

Southern Seawater Desalination Plant

Contamination Assessment

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EXECUTIVE SUMMARY

Background

360 Environmental Pty Ltd (360 Environmental) was commissioned by the Water Corporation to undertake a contamination assessment of the proposed Southern Seawater Desalination site in Binningup. The site, comprising part Lot 8 Binningup Road and Lots 32 and 33 Taranto Road, Binningup, is approximately 80 hectares in size, and is located 150 kilometres (km) south-west of the centre of Perth.

The site investigation was undertaken for due diligence purposes in response to the historical use of sections of the site as a Waste Water Treatment Plant (WWTP) Facility (across the northern portion of Lots 32 and 33) and as a lime quarry (the eastern half of Lot 8). Sewage Treatment Plants are recognised as being potentially contaminating activities in the Department of Environment (DoE) *Potentially Contaminating Activities, Industries and Land Uses* document (2004a), and as such require investigation for potential contamination in accordance with the Department of Environment and Conservation (DEC) (formerly Department of Environment) 2001-2006 *Contaminated Sites Management Series*. Although quarrying is not recognised as a potentially contaminating land use, fuel storage and refuelling infrastructure, which are frequently associated with quarries, are recognised as being potentially contaminating activities.

Scope

A phased contamination assessment has been undertaken by 360 Environmental in accordance with the Department of Environment and Conservation (DEC) (2001-2006) *Contaminated Sites Management Series*.

The assessment has included a preliminary site investigation (PSI) and a program of soil and groundwater sampling and analysis. Soil samples were collected from 10 bore locations and groundwater was sampled from five monitoring wells at Lots 32 and 33, whilst at Lot 8, nine soil sampling locations were established and groundwater was collected from five monitoring wells. Principal contaminants of concern identified at Lot 8 included metals, total petroleum hydrocarbons (TPH), Monocyclic Aromatic Hydrocarbons (MAHs including benzene, toluene, ethylbenzene, meta- & para-xylene and ortho-xylene (BTEX)), polycyclic aromatic hydrocarbons (PAHs) and phenolic compounds. At Lots 32 and 33 potential contaminants of concern included metals, nutrients (nitrite and nitrate, Total Kjeldahl

Nitrogen (TKN), total phosphorus, potassium), phenolic compounds and pathogens (e-coli, enterococci and thermotolerant coliforms). Limited additional groundwater sampling and analysis was subsequently undertaken to confirm results at selected monitoring bores across the three lots.

Findings

Findings of the PSI are summarised as follows:

- **Acid Sulphate Soils:** An Acid Sulphate Soils (ASS) investigation is not required for Lots 32 and 33, however one is necessary for the southern portion of Lot 8 correlating with the high to medium ASS risk area. Should dewatering works be required anywhere on Lot 8 as part of the proposed construction works, an ASS investigation of the entire lot will also be required. If disturbance of soils deeper than 3 m from the surface are proposed anywhere across the site, further investigations and development of management strategies may be required.
- **Zoning:** Lots 32 and 33 are presently zoned “Public Purposes” under the Greater Bunbury Region Scheme (WAPC, 2007), whilst Lot 8 is zoned “rural”.
- **Geology and Geomorphology:** The majority of the site is comprised of calcareous sands of the Quindalup Dune system. They occur across Lots 32, 33 and the western portion of Lot 8. The central section of Lot 8 is composed of variably undifferentiated estuarine and marine deposits forming the poorly drained Vasse Plains. At the far eastern portion of the site are shallow, yellow and brown sands overlying marine limestones of the Yoongarillup Plain system, forming low ridges and swales (Churchward and McArthur, 1978).
- **Topography:** The majority of Lots 32 and 33, and the western half of Lot 8 is relatively undulating, ranging from 2 metres Australian Height Datum (mAHD) near the boundary between Lots 32 and 33, up to 30 mAHD in the south-western corner of Lot 33. The hilly topography across this area is attributed to the coastal dune geomorphology. On Lot 8, a sharp descent in topography occurs from the western half of the lot to the eastern half, declining from a maximum of approximately 19 mAHD to 2 mAHD or less. The majority of the eastern portion of Lot 8 remains flat at between 1 to 2 mAHD, with the exception of the northern and eastern boundaries, where the topography rises to approximately 8 to 10 mAHD at the very edges of the site.

