.

Monitoring Well	Total Depth of Well	Screen Interval	Top of Casing	Top of Screen	Bottom of Screen	10 April 2017				
						Depth to LNAPL	Depth to water	LNAPL Elevation	Groundwater Elevation	LNAPL Thickness
	m bgl	m bgl	m RL	m RL	m RL	m BTOC	m BTOC	m RL	m RL	m
BH1	3.0	0.6 - 3.0	103.03	102.43	100.03	-	1.956		101.074	-
BH9	3.1	0	Unknown			Well Destroyed				
BH15	3.0	0.6 - 3.0	Unknown	0.6	3.0	Well Destroyed				
BH19	4.0	0.5 - 4.0	103.205	102.705	99.205	-	2.146	-	101.059	-
BH20	4.0	0.5 - 4.0	103.15	102.65	99.15	-	2.126	-	101.024	-
BH21	4.5	0.9 - 4.5	103.47			-	2.452	-	101.018	-
BH22	4.0	0.5 - 4.0	103.25	102.75	99.25	-	2.078	-	101.172	-
BH23	4.0	0.5 - 4.0	103.1	102.6	99.1	-	1.301	-	101.799	-
BH24	4.0	0.5 - 4.0	102.945	102.445	98.945	1.586	1.59	101.359	101.355	0.004
BH25	4.0	0.5 - 4.0	102.855	102.355	98.855	1.339	1.571	101.516	101.284	0.232
BH26	4.0	0.5 - 4.0	103.045	102.545	99.045	-	1.233	-	101.812	-
BH27	4.0	0.5 - 4.0	102.925	102.425	98.925	-	1.172	-	101.753	-
BH28	4.0	0.5 - 4.0	103.1	102.6	99.1	-	1.231	-	101.869	-
BH29	4.0	0.5 - 4.0	103.02	102.52	99.02	1.998	2.004	101.022	101.016	0.006
BH30	4.5	0.9 - 4.5	103.555	102.655	99.055	-	2.269	-	101.286	-
BH31	4.0	0.5 - 4.0	103.055	102.555	99.055	1.552	1.552	101.503	101.503	Globules
BH32	4.0	0.5 - 4.0	103.155	102.655	99.155	-	1.831	-	101.324	-
BH33	4.0	0.5 - 4.0	102.645	102.145	98.645	-	1.573	-	101.072	-
BH34	4.0	0.5 - 4.0	102.935	102.435	98.935	-	1.632	-	101.303	-
BH35	4.0	0.5 - 4.0	102.88	102.38	98.88	1.458	1.46	101.422	101.42	0.002
BH36	4.0	0.5 - 4.0	103.12	102.62	99.12	1.551	1.554	101.569	101.566	0.003
BH37	4.0	0.5 - 4.0	103.015	102.515	99.015	-	1.331	-	101.684	-
BH38	4.0	0.5 - 4.0	102.825	102.325	98.825	-	1.24	-	101.585	-
BH39	4.0	0.5 - 4.0	103.06	102.56	99.06	-	1.618	-	101.442	-
BH40	4.0	0.5 - 4.0	102.885	102.385	98.885	-	1.542	-	101.343	-
BH41	4.0	0.5 - 4.0	102.875	102.375	98.875	-	1.933	-	100.942	
BH42	4.0	0.5 - 4.0	102.7	102.2	98.7	-	1.713	-	100.987	
BH43	4.0	0.5 - 4.0	102.875	102.375	98.875	-	1.492	-	101.383	
BH44	4.0	0.5 - 4.0	102.975	102.475	98.975	-	2.128	-	100.847	
BH45	4.0	0.5 - 4.0	103.14	102.64	99.14	-	2.312	-	100.828	
BH46	4.0	0.5 - 4.0	103.01	102.51	99.01	2.116	2.209	100.894	100.801	0.093
BH47	4.0	0.5 - 4.0	102.75	102.25	98.75	1.651	1.661	101.099	101.089	0.01
BH48	4.0	0.5 - 4.0	102.71	102.21	98.71	-	1.197	-	101.513	
BH49	4.0	0.5 - 4.0	102.64	102.14	98.64	-	1.638	-	101.002	
BH50	5.0	0.5 - 5.0	103.09	102.59	99.09	Dry				
BH51	4.0	0.5 - 4.0	102.656	102.156	98.656	-	1.544	-	101.112	
BH52	4.0	0.5 - 4.0	102.432	101.932	98.432	-	1.33	-	101.102	
BH53	5.0	0.5 - 5.0	103.072	102.572	98.072	-	2.151	-	100.921	
BH54	3.0		102.840	102.340	99.840	-	2.019	-	100.821	
BH55	3.0		102.765	102.265	99.765	-	1.948	-	100.817	
BH56	3.0		102.852	102.352	99.852	-		-	102.852	
BH57	3.0		102.770	102.270	99.770	1.837	1.856	100.933	100.914	0.019
BH58	3.0		102.693	102.193	99.693	-	1.669	-	101.024	
BH59	3.0		102.625	102.125	99.625	-	1.337	-	101.288	
BH60	3.0		102.621	102.121	99.621	-	1.542	-	101.079	
BHA	5.2	2.5 - 5.19	103.095	100.595	97.905	2.058	2.091	101.037	101.004	0.033
BHB	5.1	2.5 - 5.10	103.32	100.82	98.22	2.337	2.341	100.983	100.979	0.004
BHC	5.2	2.5 - 5.18	102.91	100.41	97.73	-	1.943		100.967	

Notes:
Data collected prior to December 2013 reported by PDP (2013).
Data from December 2013 to 2017 collected by Golder.

APPENDIX B

Groundwater Quality Data

Table B1: Tier 1 Groundwater Quality Assessment

Location Code	Location	Sample Date	Sample Code	Total Petroleum Hydrocarbons: C_7 - C_9 TPH	C_{10} - C_{14} TPH	C_{15} - C_{36} TPH	C_7 - C_{36} TPH	BTEX: Benzene	Toluene	Ethylbenzene	m&p-Xylene	o-Xylene	Total Xylene
MfE (2011) Indoor Inhalation, Sand, Groundwater at 2 m [1]				S	S	S	ne	5.2	(460)	(110)	ne	ne	S
MfE (2011) Outdoor Inhalation, Sand, Groundwater at 2 m [1]				S	S	S	ne	(340)	S	S	ne	ne	S
ANZECC (2000) 95% trigger values for marine ecosystems [2]				ne	ne	ne	ne	0.7	ID	ID	ID	ID	ne
ANZECC (2000) low reliability trigger values				ne	ne	ne	ne		0.18	0.005	0.075	0.35	ne
BH19	On-Site	13-04-11	888304.4	< 0.1	< 0.2	< 0.4	< 0.7	0.023	0.0011	< 0.001	0.003	<0.001	0.004
BH19	On-Site	03-05-12	1004531.3	< 0.1	< 0.2	< 0.4	< 0.7	0.007	< 0.001	< 0.001	< 0.002	< 0.001	< 0.003
BH20	On-Site	12-04-11	-	LNAPL									
BH20	On-Site	02-05-12	-	LNAPL									
BH21	On-Site	13-04-11	888304.5	0.14	0.3	1	1.4	< 0.001	<0.001	0.002	0.01	<0.001	0.011
BH21	On-Site	02-05-12	1003823.6	< 0.1	< 0.2	< 0.4	< 0.7	< 0.001	<0.001	0.0028	0.029	< 0.001	0.03
BH22	On-Site	13-04-11	888304.3	0.73	1.4	1	3	0.0104	0.0011	< 0.01	0.191	<0.001	0.192
BH22	On-Site	03-05-12	1004531.4	0.12	0.8	1.8	2.7	0.0023	< 0.001	< 0.001	0.012	< 0.001	0.013
BH23	On-Site	11-04-11	887760.1	< 0.1	< 0.2	< 0.4	< 0.7	0.0024	< 0.001	< 0.001	0.013	<0.001	0.014
BH23	On-Site	01-05-12	1003823.3	< 0.1	< 0.2	0.9	0.9	< 0.001	< 0.001	< 0.001	< 0.002	< 0.001	< 0.003
BH24	On-Site	13-04-11	888304.6	0.36	0.5	1.1	2	0.0023	< 0.001	0.049	0.23	<0.001	0.23
BH24	On-Site	04-05-12	1004850.2	0.46	0.6	0.5	1.6	0.0043	< 0.001	0.0126	0.49	< 0.001	0.49
BH25	On-Site	13-04-11	888304.7	1.29	2.1	0.5	3.9	0.3	0.008	0.0107	0.88	0.0156	0.9
BH25	On-Site	30-04-12	-	LNAPL									
BH26	On-Site	13-04-11	888304.1	8.1	2.1	0.9	11	0.25	0.002	0.21	7.4	0.0019	7.4
BH26	On-Site	03-05-12	1004531.7	3.4	0.5	< 0.4	3.9	0.02	0.0052	0.31	3.6	0.0017	3.6
BH27	On-Site	13-04-11	888304.9	7.3	2.2	3.5	13	0.11	0.0013	1.09	5.9	0.002	5.9
BH27	On-Site	03-05-12	1004531.8	0.12	0.5	0.8	1.4	0.055	< 0.001	< 0.001	0.018	< 0.001	0.019
BH28	On-Site	11-04-11	887760.2	8.3	1.4	1	10.7	0.079	0.0012	0.38	6.9	0.0024	6.9
BH28	On-Site	02-05-12	1003823.5	1.32	0.4	1.5	3.3	0.036	< 0.001	0.0175	1.48	< 0.001	1.48
BH29	On-Site	13-04-11	888304.8	2.1	2.5	5	9.6	0.0164	0.0011	0.78	1.46	0.0013	1.46
BH29	On-Site	30-04-12	-	LNAPL									
BH30	On-Site	13-04-11	888304.14	2.8	3.1	1.1	7	0.44	0.0077	0.43	1.48	0.0083	1.49
BH30	On-Site	03-05-12	1004531.5	1.35	1.4	0.6	3.4	0.39	0.0066	0.36	0.54	0.0043	0.54
BH31	On-Site	13-04-11	888304.12	1.88	5.5	0.8	8.2	0.0052	< 0.001	0.0082	1.58	0.0016	1.58
BH31	On-Site	30-04-12	-	LNAPL									
BH32	On-Site	13-04-11	888304.13	2.9	4.2	0.9	8	0.042	0.0171	0.45	1.86	0.034	1.89
BH32	On-Site	03-05-12	1004531.6	2.1	2.9	< 0.4	5	0.105	0.044	0.38	1.06	0.026	1.09
BH33	On-Site	11-04-11	887760.3	2	3.4	< 0.4	5.4	0.025	0.0088	0.34	0.58	0.0111	0.59
BH33	On-Site	30-04-12	-	LNAPL									
BH34	On-Site	13-04-11	888304.15	2.8	3.7	0.4	7	0.02	0.0075	0.23	1.54	0.0097	1.55
BH34	On-Site	03-05-12	1004531.2	1.8	9.4	1.4	12.6	0.032	0.0055	0.085	0.21	0.0102	0.22
BH35	On-Site	12-04-11	887760.12	2.5	4.5	0.7	7.6	0.22	0.017	0.24	1.32	0.01	1.33
BH35	On-Site	30-04-12	-	LNAPL									
BH36	On-Site	12-04-11	887760.1	2.9	20	0.5	24	0.014	< 0.001	0.034	1.43	0.0133	1.44
BH36	On-Site	04-05-12	1004850.3	3.7	54	1.6	60	0.0038	0.001	0.0129	1.45	0.0018	1.45
BH37	On-Site	12-04-11	887760.9	< 0.1	< 0.2	< 0.4	< 0.7	< 0.001	< 0.001	< 0.001	<0.002	<0.001	< 0.003
BH37	On-Site	02-05-12	1003823.1	< 0.1	< 0.2	< 0.4	< 0.7	< 0.001	< 0.001	< 0.001	< 0.002	< 0.001	< 0.003
BH38	On-Site	12-04-11	887760.11	2.6	7.6	1.6	11.8	0.045	0.0038	0.0182	1.47	0.0041	1.47
BH38	On-Site	04-05-12	1004850.4	1.27	4	0.9	6.1	0.0185	0.003	0.0147	1.34	0.0032	1.34
BH39	On-Site	12-04-11	887760.8	1.61	3.7	< 0.4	5.3	0.0091	0.013	0.22	0.6	0.0143	0.61
BH39	On-Site	03-05-12	1004531.1	1.93	3.3	0.5	5.7	0.0077	0.017	0.4	0.89	0.0188	0.91
BH40	On-Site	13-04-11	888304.16	0.89	1.6	< 0.4	2.5	0.035	0.0046	0.039	0.102	0.0044	0.106
BH40	On-Site	02-05-12	1003823.4	0.7	1.5	< 0.4	2.2	0.024	0.0042	0.05	0.011	0.0045	0.016
BH41	Off-Site	13-04-11	888304.2	3.4	1.5	1	5.9	0.034	0.0041	1.39	1.52	0.0062	1.53
BH41	Off-Site	04-05-12	1004850.5	2	0.7	0.5	3.2	0.0178	0.0025	0.97	0.87	0.0034	0.87
BH41	Off-Site	06-05-15	1422884.15	1.53	0.7	< 0.4	2.2	0.0036	0.0011	0.183	0.181	0.0021	0.1831
BH41	Off-Site	05-11-15	1497677.14	2.8	0.7	< 0.4	3.5	0.0115	0.0026	1.21	1.13	0.0046	1.1346
BH41	Off-Site	02-06-16	1595593.12	< 0.10	< 0.2	0.7	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH41	Off-Site	11-04-17	1758285.9	3.4	1	< 0.4	4.4	0.0183	0.0033	1.77	1.2	0.0047	1.2047
BH42	Off-Site	13-04-11	888304.10	2.4	1.8	< 0.4	4.3	0.065	0.03	0.49	1.56	0.034	1.59
BH42	Off-Site	04-05-12	1004850.6	0.61	0.5	< 0.4	1.1	0.0163	0.0083	0.139	0.23	0.0102	0.24
BH42	Off-Site	05-12-13	1212710.1	0.22	< 0.2	< 0.4	< 0.7	0.0029	0.003	0.048	0.045	0.004	0.0049
BH42	Off-Site	06-05-15	1422884.14	0.16	< 0.2	< 0.4	< 0.7	0.0074	0.0023	0.0027	0.004	0.0018	0.0058
BH42	Off-Site	05-11-15	1497677.17	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH42	Off-Site	03-06-16	1595593.16	0.17	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH42	Off-Site	11-04-17	1758285.11	0.24	< 0.2	< 0.4	< 0.7	0.0021	0.0042	0.0143	0.062	0.0057	0.0677
BH43	Off-Site	12-04-11	-	LNAPL									
BH43	Off-Site	30-04-12	-	LNAPL									
BH43	Off-Site	10-07-13	1155908.1	< 0.10	< 0.2	0.6	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH43	Off-Site	05-12-13	1212710.2	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH43	Off-Site	06-05-15	1422884.1	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH43	Off-Site	04-11-15	1497677.9	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH43	Off-Site	02-06-16	1595593.5	< 0.10	< 0.2	1	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH43	Off-Site	11-04-17	1758285.6	< 0.06	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.0030
BH44	Off-Site	12-04-11	887760.4	2.7	2	< 0.4	4.7	0.21	0.056	0.46	0.92	0.042	0.96
BH44	Off-Site	02-05-12	1003823.10	0.75	0.8	< 0.4	1.5	0.108	0.023	0.26	0.32	0.0146	0.33
BH44	Off-Site	10-07-13	1155908.2	< 0.10	< 0.2	< 0.4	< 0.7	0.0013	< 0.001	< 0.001	0.004	0.0028	0.007
BH44	Off-Site	05-12-13	1212710.3	0.19	< 0.2	< 0.4	< 0.7	0.031	0.0078	0.0052	0.057	0.0103	0.0673
BH44	Off-Site	06-05-15	1422884.12	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	0.004	0.0013	0.0053
BH44	Off-Site	03-11-15	1497677.5	< 0.10	< 0.2	< 0.4	< 0.7	0.0018	< 0.0010	0.0031	0.011	0.0018	0.0128
BH44	Off-Site	02-06-16	1595593.9	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH44	Off-Site	11-04-17	1758285.5	< 0.06	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	0.003	< 0.0010	0.004
BH45	Off-Site	12-04-11	887760.5	2.3	3.5	1	6.8	0.047	0.003	0.34	0.105	0.0067	0.112
BH45	Off-Site	02-05-12	1003823.11	0.77	0.7	< 0.4	1.5	0.051	0.0033	0.22	0.127	0.0054	0.132
BH45	Off-Site	10-07-13	1155908.3	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	0.002	< 0.0010	0.002
BH45	Off-Site	05-12-13	1212710.4	0.43	0.4	< 0.4	0.8	0.032	0.0023	0.076	0.061	0.0034	0.0644
BH45	Off-Site	06-05-15	1422884.11	0.6	0.7	< 0.4	1.3	0.022	0.0023	0.03	0.053	0.0037	0.0567
BH45	Off-Site	03-11-15	1497677.6	0.1	< 0.2	< 0.4	< 0.7	0.0099	< 0.0010	0.0142	0.041	0.0019	0.0429
BH45	Off-Site	02-06-16	1595593.8	0.12	< 0.2	< 0.4	< 0.7	0.0119	0.0011	0.009	0.028	0.0016	0.0296
BH45	Off-Site	11-04-17	1758285.4	0.15	< 0.2	< 0.4	< 0.7	0.0090	< 0.0010	< 0.0010	0.022	< 0.0010	0.023
BH46	Off-Site	12-04-11	-	LNAPL									
BH46	Off-Site	02-05-12	-	LNAPL									
BH46	Off-Site	10-07-13	-	LNAPL									
BH46	Off-Site	06-05-15	1422884.10	1.37	1.3	0.8	3.5	0.118	0.0025	0.165	0.182	0.0035	0.2
BH46	Off-Site	03-11-15	1497677.1	2	1.7	1	4.8	0.33	0.0055	0.54	0.84	0.009	0.849
BH46	Off-Site	02-06-16	-	LNAPL									
BH46	Off-Site	11-04-17	-	LNAPL									
BH47	Off-Site	12-04-11	-	LNAPL									
BH47	Off-Site	02-05-12	-	LNAPL									
BH47	Off-Site	10-07-13	-	LNAPL									
BH47	Off-Site	05-05-15	1422884.6	1.66	2.7	< 0.4	4.3	0.051	0.0016	0.045	0.01	< 0.0010	0.010
BH47	Off-Site	04-11-15	1497677.8	1.02	3.6	1.3	5.9	0.047	< 0.0010	0.066	0.005	< 0.0010	0.006
BH47	Off-Site	02-06-16	-	LNAPL									
BH47	Off-Site	11-04-17	-	LNAPL									
BH48	Off-Site	12-04-11	887760.6	0.34	9.2	3.1	12.6	0.0014	< 0.0010	0.0019	<0.002	0.0012	0.002
BH48	Off-Site	02-05-12	1003823.12	< 0.1	2.3	0.5	2.8	< 0.0010	< 0.0010	0.0014	< 0.002	0.0013	0.002
BH48	Off-Site	10-07-13	1155908.4	< 0.10	0.4	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH48	Off-Site	04-12-13	1212710.5	< 0.10	2.3	< 0.4	2.3	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH48	Off-Site	12-06-14	1287325.1	< 0.10	2.5	0.4	2.9	< 0.0010	< 0.0010	0.0016	< 0.002	< 0.0010	< 0.003
BH48	Off-Site	05-05-15	1422884.2	< 0.10	0.9	< 0.4	0.9	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH48	Off-Site	03-11-15	1497677.4	< 0.10	1	< 0.4	1	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH48	Off-Site	02-06-16	1595593.1	< 0.10	0.6	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH48	Off-Site	11-04-17	1758285.12	0.07	0.9	< 0.4	0.9	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.0030
BH49	Off-Site	12-04-11	-	LNAPL									
BH49	Off-Site	02-05-12	-	LNAPL									
BH49	Off-Site	12-07-13	1155908.5	1.6	2.6	< 0.4	4.2	0.027	< 0.0010	0.178	0.3	< 0.0010	0.3
BH49	Off-Site	12-06-14	1287325.2	1.47	2.6	< 0.4	4.1	0.0113	< 0.0010	0.076	0.164	< 0.0010	0.164
BH49	Off-Site	06-05-15	1422884.19	2.7	3.6	< 0.4	6.4	0.02	< 0.0010	0.167	0.22	< 0.0010	0.22
BH49	Off-Site	05-11-15	1497677.13	2	3.3	< 0.4	5.4	0.0116	< 0.0010	0.113	0.146	< 0.0010	0.146
BH49	Off-Site	02-06-16	-	LNAPL									
BH49	Off-Site	11-04-17	1758285.15	2.1	3.1	< 0.4	5.2	0.0104	< 0.0010	0.1	0.039	< 0.0010	0.040