- **Wetlands:** A portion of a large wetland (DEC Unique Feature Identifier (UFI) No. 13239) classified as a 'conservation category' wetland, occurs on the southern boundary of Lot 8 and extends southwards from the site. However, a detailed inspection of Lot 8 has revealed that although remnant wetland vegetation occurs in patches, the wetland vegetation has been extensively degraded due to use of this area for grazing purposes. Nonetheless, the potential for impacts, whether direct or indirect from any proposed works, would likely be closely assessed by the DEC, who would require considerable planning and management to reduce these impacts, given the close proximity of the wetland.
- **DEC Contaminated Sites Database:** A search of the DEC's *Contaminated Sites Database* and Reported Sites Register indicated that neither Lots 32 and 33, nor any sites within a 5km radius, have been reported to the DEC as known or suspected contaminated site either prior to or after the commencement of the *Contaminated Sites Act 2003* in December 2006. The results of the search for Lot 8 were not received in time to be included in this report. Upon their receipt, the information will be provided to the Water Corporation in an addendum to this report.
- **Heritage:** A search of the Aboriginal Heritage and the Heritage Council of Western Australia (HCWA) database of culturally significant sites in Western Australia indicated that the site does not contain any listed heritage sites.
- **Historical landuse:** The site history has confirmed that the majority of Lots 32 and 33 has remained undeveloped coastal dunes covered in natural vegetation up to the present day. In the 1990s a small WWTP was constructed in an area bounding the border between Lots 32 and 33, and has been operating since that time under the auspice of the Water Corporation. Infrastructure associated with the WWTP at Lots 32 and 33 includes a fenced area containing two wastewater treatment ponds (a lined settlement pond and an unlined overflow infiltration pond), a fenced weather station which was installed in 2006, and two groundwater monitoring bores located to the north-west and east of the WWTP. No fuel storage has ever been undertaken at the site.
- The western portion of Lot 8 has remained as undeveloped coastal dunes covered in natural vegetation over its entire history. Although the lot has historically been owned by a number of farmers, grazers and orchardists, landuses across the central and eastern portions of



the lot appear to have been limited to quarrying and grazing. Lime quarrying commenced in 1977, with most of the excavation works being undertaken on the central portion of the lot, and the eastern section primarily been utilised for stockpiling of the quarried lime. Infrastructure associated with the quarry appears to have been limited to an unmanned office and automatic weigh-bridge. Grazing appears to have been undertaken across the southern and eastern portions of the lot.

- Although the site history has indicated that a refuelling facility associated with the quarry was initially planned, there is no evidence that one was ever constructed. Shire of Harvey records and communications with the site owner indicate that a mobile fuel service was used instead.
- Whilst the site history indicates that the site has been owned by farmers, graziers and orchardists through its history, there are no indications in the historical aerial photographs of orchards or agricultural activities having been undertaken at any time at the site.

The outcome of the contamination assessment of soils across the site has indicated that levels of metals, TPH, BTEX, PAHs and phenolic compounds in all soils samples collected and analysed from Lot 8, are below recommended guideline levels (EIL and HIL-F guidelines (commercial/industrial landuse)). These results indicate that the impact of potentially contaminating activities undertaken at the site associated with the quarry appears to have been minimal on surrounding soils.

Levels of metals, nutrients and phenolic compounds in all soils samples collected and analysed from Lots 32 and 33 are below recommended guidelines; however, a low level detection of thermotolerant coliforms occurred in a surface soil sample at BH1. The localised and low level presence of the pathogen at this location is considered likely a result of physical human transfer of maintenance staff (on footwear and machinery) accessing the site or from roaming animals (kangaroos, foxes, rabbits, etc).

All remaining pathogens analysed were below respective Limits of Reporting (LORs). These results indicate that soils in the north-eastern corner of the WWTP may potentially be impacted by faecal contamination originating from the WWTP.

Whilst the concentrations of most metals in groundwater at the site are below DoE (2003) *Marine Water, Freshwater and Drinking Water*



Guidelines, some exceedences were detected, particularly in groundwater at Lot 8. These included:

- Dissolved cadmium at DS4 and DS6 marginally exceeded the Freshwater guideline level of 0.2 µg/L. However, a second round of monitoring at DS4 and DS8 for dissolved cadmium indicated that concentrations at these two monitoring bores were below the LOR.
- Total zinc at all five monitoring bores located at Lot 8 exceeded the Freshwater guideline concentration of 8 µg/L, and a zinc level of 37 µg/L at DS4 also failed to meet the DoE Marine Water guideline level of 15 µg/L.
- Total aluminium concentrations at nearly all monitoring bores across the site, with the exception of DS3, exceeded the DoE (2003) Freshwater guideline level of 55 µg/L, whilst concentrations at MW1, DS1, DS4, DS5 and DS8 also exceeded the Drinking Water – Aesthetic guideline level of 200 µg/L.
- Dissolved iron at DS8 and total iron at MW1, MW4, GW1/WC1, DS4, DS5 and DS8 all exceeded the DoE (2003) Drinking Water – Aesthetic guideline level of 300 µg/L, with concentrations in groundwater at Lot 8 generally higher than at Lots 32 and 33.

On the basis of high sulphate:chloride ratios and low total alkalinity:sulphate ratios in groundwater at the five bores located across Lot 8, the elevated metal concentrations occurring in groundwater at this lot are possibly attributable to the oxidation and conversion of ASS in high to moderate and moderate to low ASS risk areas located in the southern and eastern portions of Lot 8, and the likely subsequent acidification of the underlying groundwater some time earlier in the site's history.

A concentration of TPH C₁₅-C₂₈ fraction of 100 µg/L measured in site groundwater at DS3 and confirmed in a second monitoring event, was greater than the low-reliability trigger value in ANZECC 2000; however, it was well below the trigger level suggested by Tsvetnenko (1998) which may cause acute toxicity to a wide range of marine organisms (300 to 4500 µg/L). As TPH concentrations in all soil samples collected were below respective LORs and no indicators of a hydrocarbon spill or staining were observed during site visits, the source of the TPH detected at DS3 is not yet evident.



On the basis of the results of the soil and groundwater sampling program the following recommendations are made:

- Further investigations to delineate the extent of TPH impacted groundwater in the vicinity of DS3 should be carried out.
- Additional monitoring should be undertaken at all monitoring bores located in the vicinity of the WWTP to better understand the fluctuating levels of enterococci in these bores.
- Additional monitoring should be undertaken at monitoring bores DS4 and DS8 to monitor the fluctuating levels of dissolved cadmium in these bores, given the close proximity of the Conservation Category wetland.
- Further soil sampling and analysis for pathogens in the immediate vicinity of BH1 be carried out to confirm the presence and extent of faecal-impacted soils in this area.
- Due to the elevated levels of some metals in groundwater at Lot 8, appropriate management strategies should be implemented during construction works and most particularly if any associated dewatering works are proposed across this portion of the site. Due consideration should be given and appropriate additional monitoring undertaken when considering future beneficial reuse of the groundwater at the site.

In conclusion, the contamination assessment has indicated that potentially contaminating activities undertaken at the site during its use as a quarry at Lot 8 and as a WWTP at Lots 32 and 33 may have had some impact on the surrounding environment in the areas investigated, in particular metal, TPH and enterococci levels in the groundwater. Additional monitoring and investigations are recommended to assess potential risks to human health and the environment.



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- Appendix B Current and Historical Certificates of Title
- Appendix C DEC Contaminated Sites Database
- Appendix D DoW Groundwater Bore Database Search Results
- Appendix E Database Heritage Register Search
- Appendix F Soil Borelogs and Groundwater Construction Logs
- Appendix G Chain of Custody and Sample Receipt Documentation
- Appendix H Groundwater Field Data Sheets
- Appendix I Calibration Certificates
- Appendix J 360 Environmental QA/QC Report
- Appendix K Laboratory QA/QC Report
- Appendix L Laboratory Analytical Certificates



1. Introduction

1.1. Background

360 Environmental Pty Ltd (360 Environmental) was commissioned by the Water Corporation to undertake a contamination assessment of the proposed Southern Seawater Desalination site in Binningup. The site, comprising part Lot 8 (northern portion only) Binningup Road, and Lots 32 and 33 Taranto Road, Binningup, is approximately 80 hectares in size, and is located 150km south-west of the centre of Perth.

The assessment was prompted by the historical use of portions of the site as a Waste Water Treatment Plant (WWTP) Facility (Lots 32 and 33) and as a lime quarry (Lot 8). Sewage Treatment Plants are recognised as being potentially contaminating activities in the Department of Environment (DoE) *Potentially Contaminating Activities, Industries and Land Uses* document (2004a), and as such require investigation for potential contamination in accordance with the Department of Environment and Conservation (DEC) (formerly Department of Environment) 2001-2006 *Contaminated Sites Management Series*. Although quarrying is not recognised as a potentially contaminating land use, fuel storage and refuelling infrastructure, which are frequently associated with quarries, are recognised as being potentially contaminating activities.

In accordance with the DEC *Contaminated Sites Management Series* (2001-2006), a contamination assessment and reporting were undertaken to identify any contamination which may be present at the sites, any subsequent constraints on the proposed Southern Seawater Desalination Plant.

1.2. Objectives

Consistent with the approach recommended in the DEC *Contaminated Sites Management Series* (2001-2006), the objectives of the contamination assessment were to assess site characteristics, potentially contaminating historical land uses and current site activities to determine the contamination status of the site, to ensure that any future dewatering and construction activities undertaken at the site are appropriately managed.



1.3. Scope of Works

The scope of work undertaken for this investigation was generally in accordance with 360 Environmental proposals 336-AA (dated 29 June 2007) and 336-AB (dated 16 October 2007), and consistent with procedures detailed in the DEC *Contaminated Sites Management Series* (2001-2006).