Location Code	Sample Date	PAH: Acenaphthene	Acenaphthylene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)&(j)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-c,d)pyrene	Naphthalene	Phenanthrene	Pyrene
MfE (2011) Indoor Inhalation, Sand, Groundwater at 2 m [1]		ne	ne	ne	ne	S	ne	ne	ne	ne	ne	ne	ne	ne	S	ne	S
MfE (2011) Outdoor Inhalation, Sand, Groundwater at 2 m [1]		ne	ne	ne	ne	S	ne	ne	ne	ne	ne	ne	ne	ne	S	ne	S
ANZECC (2000) 95% trigger values for marine ecosystems [2]		ne	ne	ID	ne	ID	ne	ne	ne	ne	ne	ID	ne	ne	0.07	ID	ne
ANZECC (2000) low reliability trigger values		ne	ne	0.0004	ne	0.0002	ne	ne	ne	ne	ne	0.0014	ne	ne	ne	0.002	ne
BH19	13-04-11	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0022	< 0.0004	< 0.0002
BH19	03-05-12	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH20	12-04-11	LNAPL															
BH20	02-05-12	LNAPL															
BH21	13-04-11	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0008	< 0.0004	< 0.0002
BH21	02-05-12	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH22	13-04-11	0.00026	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0005	< 0.00010	0.0035	< 0.0004	< 0.0002
BH22	03-05-12	0.00016	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00013	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00039	0.0003	< 0.00010	0.001	< 0.0004	0.0005
BH23	11-04-11	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH23	01-05-12	< 0.00010	< 0.00010	0.0001	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0007	< 0.0004	< 0.0002
BH24	13-04-11	0.00023	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0006	< 0.00010	0.0049	< 0.0004	< 0.0002
BH24	04-05-12	0.00051	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0005	< 0.00010	0.0167	< 0.0004	< 0.0002
BH25	13-04-11	0.00099	0.00026	0.00013	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0027	< 0.00010	0.0199	< 0.0004	< 0.0002
BH25	30-04-12	LNAPL															
BH26	13-04-11	0.00097	< 0.00010	0.00011	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00011	0.0015	< 0.00010	0.09	0.0005	< 0.0002
BH26	03-05-12	0.00031	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0007	< 0.00010	0.031	< 0.0004	< 0.0002
BH27	13-04-11	0.00085	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00011	0.0047	< 0.00010	0.029	0.0009	< 0.0002
BH27	03-05-12	0.00042	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0007	< 0.00010	0.001	< 0.0004	< 0.0002
BH28	11-04-11	0.00164	0.00041	0.00021	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0033	< 0.00010	0.098	0.002	< 0.0002
BH28	02-05-12	0.00035	< 0.00010	0.00017	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0005	< 0.00010	0.0047	< 0.0004	< 0.0002
BH29	13-04-11	0.00066	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0023	< 0.00010	0.034	0.001	< 0.0002
BH29	30-04-12	LNAPL															
BH30	13-04-11	0.0023	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0007	< 0.00010	0.06	< 0.0004	< 0.0002
BH30	03-05-12	0.0001	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0003	< 0.00010	0.076	< 0.0004	< 0.0002
BH31	13-04-11	0.00024	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0004	< 0.00010	0.055	< 0.0004	< 0.0002
BH31	30-04-12	LNAPL															
BH32	13-04-11	0.00034	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0005	< 0.00010	0.028	< 0.0004	< 0.0002
BH32	03-05-12	0.00017	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00014	0.0003	< 0.00010	0.191	< 0.0004	< 0.0002
BH33	11-04-11	0.00066	0.00017	0.00011	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00017	0.0014	< 0.00010	0.37	0.0009	< 0.0002
BH33	30-04-12	LNAPL															
BH34	13-04-11	0.00051	< 0.00010	0.00013	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00022	0.001	< 0.00010	0.32	0.001	< 0.0002
BH34	03-05-12	0.00064	0.00026	0.00023	0.00026	0.00021	0.00029	0.00013	< 0.00010	0.00021	< 0.00010	0.00089	0.0014	0.00012	0.31	0.002	0.0009
BH35	12-04-11	0.0006	< 0.00010	0.00014	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00024	0.0014	< 0.00010	0.46	0.0012	0.0002
BH35	30-04-12	LNAPL															
BH36	12-04-11	0.00011	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0002	< 0.00010	0.26	< 0.0004	< 0.0002
BH36	04-05-12	0.00035	0.00015	0.0001	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00032	0.0005	< 0.00010	0.27	0.0008	0.0003
BH37	12-04-11	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH37	02-05-12	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0012	< 0.0004	< 0.0002
BH38	12-04-11	0.00094	0.00039	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0023	< 0.00010	0.6	0.0011	< 0.0002
BH38	04-05-12	0.00094	0.00035	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0022	< 0.00010	0.41	0.0012	< 0.0002
BH39	12-04-11	0.00033	0.00013	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0007	< 0.00010	0.34	< 0.0004	< 0.0002
BH39	03-05-12	0.00022	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0006	< 0.00010	0.32	< 0.0004	< 0.0002
BH40	13-04-11	0.00035	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0006	< 0.00010	0.31	0.0004	< 0.0002
BH40	02-05-12	0.00029	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0005	< 0.00010	0.41	< 0.0004	< 0.0002
BH41	13-04-11	0.00063	< 0.00010	0.00012	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.002	< 0.00010	0.089	0.0014	< 0.0002
BH41	04-05-12	0.00052	0.00017	0.00012	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00015	0.0014	< 0.00010	0.055	0.0012	< 0.0002
BH41	06-05-15	0.00063	< 0.00010	0.00012	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0016	< 0.00010	0.044	0.0009	< 0.0002
BH41	05-11-15	0.00041	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0011	< 0.00010	0.052	0.0004	< 0.0002
BH41	02-06-16	0.00004	< 0.00002	0.00004	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00004	< 0.00002	0.00134	< 0.00002	< 0.00002
BH41	11-04-17	0.00055	0.00013	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0014	< 0.00010	0.0146	0.0006	< 0.0002
BH42	13-04-11	0.00026	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0007	< 0.00010	0.043	< 0.0004	< 0.0002
BH42	04-05-12	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0026	< 0.0004	< 0.0002
BH42	05-12-13	0.000052	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	0.000023	0.000061	< 0.000008	0.00102	< 0.000008	0.00003
BH42	06-05-15	0.00012	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0003	< 0.00010	0.0021	< 0.0004	< 0.0002
BH42	05-11-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH42	03-06-16	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00002	< 0.00002	0.00025	< 0.00002	< 0.00002
BH42	11-04-17	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0013	< 0.0004	< 0.0002
BH43	12-04-11	LNAPL															
BH43	30-04-12	LNAPL															
BH43	10-07-13	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0002	< 0.00010	0.0005	< 0.0004	< 0.0002
BH43	05-12-13	0.000088	< 0.000008	0.000014	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	0.000025	0.00022	< 0.000008	< 0.00004	0.00017	0.000069
BH43	06-05-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH43	04-11-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH43	02-06-16	0.00009	0.00003	0.00003	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00003	0.00022	< 0.00002	0.00019	0.00005	0.00006
BH43	11-04-17	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH44	12-04-11	0.00014	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00038	0.0005	< 0.00010	0.036	0.0005	0.0003
BH44	02-05-12	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00019	< 0.0002	< 0.00010	0.0084	< 0.0004	0.0003
BH44	10-07-13	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH44	05-12-13	0.000012	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	0.00003	0.000009	< 0.000008	0.0022	< 0.000008	0.000047
BH44	06-05-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0011	< 0.0004	< 0.0002
BH44	03-11-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH44	02-06-16	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00011	< 0.00002	< 0.00002
BH44	11-04-17	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH45	12-04-11	0.00066	0.00018	0.00016	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00021	0.0016	< 0.00010	0.142	0.00180	< 0.0002
BH45	02-05-12	0.00031	< 0.00010	0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0007	< 0.00010	0.068	0.00080	< 0.0002
BH45	10-07-13	0.00034	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0003	< 0.00010	0.0049	< 0.0004	< 0.0002
BH45	05-12-13	0.00027	< 0.000008	0.00005	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	0.00007	0.00045	< 0.000008	0.056	0.0004	0.000064
BH45	06-05-15	0.00031	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00011	0.0006	< 0.00010	0.053	0.0007	< 0.0002
BH45	03-11-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0116	< 0.0004	< 0.0002
BH45	02-06-16	0.00017	0.00003	0.00004	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00003	0.00023	< 0.00002	0.021	0.00027	0.00003
BH45	11-04-17	0.00021	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0003	< 0.00010	0.0128	< 0.0004	< 0.0002
BH46	12-04-11	LNAPL															
BH46	02-05-12	LNAPL															
BH46	10-07-13	LNAPL															
BH46	06-05-15	0.00091	< 0.00010	0.00016	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00011	0.0013	< 0.00010	0.106	0.0007	< 0.0002
BH46	03-11-15	0.00067	< 0.00010	0.00011	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00016	0.0013	< 0.00010	0.093	0.0008	< 0.0002
BH46	02-06-16	LNAPL															
BH46	11-04-17	LNAPL															
BH47	12-04-11	LNAPL															
BH47	02-05-12	LNAPL															
BH47	10-07-13	LNAPL															
BH47	05-05-15	0.00088	< 0.00010	0.00016	< 0.00010	< 0.00010	0.00012	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0004	0.0019	< 0.00010	0.47	0.0013	0.0003
BH47	04-11-15	0.00097	< 0.00010	<0.0001	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00019	0.023	< 0.00010	0.42	0.0008	< 0.0002
BH47	02-06-16	LNAPL															
BH47	11-04-17	LNAPL															
BH48	12-04-11	0.00128	0.00054	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0024	< 0.00010	0.35	0.0009	< 0.0002
BH48	02-05-12	0.00066	0.00019	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0001	< 0.00010	0.115	< 0.0004	< 0.0002
BH48	10-07-13	0.00023	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0003	< 0.00010	0.0127	< 0.0004	< 0.0002
BH48	04-12-13	0.00075	< 0.000008	0.000046	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	0.00001	0.00133	< 0.000008	0.104	0.00047	< 0.000008
BH48	12-06-14	0.00091	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0016	< 0.00010	0.25	0.0007	< 0.0002
BH48	05-05-15	0.00071	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0011	< 0.00010	0.081	0.0004	< 0.0002
BH48	03-11-15	0.00085	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0014	< 0.00010	0.0197	< 0.0004	< 0.0002
BH48	02-06-16	0.0005	0.00015	0.00003	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.0007	< 0.00002	0.027	0.00018	< 0.00002
BH48	11-04-17	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0007	< 0.0004	< 0.0002
BH49	12-04-11	LNAPL															
BH49	02-05-12	LNAPL															
BH49	12-07-13	0.00069	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0001	< 0.00010	0.41	0.0006	< 0.0002
BH49	12-06-14	0.00079	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0013	< 0.00010	0.45	0.0009	< 0.0002
BH49	06-05-15	0.001	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0014	< 0.00010	0.64	0.0007	< 0.0002
BH49	05-11-15	0.00078	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0013	< 0.00010	0.49	< 0.0004	< 0.0002
BH49	02-06-16	LNAPL															
BH49	11-04-17	0.00092	0.00024	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0014	< 0.00010	0.4	0.0008	< 0.0002