Work undertaken included the following:

- A preliminary site investigation (PSI), or desktop site history study, comprising the review of historical aerial photographs, title information, previous environmental investigations, information relating to site characteristics, interviews with persons knowledgeable of past landuse activities and a detailed site inspection.
- Development of a Sampling and Analysis Plan (SAP).
- A field investigation based on the findings of the PSI, comprising soil and groundwater sampling and analysis.
- Sampling across Lots 32 and 33 included the advancement of ten soil boreholes and the installation of four groundwater monitoring wells. Selected soil and groundwater samples were analysed for a suite of contaminants identified from the PSI as being of potential concern around the WWTP, including metals (aluminium, arsenic, cadmium, copper, cobalt, chromium, lead, mercury, zinc), nutrients (phosphorus, potassium, nitrogen), phenols and pathogens (e-coli, enterococci, thermotolerant coliforms).
- The sampling program across Lot 8 comprised the establishment of nine soil boreholes and the installation of five groundwater monitoring wells. Selected soil and groundwater samples were analysed for a suite of contaminants identified from the PSI as being of potential concern across this area of the site, including metals (aluminium, arsenic, cadmium, copper, chromium, lead, mercury and zinc), total petroleum hydrocarbons (TPH), benzene, toluene, ethyl-benzene and xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs) and phenolic compounds.
- Assessment and reporting consistent with DEC guidelines and requirements.



1.4. Report Format

The remainder of this report comprises the following sections:

Section 2 - Site Description

Section 3 - Site History

Section 4 - Assessment Criteria

Section 5 - Conceptual Site Model

Section 6 - Field Investigations and Laboratory Analysis Program

Section 7 - Results

Section 8 - Conclusions and Recommendations

Section 9 - Limitations

Section 10 - References



2. Site Description

2.1. Site Location and Features

The investigation site is located at Lot 8 Binningup Road and Lots 32 and 33 Taranto Road, Binningup, and is situated approximately 150km south-west of the centre of Perth and 35km north of Bunbury (Figure 1). The site is located on the southern side of Taranto Road, approximately one kilometre north of Binningup township. Lots 32 and 33 Taranto encompass an area of approximately 41 hectares, whilst the portion of Lot 8 which is included in this assessment (northern quarter of the lot only) covers an area of around 40 hectares.

Lots 32 and 33 are predominantly uncleared and vegetated in their natural state, with the only development on the site limited to a fenced area containing two wastewater treatment ponds (a lined settlement pond and an unlined overflow infiltration pond), a fenced weather station and two groundwater monitoring bores (located to the north-west and east of the treatment ponds) which are associated with the WWTP. The western half of Lot 8 is similarly undeveloped and covered in coastal dune vegetation, whilst much of the eastern half has undergone clearing and development associated with its historical use as a lime quarry. Infrastructure associated with the former lime quarry is limited to concrete foundations blocks from the former weigh-in bridge located approximately 30 metres from the quarry entrance on the northern perimeter of the lot. However, numerous large and small stockpiles of quarried lime spoil occur in the central portion of Lot 8. The eastern third of Lot 8 and a section along its southern perimeter are flat, grassed and utilised for grazing purposes. Photographs taken of the site are presented in Appendix A.

2.2. Property and Zoning Information

The site is located within the local government area of Shire of Harvey.

Current certificate title information (Appendix B) indicates the site comprises the following three lots as summarised below:

Lot 8

- Title Description: Lot 8 on Diagram 34501
- Property Street Address: 96 Binningup Road, Binningup



- Registered Proprietor: B & J Catalano Pty Ltd, 1 South Western Highway, Brunswick
- Registered: 20 August 1991

Lot 32

- Title Description: Lot 32 on Diagram 74570
- Property Street Address: No property street address information available.
- Registered Proprietor: Water Corporation, 629 Newcastle Street, Leederville
- Registered: 30 April 1996

Lot 33

- Title Description: Lot 33 on Diagram 74569
- Property Street Address: No property street address information available.
- Registered Proprietor: Water Corporation, 629 Newcastle Street, Leederville
- Registered: 30 April 1996

The eastings and northings of the lot boundaries are as follows:

Lot 8

- Northern-western corner: 378523.12, 6333859.8
- North-eastern corner: 379332.09, 6333893.93
- South-western corner: 378512.33, 6333310.77
- South-eastern corner: 379308.38, 6333311.67

Lot 32

- North-western corner: 378320.17, 6333856.89
- North-eastern corner: 378523.12, 6333859.8
- South-western corner: 378312.76, 6333314.63
- South-eastern corner: 378512.33, 6333310.77





Lot 33

- North-western corner: 377770.51, 6333849.48
- North-eastern corner: 378320.17, 6333856.89
- South-western corner: 377760.14, 6333304.26
- South-eastern corner: 378312.76, 6333314.63

Lots 32 and 33 are presently zoned “Public Purposes” under the Greater Bunbury Region Scheme (WAPC, 2003), whilst Lot 8 is zoned “Rural”.

2.3. Surrounding Land Use

Surrounding land is shown on Figure 1, and is predominantly undeveloped coastal dunes or utilised for agricultural purposes. More specifically, land uses on adjacent sites include:

- North of the site – Immediately north of Lots 32 and 33, and the western portion of Lot 8 are undeveloped coastal dunes covered in native vegetation which extend for tens of kilometres northward. Immediately north of the eastern half of Lot 8 is an active lime quarry and beyond that land utilised for grazing and agriculture.
- South – Undeveloped coastal dunes occur immediately south of Lot 32 and 33 and beyond that the townsite of Binningup. Land south of Lot 8 is primarily utilised for grazing purposes, although numerous sand and lime stockpiles in the eastern corner of the area indicate a historical association with the former lime quarry.
- West – The subject site is bounded by the Indian Ocean to the west.
- East – Properties east of the subject site are primarily utilised for agricultural and grazing purposes.