GOLDER

Mobil Oil New Zealand Limited
Former Mobil Dunedin Terminal

Table B1: Tier 1 Groundwater Quality Assessment

Location_Code	Location	Sample Date	Sample Code	Total Petroleum Hydrocarbons: C_7 - C_9 TPH	C_{10} - C_{14} TPH	C_{15} - C_{36} TPH	C_7 - C_{36} TPH	BTEX: Benzene	Toluene	Ethylbenzene	m&p-Xylene	o-Xylene	Total Xylene
MfE (2011) Indoor Inhalation, Sand, Groundwater at 2 m [1]				S	S	S	ne	5.2	(460)	(110)	ne	ne	S
MfE (2011) Outdoor Inhalation, Sand, Groundwater at 2 m [1]				S	S	S	ne	(340)	S	S	ne	ne	S
ANZECC (2000) 95% trigger values for marine ecosystems [2]				ne	ne	ne	ne	0.7	ID	ID	ID	ID	ne
ANZECC (2000) low reliability trigger values				ne	ne	ne	ne		0.18	0.005	0.075	0.35	ne
BH50	Off-Site	12-04-11	887760.7	1.9	3.2	1	6.2	0.44	0.0034	0.186	0.037	0.0045	0.042
BH50	Off-Site	01-05-12	1003823.2	0.47	0.8	< 0.4	1.3	0.9	0.0049	0.071	0.019	0.0035	0.023
BH50	Off-Site	11-07-13	1155908.6	0.18	< 0.2	< 0.4	< 0.7	0.183	0.0014	0.041	0.012	0.0011	0.013
BH50	Off-Site	05-12-13	1212710.6	0.35	0.3	< 0.4	< 0.7	0.46	0.0028	0.113	0.015	0.0017	0.032
BH50	Off-Site	12-06-14	1287325.3	< 0.10	< 0.2	< 0.4	< 0.7	0.126	< 0.0010	0.0023	0.002	< 0.0010	0.002
BH50	Off-Site	11-04-17	-	Not Sampled (dry)									
BH51	Off-Site	11-07-13	1155908.7	1.53	2.4	< 0.4	3.9	0.128	< 0.0010	0.26	0.25	< 0.0010	0.25
BH51	Off-Site	04-12-13	1212710.7	1.04	2.5	< 0.4	3.5	0.0193	< 0.0010	0.033	0.055	< 0.0010	0.055
BH51	Off-Site	12-06-14	1287325.4	0.32	1.4	< 0.4	1.7	0.0011	< 0.0010	0.0044	< 0.002	< 0.0010	< 0.003
BH51	Off-Site	05-05-15	1422884.5	1.04	2.1	< 0.4	3.2	0.022	< 0.0010	0.035	0.018	< 0.0010	0.018
BH51	Off-Site	04-11-15	1497677.10	0.52	1.5	< 0.4	2	0.0172	< 0.0010	0.045	0.021	< 0.0010	0.022
BH51	Off-Site	02-06-16	1595593.11	0.38	2.1	< 0.4	3	0.0139	< 0.0010	0.0182	< 0.002	< 0.0010	< 0.003
BH51	Off-Site	11-04-17	1758285.7	0.91	1.7	< 0.4	2.6	0.0183	0.0013	0.023	< 0.002	< 0.0010	< 0.0030
BH52	Off-Site	10-07-13	1155908.8	2.7	2.9	< 0.4	5.6	0.130	< 0.0010	0.27	0.25	< 0.0010	0.25
BH52	Off-Site	05-12-13	1212710.8	1.26	2.2	< 0.4	3.5	< 0.0010	< 0.0010	0.078	0.37	< 0.0010	0.37
BH52	Off-Site	12-06-14	1287325.5	0.15	0.4	< 0.4	< 0.7	< 0.0010	< 0.0010	0.0022	0.033	< 0.0010	0.033
BH52	Off-Site	06-05-15	1422884.9	1.21	2.8	< 0.4	4	0.0108	0.0033	0.043	0.159	0.0022	0.1612
BH52	Off-Site	05-11-15	1497677.11	0.79	2.1	< 0.4	3	0.0027	< 0.0010	0.061	0.3	< 0.0010	0.3
BH52	Off-Site	02-06-16	1595593.2	0.74	1.6	< 0.4	2.4	0.0016	< 0.0010	0.034	0.37	< 0.0010	0.37
BH52	Off-Site	11-04-17	1758285.8	0.58	1.5	< 0.4	2.1	0.0025	< 0.0010	0.008	0.062	< 0.0010	0.063
BH53	Off-Site	10-07-13	1155908.9	0.89	1.2	< 0.4	2.1	0.129	0.002	0.0133	0.038	< 0.0010	0.039
BH53	Off-Site	04-12-13	1212710.9	0.75	1.1	< 0.4	1.8	0.135	0.0024	0.0035	0.005	< 0.0010	0.005
BH53	Off-Site	12-06-14	1287325.6	0.8	1.4	< 0.4	2.2	0.069	< 0.0010	0.0019	< 0.002	< 0.0010	< 0.003
BH53	Off-Site	06-05-15	1422884.18	0.87	1	< 0.4	1.9	0.073	0.0013	0.0018	0.002	0.001	0.003
BH53	Off-Site	04-11-15	1497677.12	0.66	1	< 0.4	2	0.072	0.0016	0.0018	0.003	0.0012	0.0042
BH53	Off-Site	02-06-16	1595593.10	0.28	0.5	< 0.4	0.8	0.093	0.0024	< 0.0010	0.002	< 0.0010	0.003
BH53	Off-Site	11-04-17	1758285.13	0.27	0.3	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.0030
BH54	Off-Site	06-05-15	1422884.17	< 0.10	< 0.2	< 0.4	< 0.7	0.0192	< 0.0010	0.0086	0.004	< 0.0010	0.004
BH54	Off-Site	04-11-15	1497677.15	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH54	Off-Site	03-06-16	1595593.17	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH54	Off-Site	11-04-17	1758285.14	< 0.06	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.0030
BH55	Off-Site	06-05-15	1422884.16	0.27	0.5	< 0.4	0.8	< 0.0010	< 0.0010	0.0015	0.003	< 0.0010	0.003
BH55	Off-Site	04-11-15	1497677.16	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH55	Off-Site	02-06-16	1595593.3	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH55	Off-Site	11-04-17	-	No Access									
BH56	Off-Site	05-05-15	1422884.8	3	2.1	0.6	5.7	0.39	0.0036	0.57	1.09	< 0.0010	1.09
BH56	Off-Site	03-11-15	1497677.7	1.96	1.9	0.7	4.6	0.167	0.0028	0.4	0.92	< 0.0010	0.92
BH56	Off-Site	02-06-16	-	LNAPL									
BH56	Off-Site	11-04-17	1758285.3	1.5	2.2	1.1	4.9	0.22	0.0022	0.076	0.27	< 0.001	0.271
BH57	Off-Site	05-05-15	-	LNAPL									
BH57	Off-Site	04-11-15	-	LNAPL									
BH57	Off-Site	02-06-16	-	LNAPL									
BH57	Off-Site	11-04-17	-	LNAPL									
BH58	Off-Site	05-05-15	1422884.7	1.2	2	< 0.4	3.2	0.079	0.0022	0.042	0.006	< 0.0010	0.006
BH58	Off-Site	03-11-15	1497677.2	0.92	1.9	< 0.4	2.8	0.051	0.0011	0.0145	0.004	< 0.0010	0.005
BH58	Off-Site	02-06-16	1595593.6	0.46	1.1	< 0.4	2	0.08	0.0011	0.0135	< 0.002	< 0.0010	< 0.003
BH58	Off-Site	11-04-17	1758285.2	0.45	1.2	0.6	2.3	0.032	< 0.0010	0.0020	< 0.002	< 0.0010	< 0.0030
BH59	Off-Site	05-05-15	1422884.3	1.47	3.8	< 0.4	5.2	0.0138	0.0031	0.0158	0.031	0.0078	0.0388
BH59	Off-Site	03-11-15	1497677.3	0.52	2	< 0.4	2.5	0.0045	0.0013	0.0136	0.046	0.0055	0.0515
BH59	Off-Site	02-06-16	1595593.4	0.17	0.7	< 0.4	0.9	0.0057	0.0016	0.063	0.011	0.0024	0.0134
BH59	Off-Site	11-04-17	1758285.10	0.11	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.0030
BH60	Off-Site	05-05-15	1422884.4	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH60	Off-Site	03-11-15	-	Not Sampled									
BH60	Off-Site	02-06-16	1595593.7	< 0.10	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.003
BH60	Off-Site	11-04-17	1758285.1	< 0.06	< 0.2	< 0.4	< 0.7	< 0.0010	< 0.0010	< 0.0010	< 0.002	< 0.0010	< 0.0030

Location_Code	Sample Date	PAH: Acenaphthene	Acenaphthylene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)&(j)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-c,d)pyrene	Naphthalene	Phenanthrene	Pyrene
MfE (2011) Indoor Inhalation, Sand, Groundwater at 2 m [1]		ne	ne	ne	ne	S	ne	ne	ne	ne	ne	ne	ne	ne	S	ne	S
MfE (2011) Outdoor Inhalation, Sand, Groundwater at 2 m [1]		ne	ne	ne	ne	S	ne	ne	ne	ne	ne	ne	ne	ne	S	ne	S
ANZECC (2000) 95% trigger values for marine ecosystems [2]		ne	ne	ID	ne	ID	ne	ne	ne	ne	ne	ID	ne	ne	0.07	ID	ne
ANZECC (2000) low reliability trigger values		ne	ne	0.0004	ne	0.0002	ne	ne	ne	ne	ne	0.0014	ne	ne	ne	0.002	ne
BH50	12-04-11	0.00031	0.00011	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0006	< 0.00010	0.145	0.0005	< 0.0002
BH50	01-05-12	0.00035	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0005	< 0.00010	0.156	< 0.0004	< 0.0002
BH50	11-07-13	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.048	< 0.0004	< 0.0002
BH50	05-12-13	0.00011	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	0.000054	0.000125	< 0.000008	0.04	0.000031	0.000073
BH50	12-06-14	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0138	< 0.0004	< 0.0002
BH50	11-04-17	Not Sampled (dry)															
BH51	11-07-13	0.00113	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0019	< 0.00010	0.45	0.0014	< 0.0002
BH51	04-12-13	0.002	< 0.000008	0.00025	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	0.000176	0.0029	< 0.000008	0.35	0.0021	0.000127
BH51	12-06-14	0.0025	< 0.00010	0.00035	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00026	0.0031	< 0.00010	0.092	0.0031	< 0.0002
BH51	05-05-15	0.0022	< 0.00010	0.00032	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00019	0.0028	< 0.00010	0.31	0.0021	0.0002
BH51	04-11-15	0.00112	< 0.00010	0.0001	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00011	0.0017	< 0.00010	0.156	0.0011	< 0.0002
BH51	02-06-16	0.00078	0.00013	0.00013	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00008	0.00122	< 0.00002	0.131	0.00097	0.00007
BH51	11-04-17	0.00122	0.00017	0.00014	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0016	< 0.00010	0.26	0.0011	< 0.0002
BH52	10-07-13	0.00044	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0008	< 0.00011	0.35	< 0.0004	< 0.0002
BH52	05-12-13	0.00054	< 0.000008	0.000039	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	0.000047	0.00124	< 0.000008	0.105	0.00067	0.000039
BH52	12-06-14	0.00014	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0003	< 0.00010	0.0118	< 0.0004	< 0.0002
BH52	06-05-15	0.00064	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0006	< 0.00010	0.075	< 0.0004	< 0.0002
BH52	05-11-15	0.00025	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0005	< 0.00010	0.052	< 0.0004	< 0.0002
BH52	02-06-16	0.00017	0.00009	0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00043	< 0.00002	0.089	0.00011	< 0.00002
BH52	11-04-17	0.00034	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0005	< 0.00010	0.030	< 0.0004	< 0.0002
BH53	10-07-13	0.00029	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0002	< 0.00010	0.40	< 0.0004	< 0.0002
BH53	04-12-13	0.0002	< 0.000008	0.000051	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	< 0.000008	0.000066	0.000148	< 0.000008	0.32	0.000182	0.000076
BH53	12-06-14	0.00032	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0003	< 0.00010	0.35	< 0.0004	< 0.0002
BH53	06-05-15	0.00034	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0003	< 0.00010	0.32	< 0.0004	< 0.0002
BH53	04-11-15	0.00014	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0062	< 0.0004	< 0.0002
BH53	02-06-16	0.00018	0.00003	0.00003	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00005	0.00011	< 0.00002	0.144	0.00012	0.00004
BH53	11-04-17	0.00011	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00013	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH54	06-05-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0027	< 0.0004	< 0.0002
BH54	04-11-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH54	03-06-16	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00010	< 0.00002	< 0.00002
BH54	11-04-17	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH55	06-05-15	0.00025	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0001	< 0.0002	< 0.00010	0.0047	< 0.0004	< 0.0002
BH55	04-11-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	0.0008	< 0.0004	< 0.0002
BH55	02-06-16	0.00006	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00007	< 0.00002	0.003	< 0.00002	< 0.00002
BH55	11-04-17	No Access															
BH56	05-05-15	0.00086	< 0.00010	0.00019	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0022	< 0.00010	0.23	0.0013	< 0.0002
BH56	03-11-15	0.00061	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0016	< 0.00010	0.126	0.0009	< 0.0002
BH56	02-06-16	LNAPL															
BH56	11-04-17	0.00083	0.00026	0.00014	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0021	< 0.0001	0.26	0.0014	< 0.0002
BH57	05-05-15	LNAPL															
BH57	04-11-15	LNAPL															
BH57	02-06-16	LNAPL															
BH57	11-04-17	LNAPL															
BH58	05-05-15	0.00082	< 0.00010	0.00012	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0023	< 0.00010	0.41	0.0014	< 0.0002
BH58	03-11-15	0.00077	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0027	< 0.00010	0.38	0.0017	< 0.0002
BH58	02-06-16	0.00041	0.00012	0.00007	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00004	0.00112	< 0.00002	0.19	0.0009	0.00006
BH58	11-04-17	0.00048	0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0013	< 0.00010	0.039	0.0005	< 0.0002
BH59	05-05-15	0.00058	< 0.00010	0.00011	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.001	< 0.00010	0.35	0.0004	< 0.0002
BH59	03-11-15	0.00025	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0006	< 0.00010	0.122	< 0.0004	< 0.0002
BH59	02-06-16	0.00017	0.00004	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00003	0.00022	< 0.00002	0.078	0.0001	0.00005
BH59	11-04-17	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH60	05-05-15	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002
BH60	03-11-15	Not Sampled															
BH60	02-06-16	< 0.00003	< 0.00003	< 0.00003	< 0.00003	< 0.00003	< 0.00003	< 0.00003	< 0.00003	< 0.00003	< 0.00003	0.00003	< 0.00003	< 0.00003	0.00016	< 0.00003	< 0.00003
BH60	11-04-17	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.0002	< 0.00010	< 0.0005	< 0.0004	< 0.0002