2.4. Regional Geology and Geomorphology

The site occurs on the Swan Coastal Plain, which consists of a series of geomorphological elements which are sub-parallel to the present coastline (McArthur and Bettenay, 1960). Each of these geomorphic elements has distinctive geology, vegetation, topography and soils.

White, fine to medium-grained sands, with sub-rounded quartz and calcareous shell debris of eolian origin form the western-most





geomorphological unit across the site, large undulating dunes with moderate to steep slopes ranging from ~ 10 to $>20^\circ$, of the Quindalup Dune system. These dunes, the youngest across the Swan Coastal Plain (Bolland, 1998), hold very little water and are very susceptible to erosion by winds where the sparse vegetation is removed. They occur across Lots 32, 33 and the western portion of Lot 8.

The central area of Lot 8 is composed of variably undifferentiated estuarine and marine deposits forming the poorly drained Vasse Plains. The plains contain linear estuarine wetlands, which are remnants of more extensive estuarine system which has been partially covered by the inland progression of the Quindalup Dune system (Belton-Taylforth, 2006). On the far eastern portion of the site are shallow, yellow and brown sands overlying marine limestones, of the Yoongarillup Plain system forming low ridges and swales (Churchward and McArthur, 1978).

2.5. Topography and Surface Hydrology

The online *National Resources Atlas* (Department of Environment and Heritage, 2007) shows that the topography across the majority of Lots 32 and 33, and the western half of Lot 8 is relatively undulating, ranging from 2 metres Australian Height Datum (mAHD) near the boundary between Lots 32 and 33, up to 30 mAHD in the south-western corner of Lot 33. An area immediately north and north-west of the WWTP is an exception, being relatively flat with an average elevation of approximately 5 mAHD. The hilly topography across this area is attributed to the coastal dune geomorphology.

On Lot 8, a sharp descent in topography occurs from the western half of the lot to the eastern half, declining from a maximum of approximately 19 mAHD to 2 mAHD or less. The majority of the eastern portion of Lot 8 remains flat at between 1 to 2 mAHD, with the exception of the northern and eastern boundaries, where the topography rises to approximately 8 to 10 mAHD at the very edges of the site. In addition, numerous large and small stockpiles of lime gravel spoil in the central and southwestern portions of Lot 8, within the former quarry excavation pit, alter the elevation in some places by up to eight metres.

Due to the high permeability of the sandy soils comprising the Quindalup Dunes (Belton –Taylforth, 2006) which cover Lots 32, 33 and the western portion of Lot 8, very little natural surface runoff is likely to occur in these areas. However, on the poorly drained Vasse Plains ponding is common.



2.6. Hydrogeology

The site is outside the coverage of the online *Perth Groundwater Atlas* (2006) for groundwater contour data. However, standing water levels measured at the ten monitoring bores across the site in August and November 2007 as part of this contamination assessment, have shown that groundwater in the vicinity of the WWTP occurs at depths between approximately 2.5 and 3.5 metres below ground level (mbgl), whilst levels across the eastern half of Lot 8 on the Vasse Plains, range from between 0.5 and 1.5 mbgl (assuming an average casing height of approximately 0.5 metres). It is anticipated that groundwater flow is to the west towards the Indian Ocean.

The unconfined superficial aquifer beneath the sites consists predominantly of limestone, and attains a saturated thickness of approximately 20 to 40 m (Belford-Talyforth, 2006).

2.7. Acid Sulphate Soils

The DEC has compiled maps of Acid Sulphate Soil (ASS) risk areas for several regions of Western Australia, which provide a broad-scale indication of the areas where ASS are most likely to exist (DEC, 2007). ASS risk mapping (Figure 2) indicates that the entire area across Lots 32 and 33, and the western half of Lot 8 are classified as having “no known ASS disturbance risk within 3m of the natural surface (WAPC, 2007). However, the southern boundary of Lot 8 is classified as having a high to medium risk of ASS occurring within 3 m of the surface, whilst the eastern third of the lot is classified as having a moderate to low risk of ASS occurrence in this area.

In accordance with the requirements of the DEC (2003-2006) *Acid Sulphate Soil Guideline Series* the results of the WAPC (2007) *Bulletin No. 64 Acid Sulphate Soils* indicate that:

- Although an ASS investigation is not required for Lots 32 and 33 and the western portion of Lot 8, one is required for the southern portion of Lot 8 correlating with the high to medium ASS risk area (Figure 2). However, should dewatering works be required as part of the proposed construction works anywhere on Lot 8, an ASS investigation of the entire lot will be required.
- If disturbance of soils deeper than 3 m from the surface is likely at any location across the site, further investigations and development of management strategies may be required.