Notes
Concentrations expressed in units of mg/L.
LNAPL denotes the presence of measurable LNAPL in the monitoring well.
Grey text denotes concentration below the laboratory LORs.
[1] MfE 2011: Inhalation Pathway - Sand - Groundwater 2m - Commercial/Industrial land use.
[2] ANZECC 2000: 95 % protection level for marine species.
S indicates calculated water criteria exceeds solubility limit for pure compound in water.
Values in brackets exceed solubility limit for compound in water when present as part of a typical gasoline mixture.
ID = Insufficient data to derive a reliable trigger value. Low reliability trigger values adopted.
ne' denotes criteria or trigger values not derived.

APPENDIX C

LNAPL and Groundwater Hydrographs

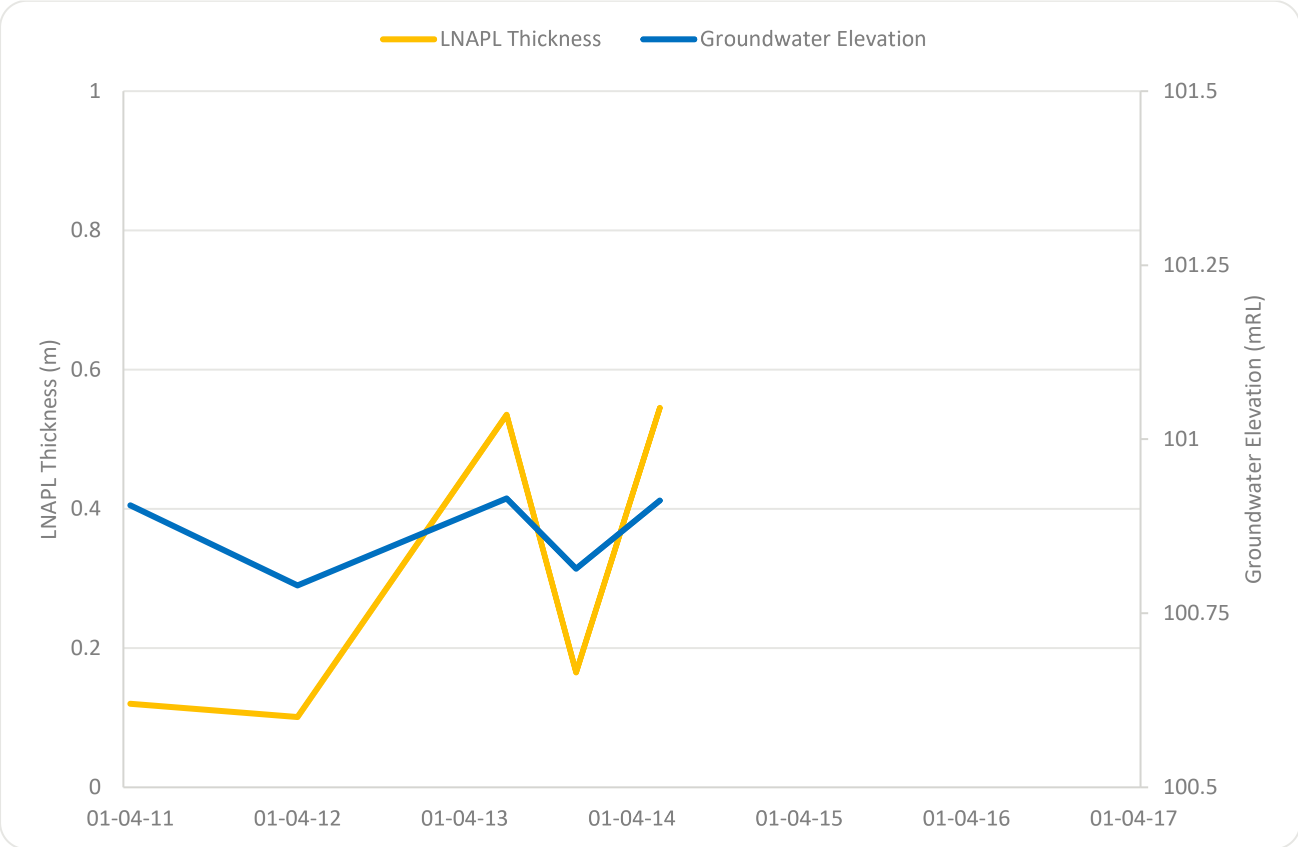


Figure C1: Hydrograph for monitoring well BH1.

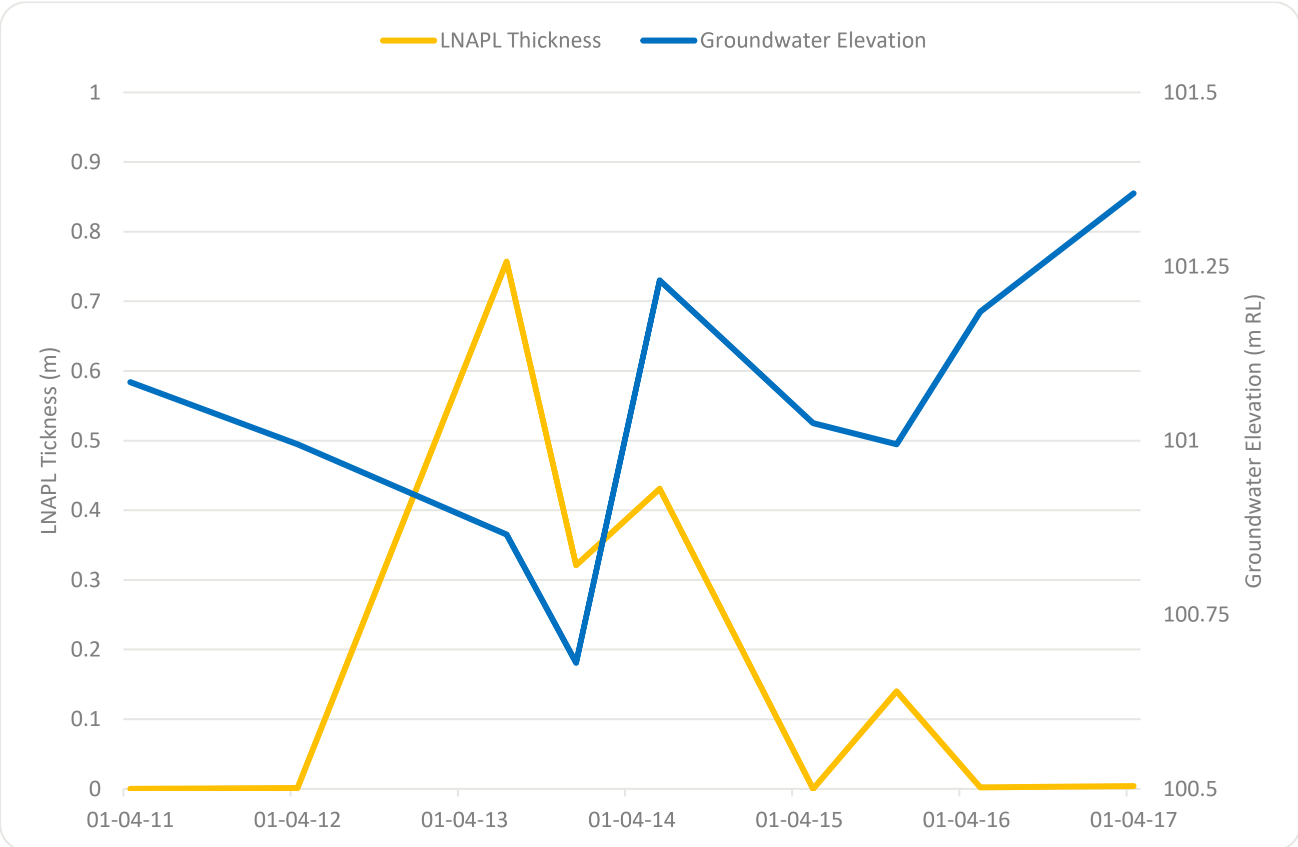


Figure C2: Hydrograph for monitoring well BH24.

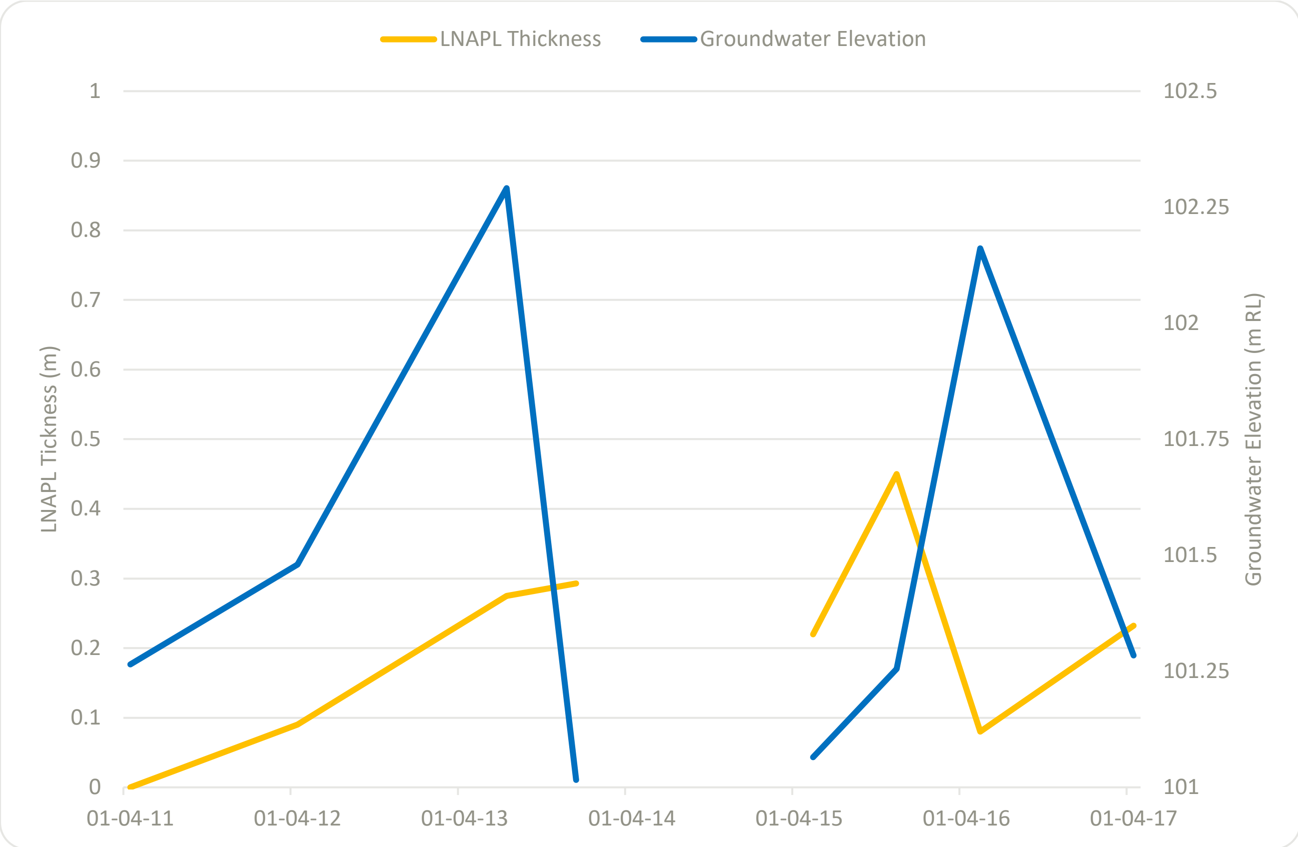


Figure C3: Hydrograph for monitoring well BH25.

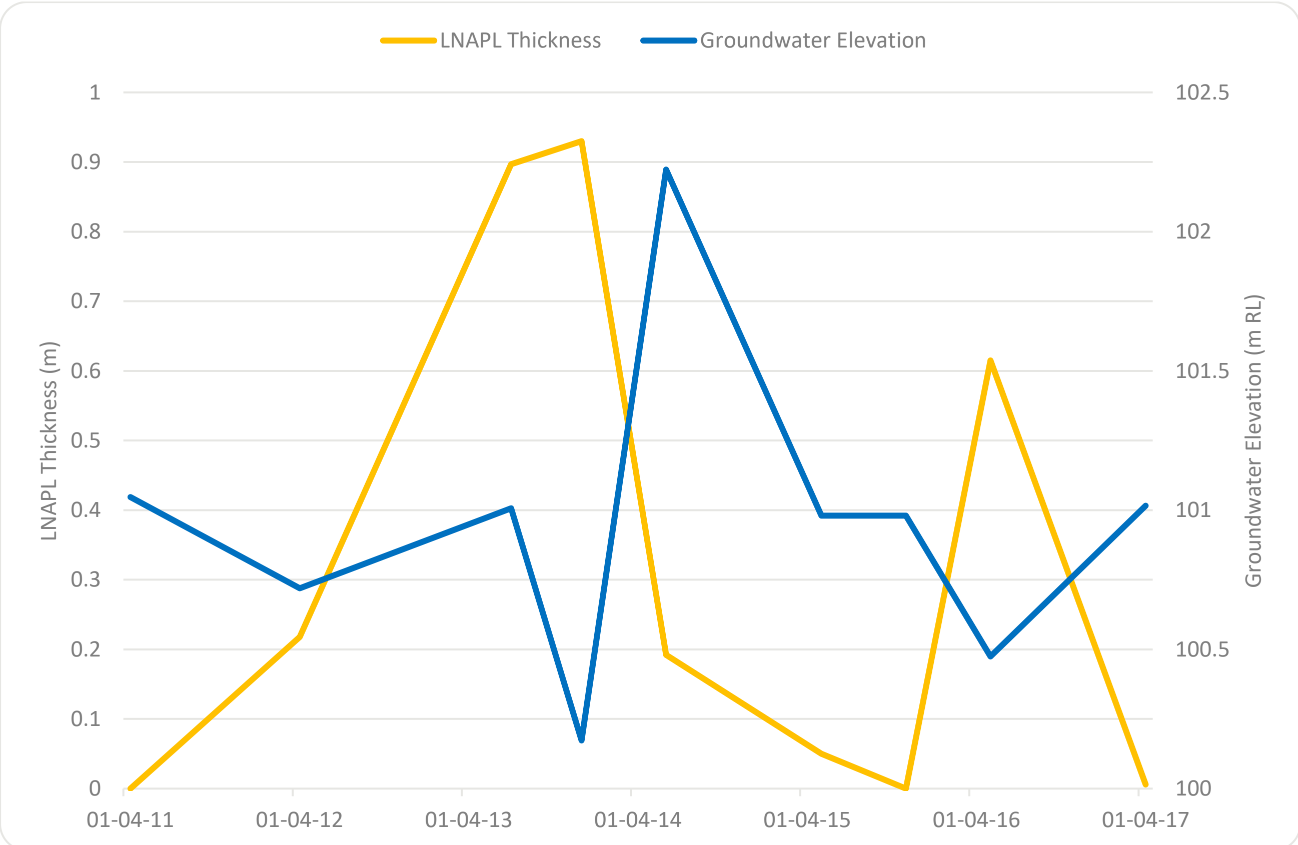


Figure C4: Hydrograph for monitoring well BH29.

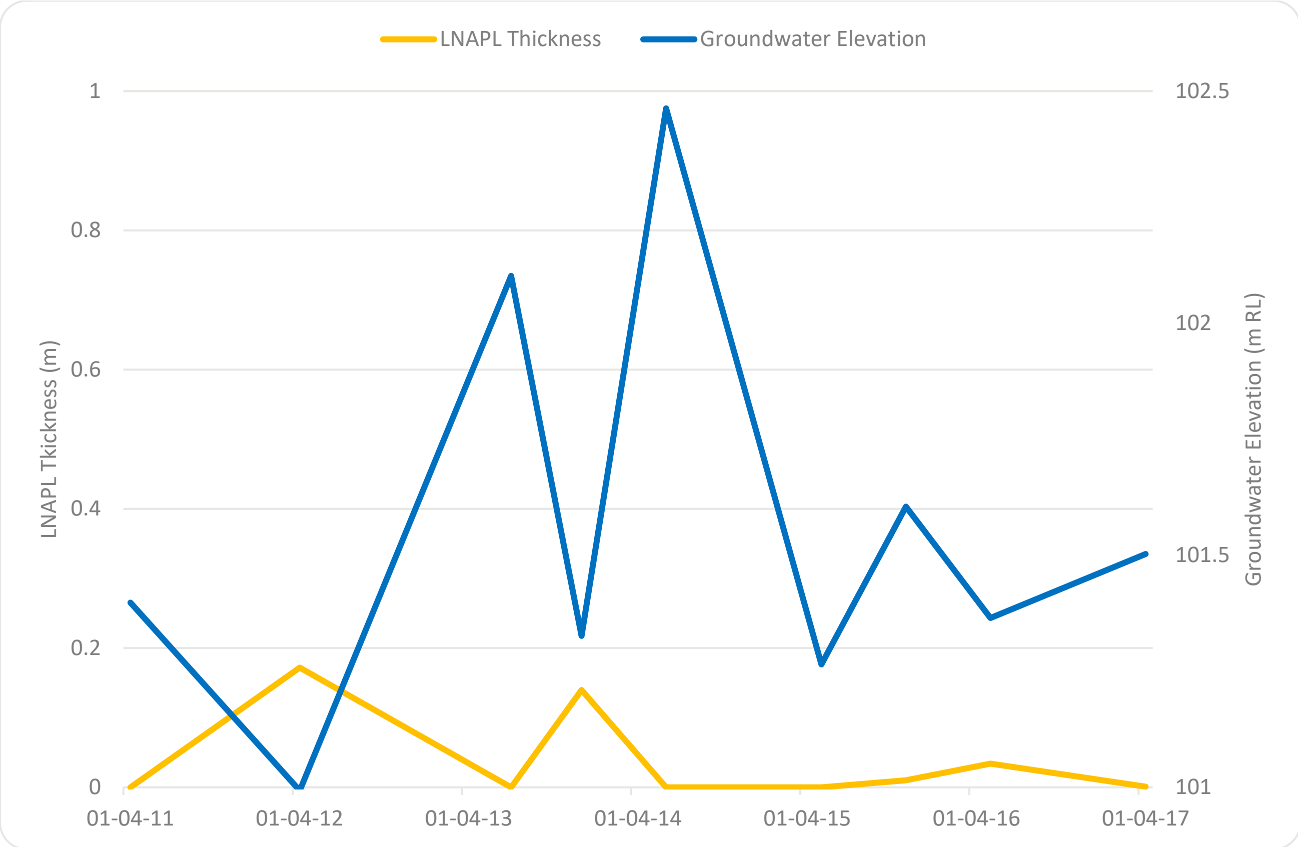


Figure C5: Hydrograph for monitoring well BH31.

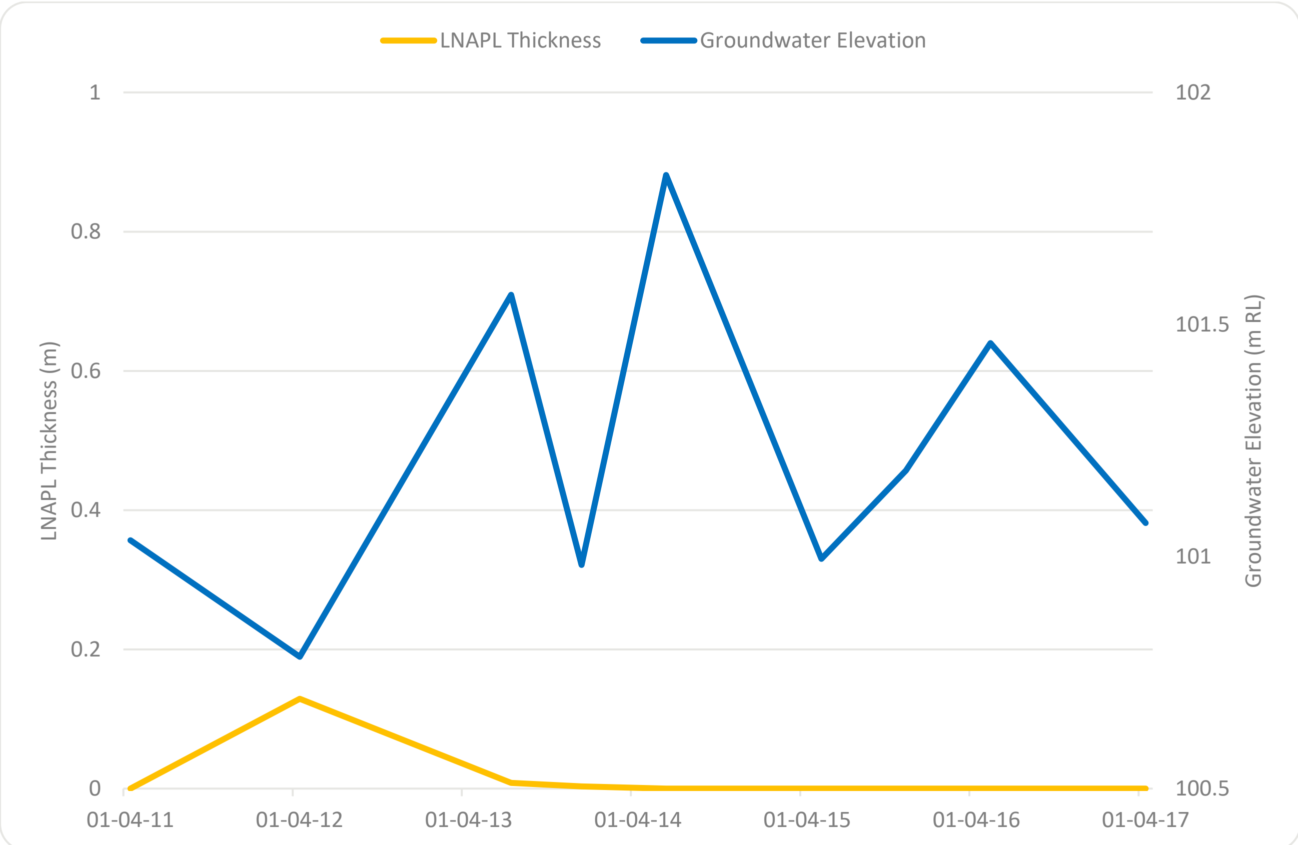


Figure C6: Hydrograph for monitoring well BH33.

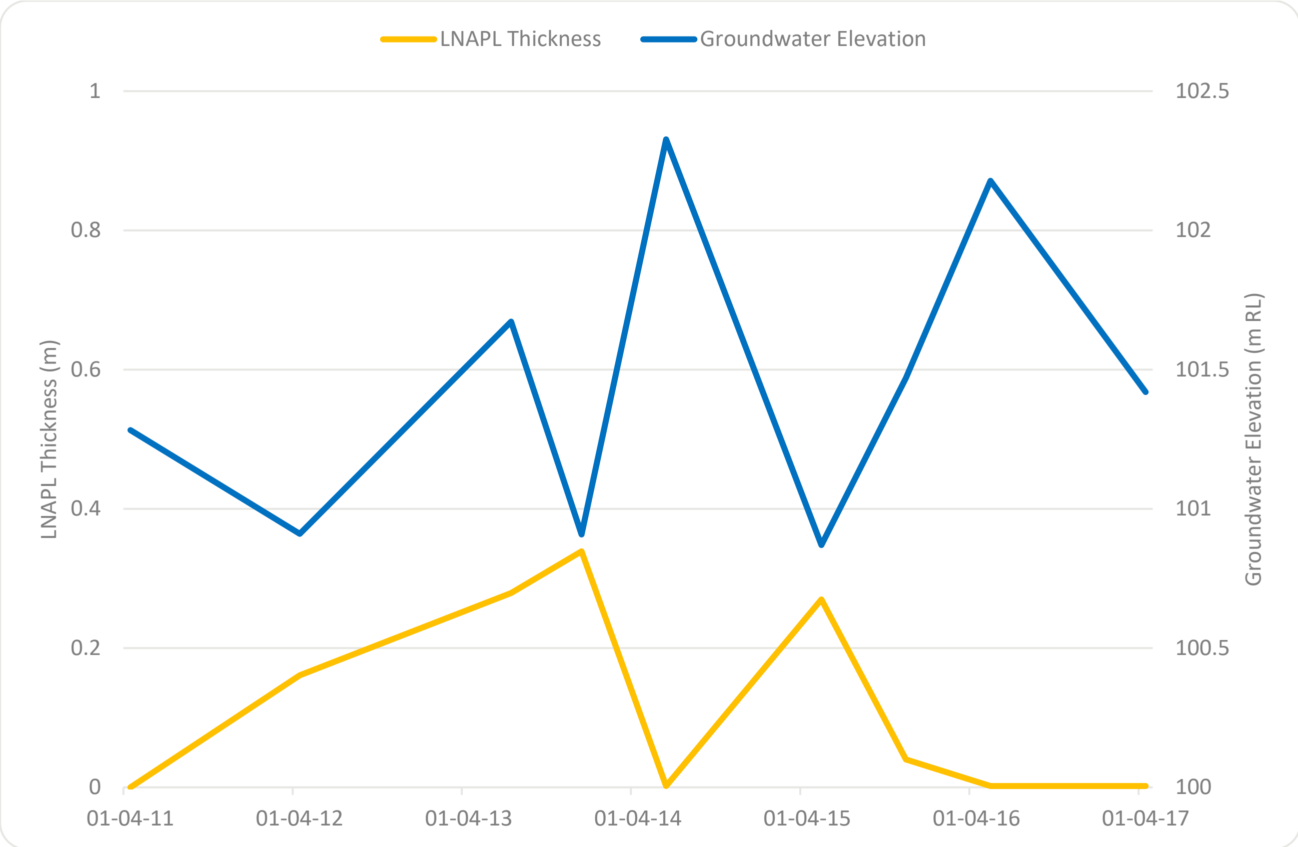


Figure C7: Hydrograph for monitoring well BH35.