2.8. Wetlands

Wetlands of the Swan Coastal Plain have been described and mapped by Hill et al. (1996) and assigned a management category which reflects their condition and environmental values. There are three categories that wetlands are assigned, 'Conservation Category', 'Resource Enhancement' and 'Multiple Use' depending on their condition and environmental values, with 'Conservation Category' wetlands being those with the highest level of ecological attributes and functions, followed by 'Resource Enhancement' then 'Multiple Use'.

A search of the DEC Geomorphic Wetland database has indicated that a portion of a large wetland (DEC Unique Feature Identifier (UFI) No. 13239) classified as a 'conservation category' wetland, occurs on the southern boundary of Lot 8 and extends southwards from the site (Figure 3). However, a detailed inspection of Lot 8 (discussed further in Section 3.7) has revealed that although remnant wetland vegetation occurs in patches, the wetland vegetation has been extensively degraded due to use of this area for grazing purposes.

Nonetheless the Environmental Protection Authority's (EPA) draft *Guidance Statement No. 33 – Environmental Guidance for Planning and Development (2005)*, the primary document of reference for the management of wetlands, states the following:

The EPA's position is that it is preferable to avoid direct, indirect and cumulative impacts that may adversely affect the environmental values and functions of wetland areas. In all cases where some loss of any wetland value or function is unavoidable, the EPA recommends that compensatory actions are implemented, with a view to achieving "no net loss of wetland values and functions".

Guidance Statement 33 (EPA, 2005) states the following about Conservation Category Wetlands (CCW):

The EPA urges that all CCW and their buffers are fully protected. Schemes and proposals that are likely to lead to a significant adverse impact on these wetlands are likely to be formally assessed by the EPA.

The potential for impacts, whether direct or indirect from any proposed works, would therefore be likely to be closely assessed by the DEC, and require considerable planning and management to reduce these impacts, given the close proximity of the wetland.





A multiple use wetland (UFI No.1214) also occurs in the vicinity of the site, approximately 250 metres north of Lot 8. However, as this wetland is not located hydraulically down-gradient of the site, it is not considered likely that it would have or will be impacted either by historical or proposed future activities or land uses undertaken at the subject site, provided due environmental care is taken during construction and operation of the site.

2.9. Underground Services

A search of the Water Corporation's records indicates that there are currently no underground services beneath Lots 8 or 33. Services associated with Lot 32 are limited to a sewer main, which runs from Binningup township to the southern perimeter of Lot 32 and then northwards towards the WWTP.



3. Site History

3.1. Site History Investigations

Historical activities of the site were investigated from the following sources:

- A review of historical aerial photographs from 1966 to present (Figure 4a – 4d).
- A review of current and historical title information to identify previous landholders and any memorial listings.
- A search of the DEC's *Contaminated Sites Database* for previous site contamination assessments and known sources of contamination in the vicinity of the site.
- A search of the Department of Water's (DoW) groundwater bore database for the location of registered bores near the site that may be impacted by on-site works.
- A detailed site walkover to inspect for signs of contamination.
- Consultations with persons knowledgeable of historical site activities associated with the site.

3.2. Historical Aerial Photographs

Historical aerial photographs dating back to 1966 were viewed to assess land use and developmental changes over time across the site and surrounding areas (selected frames shown in Figure 4a to 4d). Observations are presented in Table 1 and described in the following sections.

3.2.1 Lot 8

Lot 8 remained undeveloped and covered in native vegetation until some time between 1977 and 1988, with the exception of a track occurring in a north-south orientation constructed some time prior to that. In the interval between 1977 and 1988, vegetation in the south-eastern corner of Lot 8 was cleared, with an area of approximately 1.4 hectares of the cleared land being excavated. A track leading westward from the excavation area to the boundary between Lots 8 and 32 had also been constructed, and the older track running north-south had been further developed. In subsequent aerial photographs, further clearing of vegetation and expansion of quarrying and stockpiling activities were observed in the central and south-eastern portions of the lot. Additionally, in the 1996 photograph, it is evident that the wetland



which crosses the southern boundary of Lot 8 had been notably redeveloped, most likely for grazing purposes.

3.2.2 Lots 32 and 33

Lots 32 and 33 remained largely undeveloped coastal dunes until some time between 1988 and 1996, with tracks along the perimeters between Lots 8, 32 and 33 being the only alterations to the natural environment prior to that time. In the interval between 1988 and 1996, an area around the northern portion of the boundary between Lots 32 and 33 was developed, with the construction of a large pond (the lined WWTP settlement pond) and adjoining pit (the unlined overflow infiltration pond). In addition, access tracks leading around and from the WWTP to Taranto Road, and two leading southward across Lot 32, were constructed. No significant changes across Lots 32 and 33 were evident in subsequent aerial photographs.