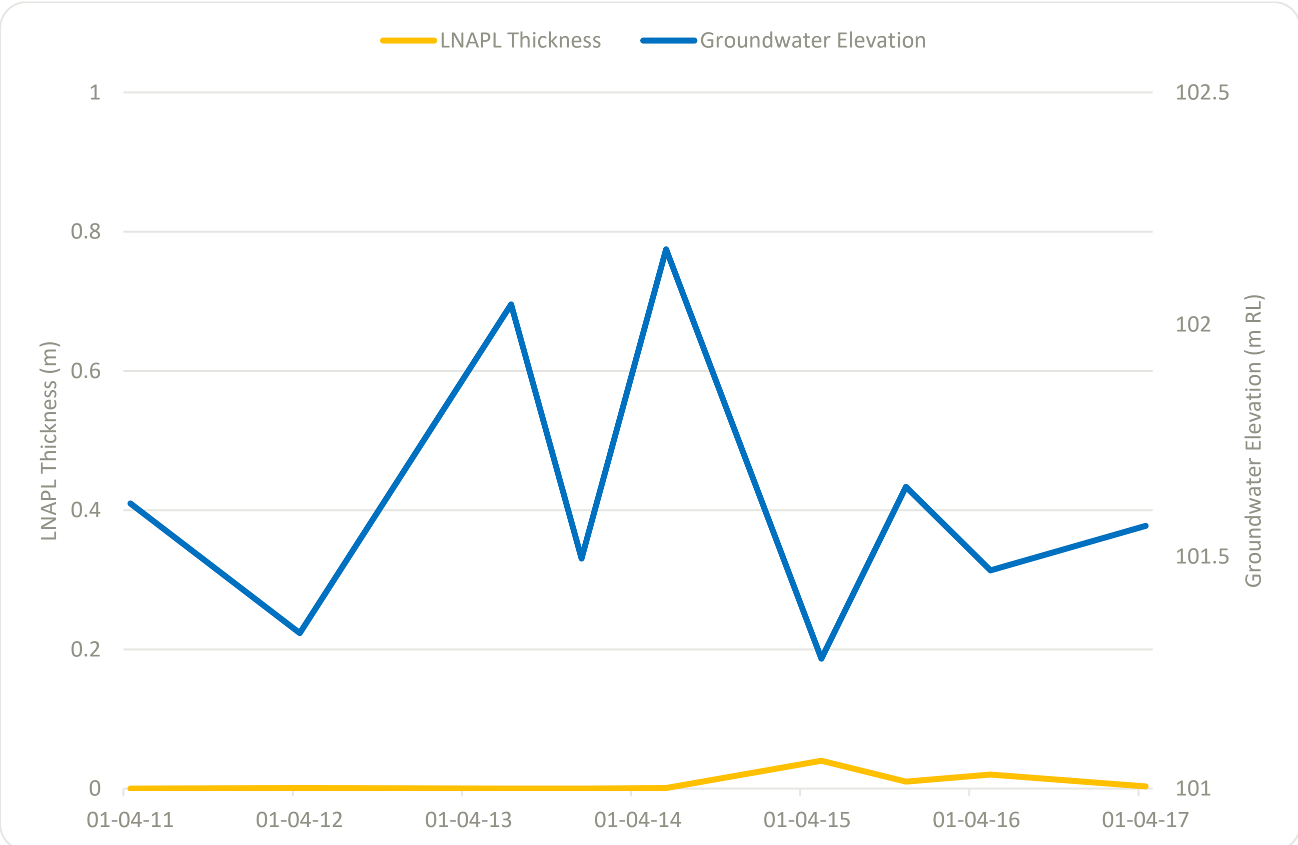


Figure C8: Hydrograph for monitoring well BH36.

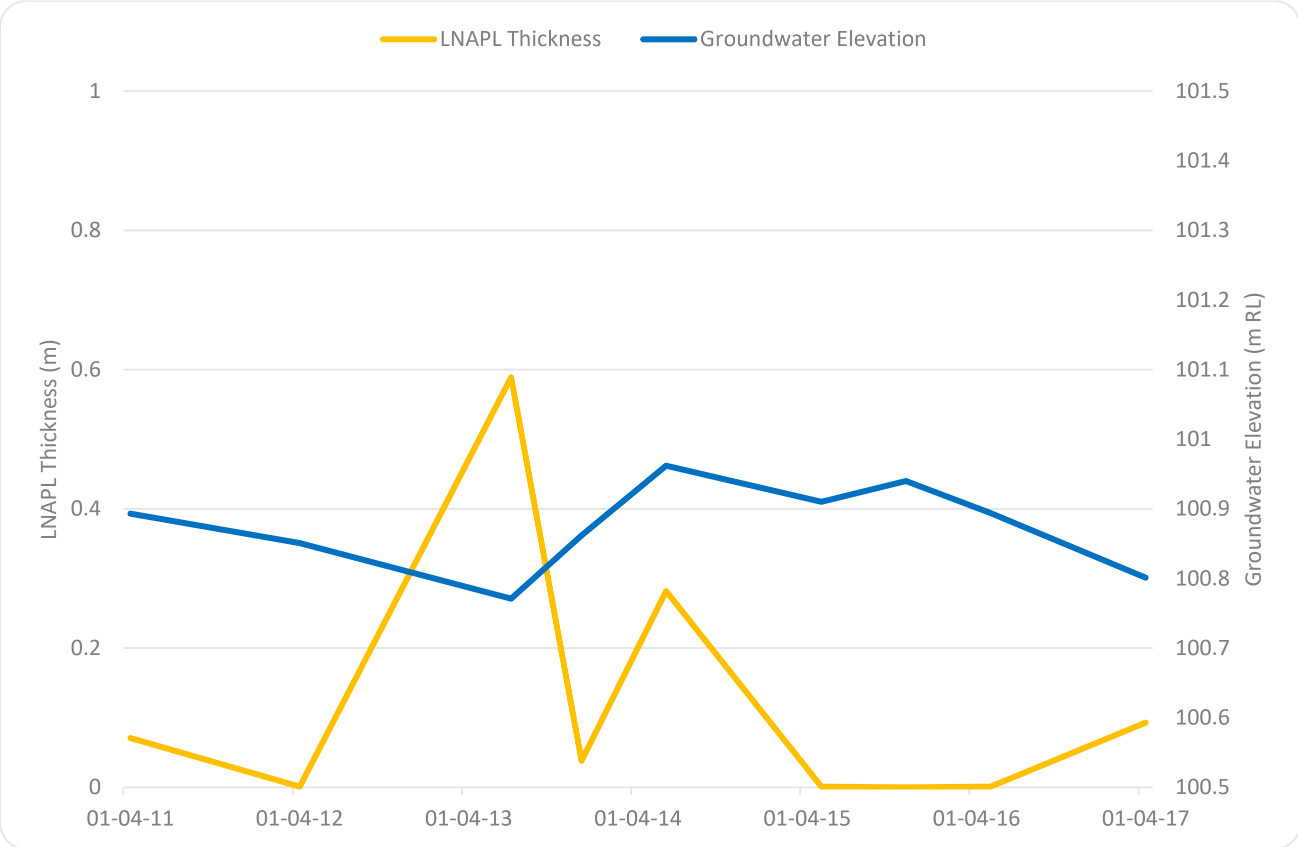


Figure C9: Hydrograph for monitoring well BH46.

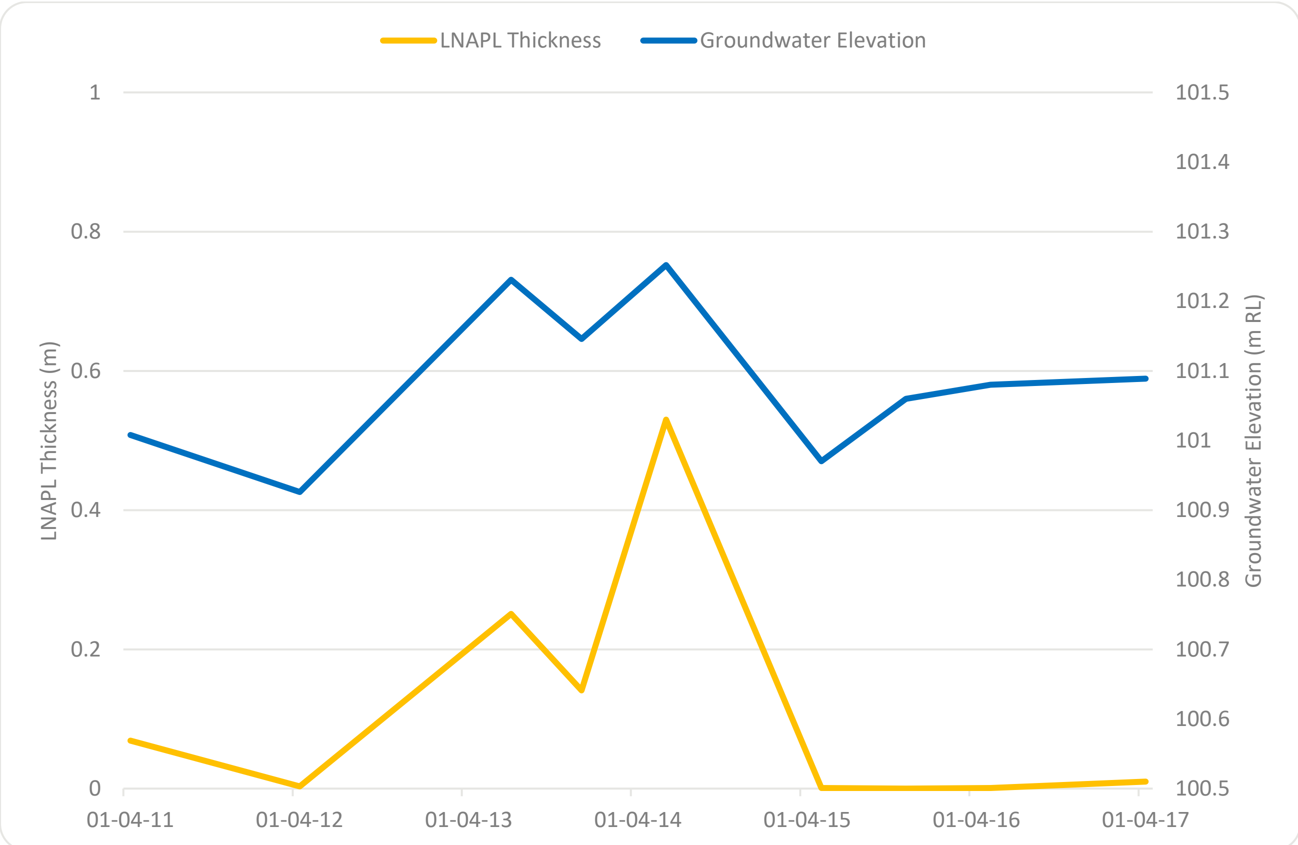


Figure C10: Hydrograph for monitoring well BH47.

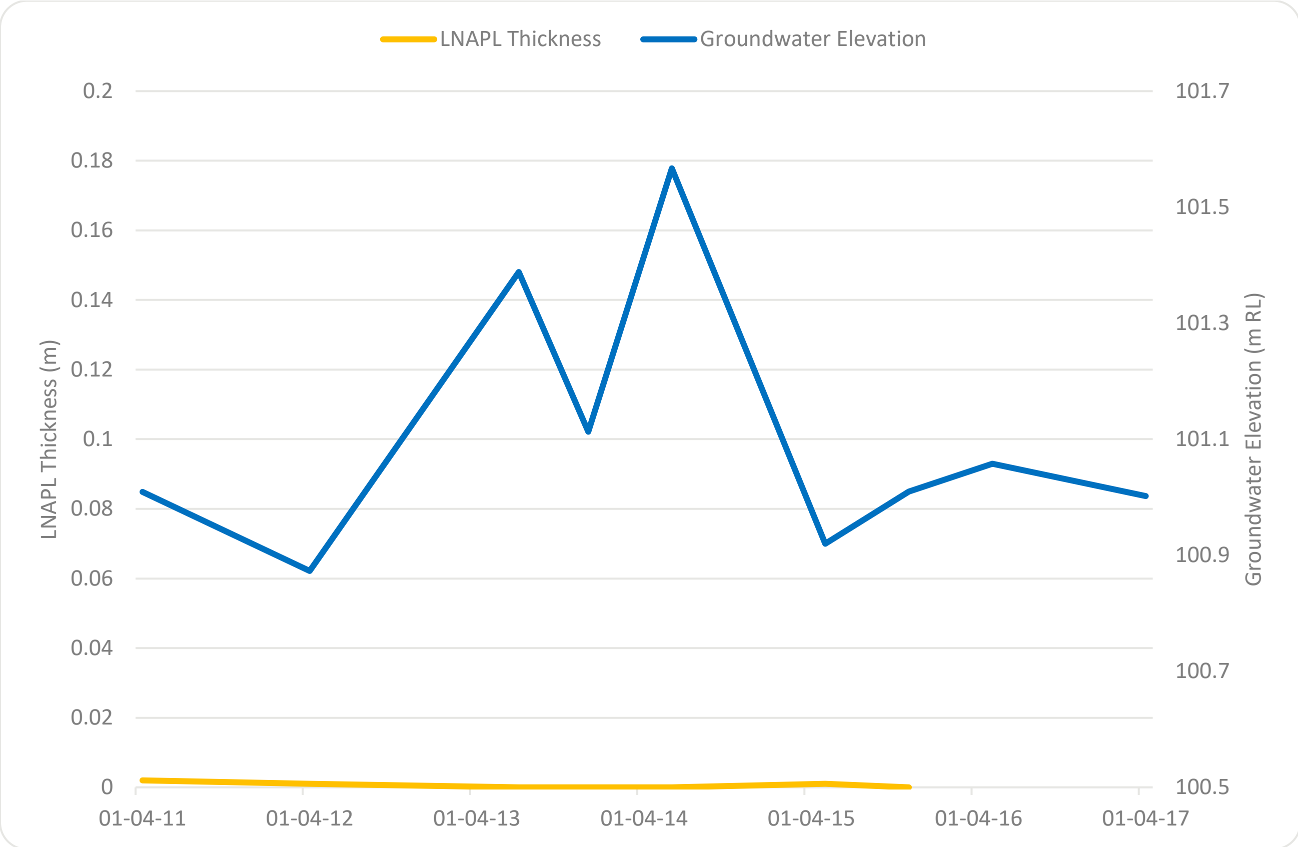


Figure C11: Hydrograph for monitoring well BH49.

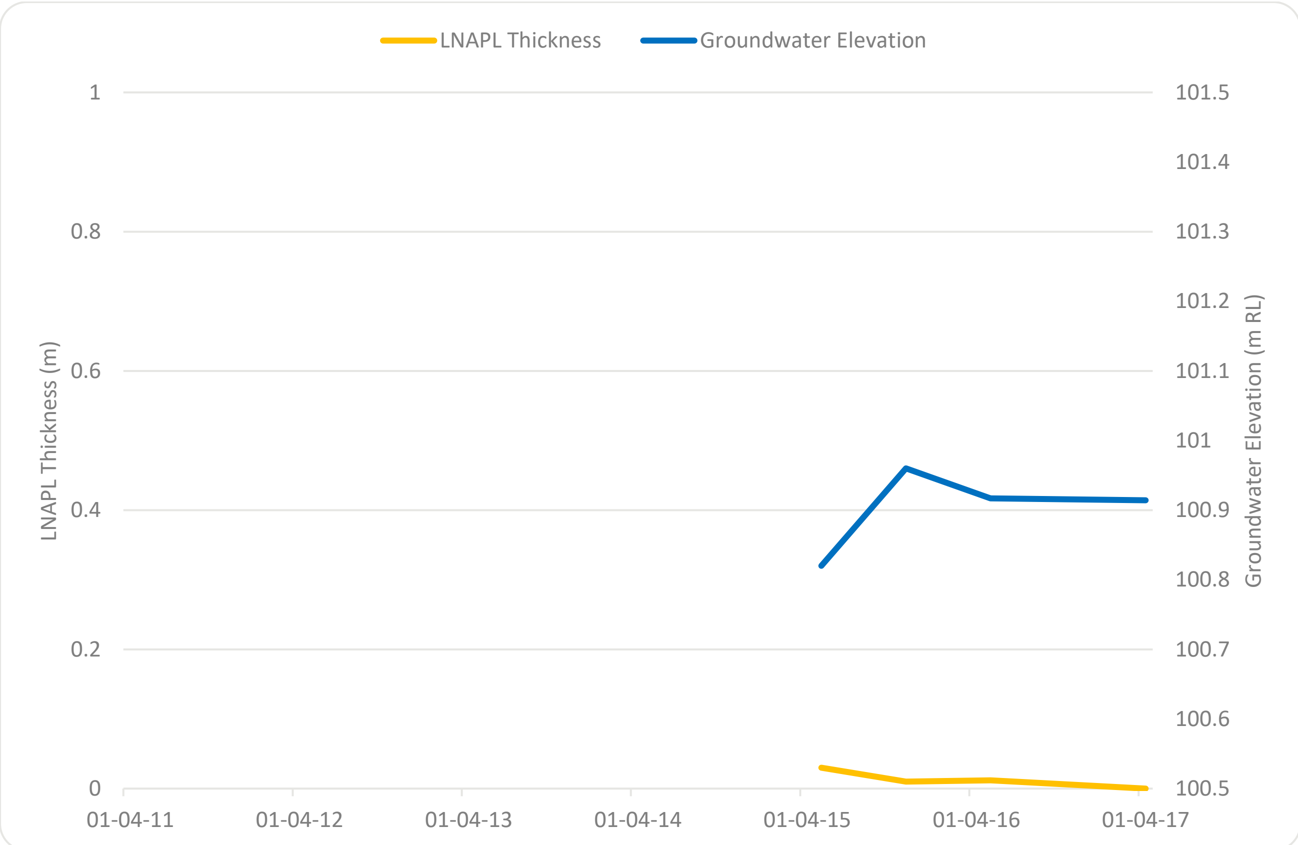


Figure C12: Hydrograph for monitoring well BH57.

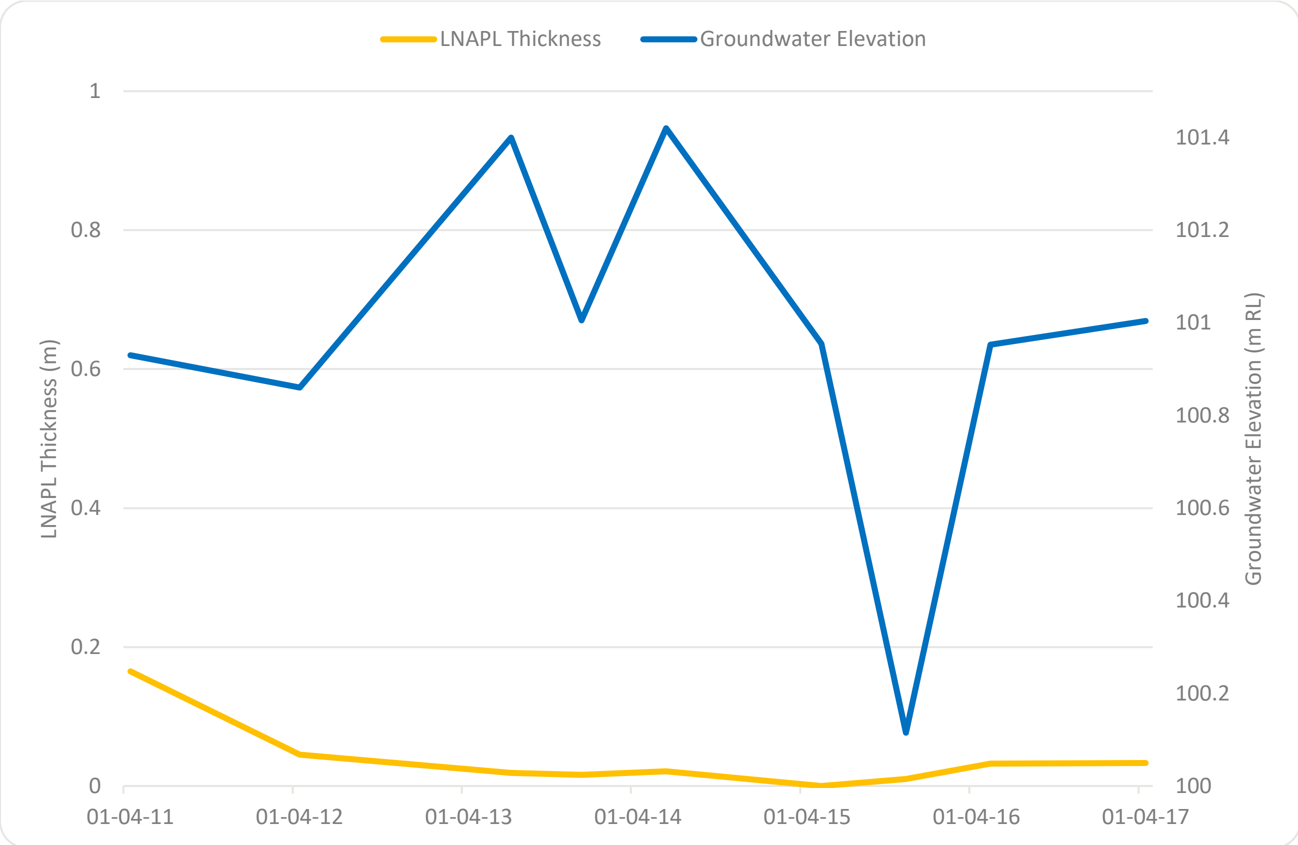


Figure C13: Hydrograph for monitoring well BHA.

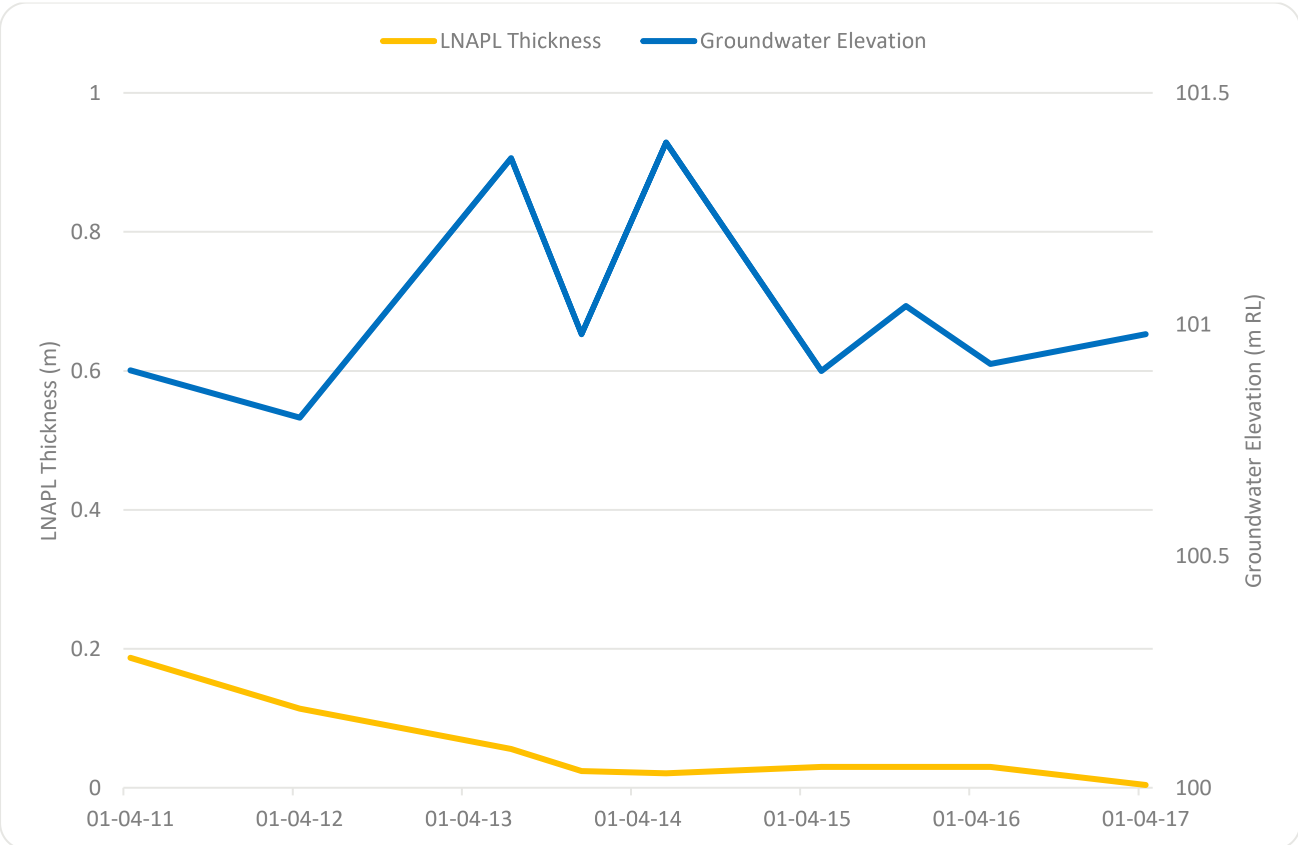


Figure C14: Hydrograph for monitoring well BHB.

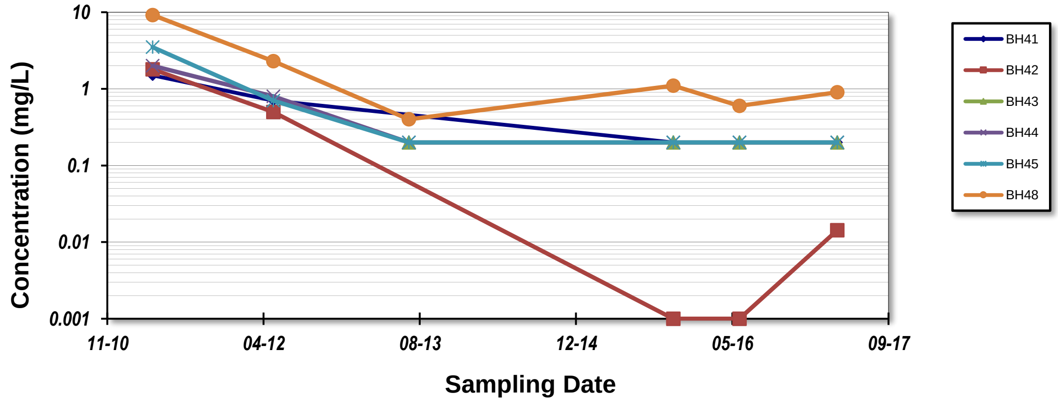
APPENDIX D

Mann-Kendall Trend Analysis Worksheets

GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	20-Sep-19	Job ID:	1792933
Facility Name:	Mobil Dunedin	Constituent:	TPH C10-C14
Conducted By:	A Hart	Concentration Units:	mg/L

Sampling Point ID:		BH41	BH42	BH43	BH44	BH45	BH48	
Sampling Event	Sampling Date	TPH C10-C14 CONCENTRATION (mg/L)						
1	12-04-11	1.5	1.8		2	3.5	9.2	
2	02-05-12	0.7	0.5		0.8	0.7	2.3	
3	10-07-13			0.2	0.2	0.2	0.4	
4	03-11-15	0.2	0.001	0.2	0.2	0.2	1.1	
5	02-06-16	0.2	0.001	0.2	0.2	0.2	0.6	
6	11-04-17	0.2	0.0143	0.2	0.2	0.2	0.9	
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		1.01	1.68	0.00	1.21	1.59	1.40	
Mann-Kendall Statistic (S):		-7	-5	0	-9	-9	-7	
Confidence Factor:		92.1%	82.1%	37.5%	93.2%	93.2%	86.4%	
Concentration Trend:		Prob. Decreasing	No Trend	Stable	Prob. Decreasing	Prob. Decreasing	No Trend	



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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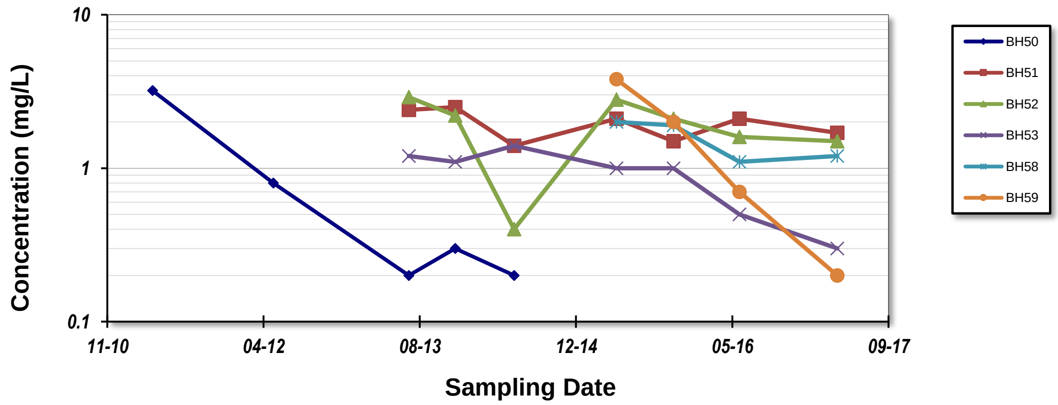
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date: 20-Sep-19 | **Job ID:** 1792933
Facility Name: Mobil Dunedin | **Constituent:** TPH C10-C14
Conducted By: A Hart | **Concentration Units:** mg/L

Sampling Event	Sampling Date	BH50	BH51	BH52	BH53	BH58	BH59	
		TPH C10-C14 CONCENTRATION (mg/L)						
1	12-04-11	3.2						
2	02-05-12	0.8						
3	10-07-13	0.2	2.4	2.9	1.2			
4	05-12-13	0.3	2.5	2.2	1.1			
5	12-06-14	0.2	1.4	0.4	1.4			
6	05-05-15		2.1	2.8	1	2	3.8	
7	04-11-15		1.5	2.1	1	1.9	2	
8	02-06-16		2.1	1.6	0.5	1.1	0.7	
9	11-04-17		1.7	1.5	0.3	1.2	0.2	
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		1.37	0.22	0.45	0.42	0.30	0.96	
Mann-Kendall Statistic (S):		-7	-6	-11	-16	-4	-6	
Confidence Factor:		92.1%	76.4%	93.2%	99.0%	83.3%	95.8%	
Concentration Trend:		Prob. Decreasing	Stable	Prob. Decreasing	Decreasing	Stable	Decreasing	