3.2.3 Surrounding Land

With the exception of a few roads and tracks, minimal clearing or development of bushland surrounding the site occurred until some time between 1966 and 1977. In that interval, limited excavation/quarrying works occurred immediately south of the subject site, on the portion of Lot 8 not included in this assessment. Further south, additional vegetation clearing had been undertaken possibly for grazing or agricultural purposes.

Between 1977 and 1988 patches of remnant bushland were progressively cleared and divided into paddocks for grazing and possibly crops, most noticeably across the large patch of remnant bushland to the east of the site. In addition, quarrying and stockpiling continued to expand on land immediately south of Lot 8. Limited quarrying was also observed on the property located immediately north of Lot 8. The town of Binningup commenced expanding fairly rapidly in this interval, with a network of streets and housing being constructed.

Between 1988 and 1996 further bushland to the east of Lot 8 was cleared for agricultural purposes, whilst quarrying activities at the site immediately north of Lot 8 were notably expanded. Binningup township continued to develop in this interval.



3.3. Historical Titles Information

Inspection of the historical certificates of title (Appendix B) indicates that the three lots on the site were all part of much larger lot until 1968. Prior to separation of the lots, the site was owned by a number of farmers, graziers and orchardist and a solicitor. Lot 8 was owned by an orchardist (Bernard and Gladys Langridge) from 1968 until 1977, a farmer (Bruce Cooling) from 1977 until 1991 and B & J Catalano from 1991. Lots 32 and 33 were owned by Farmer and Orchardist Alfred Combes from 1968 til 1977, Binningup Nominees Pty Ltd from 1977 until 1996, and by the Water Corporation from 1996.

Orchards are recognised as being potentially contaminating activities in the Department of Environment (DoE) *Potentially Contaminating Activities, Industries and Land Uses* document (2004a), and as such require investigation for potential contamination in accordance with the Department of Environment and Conservation (DEC) (formerly Department of Environment) 2001-2006 *Contaminated Sites Management Series*. Similarly, although farming and grazing are not specifically recognised as a potentially contaminating activities or land uses, some associated activities may be of potential concern.

3.4. Contaminated Sites Database Search

A search of the DEC's *Contaminated Sites Database* and registry of all suspected contaminated sites indicated that Lots 32 and 33 have not, nor any sites within a 5km radius, have been reported to the DEC as known or suspected contaminated site either prior to or after the commencement of the *Contaminated Sites Act 2003* in December 2006 (Appendix C). It should be noted however, that a large number of known or suspected contaminated sites were reported to the DEC in May 2007, and DEC is still in the process of identifying and capturing these sites. The search of the DEC records undertaken for this study therefore does not consider any sites which may have been reported after 21/05/2007.

An application to access information from the DEC *Contaminated Sites Database* for Lot 8 has been submitted to the DEC; however, due to long delays with the department, the results of the search were not received in time to be included in this report. The information will be provided to the Water Corporation in an addendum to this report, upon its receipt.



3.5. Groundwater Bore Database Search

The results of a search of the Department of Water's (DoW) database for groundwater bores within a 2km radius of the site are contained in Appendix D. Although 23 groundwater bores occur within the nominated search radius, the majority are located at a distance from the site within the township of Binningup. One bore, WIN ID #20014301, is located approximately 240 metres south of the site, on the portion of Lot 8 not included in this assessment. The DoW indicates that the bore is owned by Langridge; however, no further information is provided on the bore. No groundwater bores are located hydraulically down-gradient of the site, nor any other groundwater bores situated close enough to the subject site to be potentially impacted by activities or land uses undertaken there.

3.6. Heritage

The Aboriginal Heritage Act 1972 is the Western Australian legislation in place to protect places and objects customarily used by, or traditional to, the original inhabitants of Australia. Such places and objects are maintained in a register under the Act; however, all sites are protected under the Act whether or not they have been registered.

A search of the Aboriginal Heritage database shows that heritage surveys have been undertaken across the site, with no heritage areas located or registered (DIA, 2007) (Appendix E). The nearest registered site is an artefact/scatter site located on the eastern side of the Old Coast Highway, approximately 3km to the east of the subject site (Site ID. 5803 – Harvey/Brunswick Junction 51). It is considered unlikely that the registered site would be impacted either by historical or proposed future land use of the subject site.

European heritage is also protected and a search of the Heritage Council of Western Australia (HCWA) database of culturally significant sites in Western Australia was undertaken for the area. No European heritage sites were found within the site (HCWA, 2007). The Shire of Harvey was contacted to determine if there were any European heritage listed areas within site. The council records confirmed that the site does not contain any listed European heritage sites.



3.7. Detailed Site Inspection

Lots 32 and 33 were inspected on 1 August 2007 and Lot 8 on 9 November 2007, to examine for indicators of potential contamination and to verify the findings of the site history study. Site features are shown in Figure 1, and site photographs are presented in Appendix A.