Notes:
1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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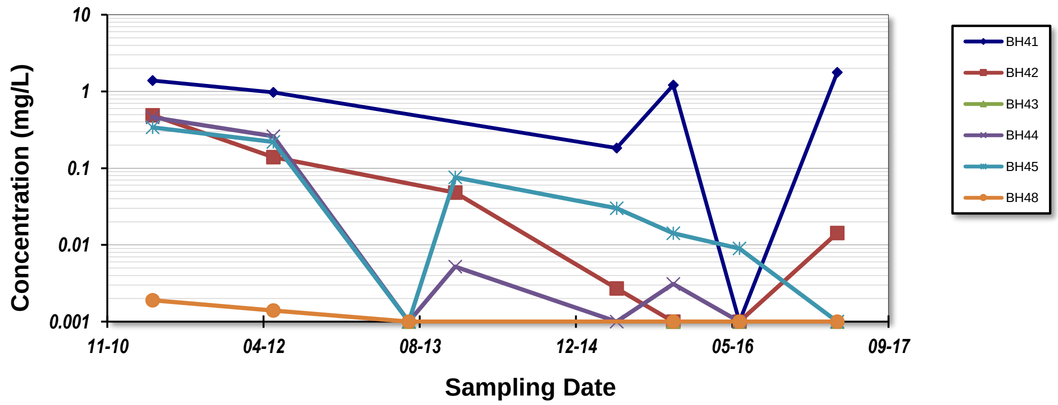
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	20-Sep-19	Job ID:	1792933
Facility Name:	Mobil Dunedin	Constituent:	Ethylbenzene
Conducted By:	A Hart	Concentration Units:	mg/L

Sampling Event	Sampling Date	BH41	BH42	BH43	BH44	BH45	BH48	
		ETHYLBENZENE CONCENTRATION (mg/L)						
1	12-04-11	1.39	0.49		0.46	0.34	0.0019	
2	02-05-12	0.97	0.139		0.26	0.22	0.0014	
3	10-07-13			0.001	0.001	0.001	0.001	
4	05-12-13		0.048		0.0052	0.076		
5	06-05-15	0.183	0.0027		0.001	0.03		
6	03-11-15	1.21	0.001	0.001	0.0031	0.0142	0.001	
7	02-06-16	0.001	0.001	0.001	0.001	0.0090	0.001	
8	11-04-17	1.77	0.0143	0.001	0.001	0.001	0.001	
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.76	1.80	0.00	1.90	1.46	0.30	
Mann-Kendall Statistic (S):		-1	-14	0	-16	-19	-9	
Confidence Factor:		50.0%	97.5%	37.5%	96.9%	98.9%	93.2%	
Concentration Trend:		Stable	Decreasing	Stable	Decreasing	Decreasing	Prob. Decreasing	



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	20-Sep-19	Job ID:	1792933
Facility Name:	Mobil Dunedin	Constituent:	Ethylbenzene
Conducted By:	A Hart	Concentration Units:	mg/L

Sampling Event	Sampling Date	BH50	BH51	BH52	BH53	BH58	BH59	
		ETHYLBENZENE CONCENTRATION (mg/L)						
1	12-04-11	0.186						
2	02-05-12	0.071						
3	10-07-13	0.041	0.26	0.27	0.0133			
4	05-12-13	0.113	0.033	0.078	0.0035			
5	12-06-14	0.0023	0.044	0.0022	0.0019			
6	05-05-15		0.035	0.043	0.0018	0.042	0.0158	
7	04-11-15		0.045	0.061	0.0018	0.0145	0.0136	
8	02-06-16		0.0182	0.034	0.001	0.0135	0.063	
9	11-04-17		0.023	0.008	0.001	0.002	0.001	
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13								
14								
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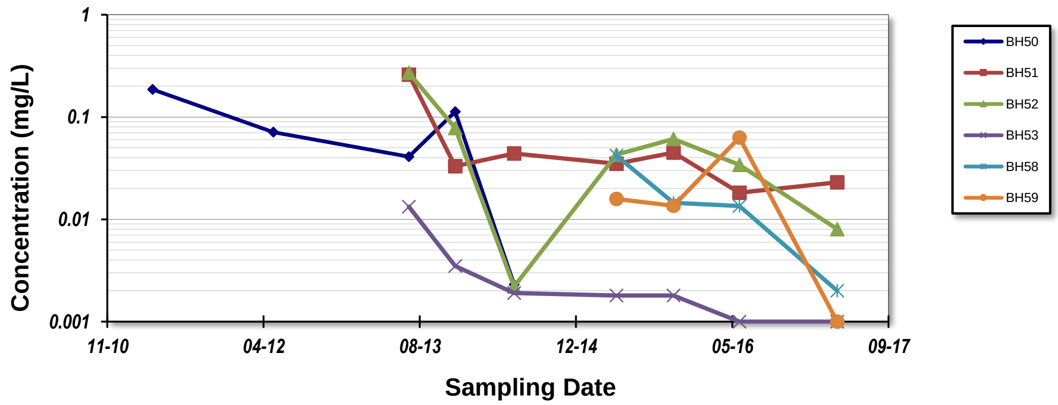
16								
17								
18								
19								
20								
Coefficient of Variation:		0.85	1.32	1.30	1.27	0.94	1.17	
Mann-Kendall Statistic (S):		-6	-9	-11	-19	-6	-2	
Confidence Factor:		88.3%	88.1%	93.2%	99.9%	95.8%	62.5%	
Concentration Trend:		Stable	No Trend	Prob. Decreasing	Decreasing	Decreasing	No Trend	



Notes:

1. At least four independent sampling events per well are required for calculating the trend. *Methodology is valid for 4 to 40 samples.*
2. Confidence in Trend = Confidence (in percent) that constituent concentration is increasing (S>0) or decreasing (S<0): >95% = Increasing or Decreasing; ≥ 90% = Probably Increasing or Probably Decreasing; < 90% and S>0 = No Trend; < 90%, S≤0, and COV ≥ 1 = No Trend; < 90% and COV < 1 = Stable.
3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water*, 41(3):355-367, 2003.

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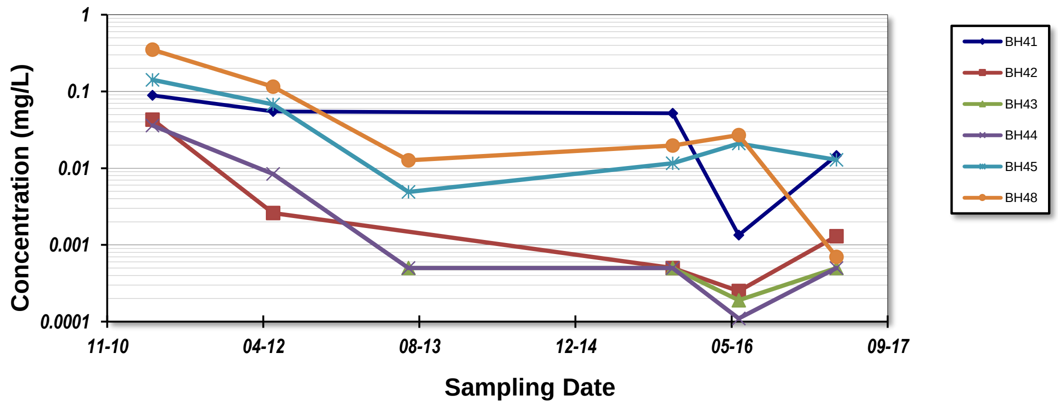
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	20-Sep-19	Job ID:	1792933
Facility Name:	Mobil Dunedin	Constituent:	Napthalene
Conducted By:	A Hart	Concentration Units:	mg/L

Sampling Event	Sampling Date	BH41	BH42	BH43	BH44	BH45	BH48	
		NAPTHALENE CONCENTRATION (mg/L)						
1	12-04-11	0.089	0.043		0.036	0.142	0.35	
2	02-05-12	0.055	0.0026		0.0084	0.068	0.115	
3	10-07-13			0.0005	0.0005	0.0049	0.0127	
4	03-11-15	0.052	0.0005	0.0005	0.0005	0.0116	0.0197	
5	02-06-16	0.00134	0.00025	0.00019	0.00011	0.021	0.027	
6	11-04-17	0.0146	0.0013	0.0005	0.0005	0.0128	0.0007	
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
Coefficient of Variation:		0.82	1.97	0.37	1.86	1.23	1.54	
Mann-Kendall Statistic (S):		-8	-6	-1	-10	-5	-9	
Confidence Factor:		95.8%	88.3%	50.0%	95.2%	76.5%	93.2%	
Concentration Trend:		Decreasing	No Trend	Stable	Decreasing	No Trend	Prob. Decreasing	



Notes:

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3. Methodology based on "MAROS: A Decision Support System for Optimizing Monitoring Plans", J.J. Aziz, M. Ling, H.S. Rifai, C.J. Newell, and J.R. Gonzales, *Ground Water* , 41(3):355-367, 2003.

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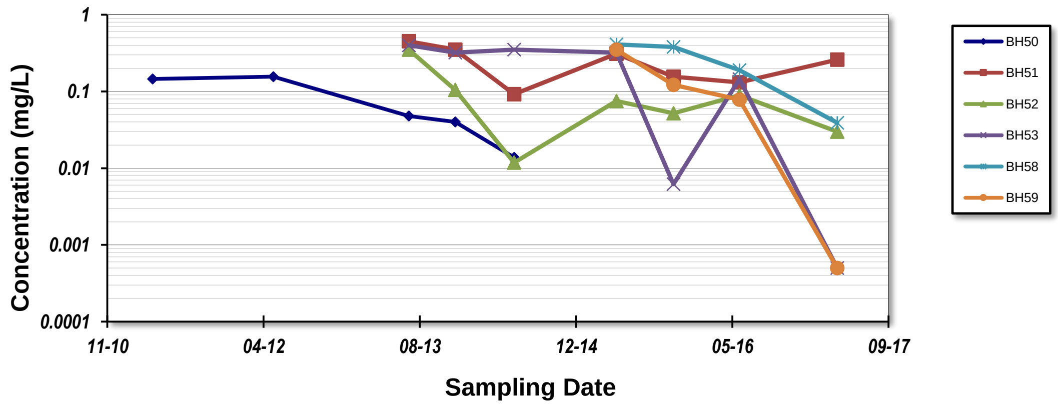
GSI MANN-KENDALL TOOLKIT
for Constituent Trend Analysis

Evaluation Date:	20-Sep-19	**Job ID:**	1792933
Facility Name:	Mobil Dunedin	**Constituent:**	Napthalene
Conducted By:	A Hart	**Concentration Units:**	mg/L

Sampling Event	Sampling Date	BH50	BH51	BH52	BH53	BH58	BH59	
	Sampling Point ID:	**BH50**	**BH51**	**BH52**	**BH53**	**BH58**	**BH59**	
		NAPTHALENE CONCENTRATION (mg/L)						
1	12-04-11	0.145						
2	02-05-12	0.156						
3	10-07-13	0.048	0.45	0.35	0.4			
4	05-12-13	0.04	0.35	0.105	0.32			
5	12-06-14	0.0138	0.092	0.0118	0.35			
6	05-05-15		0.31	0.075	0.32	0.41	0.35	
7	04-11-15		0.156	0.052	0.0062	0.38	0.122	
8	02-06-16		0.131	0.089	0.144	0.19	0.078	
9	11-04-17		0.26	0.03	0.0005	0.039	0.0005	
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
	Coefficient of Variation:	0.81	0.52	1.12	0.76	0.68	1.09	
	Mann-Kendall Statistic (S):	-8	-9	-9	-16	-6	-6	
	Confidence Factor:	95.8%	88.1%	88.1%	99.0%	95.8%	95.8%	
	Concentration Trend:	Decreasing	Stable	No Trend	Decreasing	Decreasing	Decreasing	



Notes:

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APPENDIX E

Limitations

This report has been provided by Golder Associates (NZ) Limited ("Golder") subject to the following limitations:

i) The purpose for which the works were performed is set out in Section 1.1 of the report.

ii) The scope of the works to be performed and described is in accordance with Purchase Orders 45274367, 4410563958, 4410604613, 4410649733 and 4410701962. A description of the work done is set out in the report. If a matter is not addressed, do not assume that any determination has been made by Golder in regards to it.

iii) This report is prepared based on field work undertaken between December 2013 and April 2017 and is based on the conditions encountered and information reviewed at the time of preparation of the report.

iv) Golder did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the report. If a service is not expressly indicated, do not assume it has been provided. Conclusions from field work are an expression of opinion based on samples or locations at the site. The report accordingly is not operating as a guarantee that the condition of the site could not be different at points between sampling locations or at different parts of the site. Thus, due to the inherent variability in natural soils and [subsurface] conditions it is therefore unlikely that the results, assumptions and conclusions set out in this report will represent the extremes of conditions at any location removed from the specific points of sampling.

v) Where this report indicates that information has been provided to Golder by Mobil Oil New Zealand Limited or by third parties, Golder has made no independent verification of this information except as expressly stated in the report.

vi) The analysis and conclusions presented in this report are applicable as at the date of this report. Golder does not make any representation or warranty that the conclusions in the report can be extrapolated for future use as there may be changes in the conditions of the site, applicable legislation or other factors that would affect the conclusions contained in this report.

vii) All relevant legislation in the jurisdiction in which the site is located and relating to the works has been complied with by Golder as at the date of this report.

viii) The report should be read in full and no excerpts are to be taken as representative of the conclusions. The report should not be used or relied upon for any purpose except as defined in Section 1.1 of the report and subject to the limitations set out in this section.

ix) This report has been prepared on the instruction of Mobil Oil New Zealand Limited and may be used and relied on by Mobil Oil New Zealand Limited and its Affiliates, and other entities contemplated in the agreement between Golder and Mobil Oil New Zealand Limited, such as purchasers of the site, lenders to purchasers, property owners, purchasers from property owners, lessees from property owners and assignees of lease from lessees of property owners.

x) Golder accepts no responsibility for damages, if any, suffered by any other third party as a result of decisions made or actions based on this report.

xi) Affiliates means (a) Exxon Mobil Corporation or any parent of Exxon Mobil Corporation, (b) any company or partnership in which Exxon Mobil Corporation or any parent of Exxon Mobil Corporation now or hereafter(1) owns or (2) controls, directly or indirectly, more than fifty percent (50%) of the ownership interest having the right to vote or appoint its directors or functional equivalents ("Affiliated Company"), (c) any joint venture in which Exxon Mobil Corporation, any parent of Exxon Mobil Corporation, or an Affiliated Company is the operator, and (d) any successor in interest to (a) and (c) above.

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