3.7.1 Lots 32 and 33

Findings of the site inspection undertaken at Lots 32 and 33 are as follows:

- The majority of the land across Lots 32 and 33 is undeveloped, undulating dunes, covered predominantly with native coastal dune vegetation.
- The only developed portion of Lots 32 and 33 occurs across a relatively flat area to the north on the boundary between the two lots, where the WWTP is located. Infrastructure associated with the WWTP includes two wastewater treatment ponds, one which is a lined settlement pond and was full of water at the time of the inspection, and the other a dry, unlined overflow infiltration pond. The area around both ponds is secured with wire-mesh fencing.
- A small track runs from Taranto Road to the WWTP, providing vehicular access. Several smaller tracks also cross over the remainder of Lots 32 and 33.
- A weather station is situated immediately north of the WWTP.
- Other than the ponds and surrounding fencing, no buildings or other infrastructure, including fuel storage facilities, were present at the site at the time of the inspection.
- No visible or olfactory indicators of contamination were noted at the time of the site inspection.

3.7.2 Lot 8

Outcomes of the site inspection undertaken at Lot 8 are as follows:

- The western half of Lot 8 is similar to the majority of Lots 32 and 33, comprised of undeveloped, undulating sand dunes covered in coastal dune vegetation.



- Localised occurrences of wetland vegetation, including reeds and mature Melaleucas, are present on the boundary between the western and central portions of Lot 8.
- The central portion of Lot 8 shows the remains of the former quarrying activities undertaken at the site, with a large excavation pit, approximately 285 metres long and 230 metres wide. The excavation pit has been partially backfilled with extensive stockpiles of quarried lime spoil. In some areas the backfilling has been relatively systematic, and in others, the stockpiles of soil appear to have been dumped in a random manner.
- Infrastructure associated with the former quarry appears to be restricted to the concrete footings of the weighbridge at the entrance of the site. Although an imprint in the soil from what is most likely a demountable office was visible adjacent to the weigh bridge foundations, no evidence of any other infrastructure was found at the time of the site inspection. Most significantly, no indications of any fuel storage or refuelling facilities associated with the quarrying works were found.
- The eastern and southern sections of Lot 8 are flat and utilised for grazing purposes.
- Surface ponding and associated wetland vegetation including reeds, occur at numerous locations along the boundary between the central and eastern sections of Lot 8.
- The southern portion of the site contains a Conservation Category wetland as described in the DEC Geomorphic Wetland database. The associated wetland vegetation appears to be significantly degraded, with the exception of sporadic occurrences of clumps of reeds.
- No visible or olfactory indicators of contamination were noted at the time of the site inspection.

3.8. Consultation with Knowledgeable Persons

Mr Andrew Blee, Senior Planning Officer with the Shire of Harvey was contacted by 360 Environmental to discuss any potential information held by the Council regarding the site. Mr Blee indicated that the Council had no information on past land use or activities associated with Lots 32 and 33. With regards to the quarry present on Lot 8, the Council's records showed that there was a designated refuelling and servicing site proposed for the property, comprising a hardstand area with subsurface synthetic liner and



collection tank. However, Mr Blee said that he could not find a plan showing the proposed location of the refuelling facility. In addition, he indicated that there was a chance that it may not have been constructed, as a later report for further extraction at Lot 8, mentioned refuelling at the lot being undertaken via a mobile facility.

Mr Peter Jackson, Regional WWTP Manager was also contacted by 360 Environmental to discuss historical activities undertaken at Lots 32 and 33 and any potential information he could provide with regards to contamination. Mr Jackson indicated that:

- No development has ever occurred on Lots 32 and 33 prior to the establishment of the WWTP which he thought had been on site for at least ten years.
- No fuel has ever been stored on site.
- A bobcat has been used on occasions in past to maintain the ponds and firebreaks.
- A weather station was installed onsite sometime during 2006.

Mr Clem Catalano, owner of Lot 8 was also contacted regarding information relating to the historical landuse of the lot. Mr Catalano provided the following information on the site:

- The quarry was operational when he bought the site in the early 1990's. He continued operating the quarry until 2005, upon which time it was decommissioned.
- No fuel has ever been stored on site since he took up ownership.
- Trucks working at the quarry fuelled up at Brunswick Junction before entering the quarry. If fuel was required on site it would be bought out by mobile fuel trucks.
- A weighbridge for the trucks and transportable office was present on site near the entry. These were unmanned and fully automatic.
- The quarry was decommissioned two years ago and the revegetation present along the boundaries of the quarry pit was a requirement by the shire/DEC as part of the quarry extractive license.



3.9. Summary and Conclusions of Site History

3.9.1 Lots 32 and 33

The site history has confirmed that the majority of Lots 32 and 33 has remained undeveloped coastal dunes covered in natural vegetation until the present day. In the 1990s a small WWTP was constructed in an area bounding the border between Lots 32 and 33, and has been operating since that time under the auspice of the Water Corporation. Sewage Treatment Plants are recognised as being potentially contaminating activities in the Department of Environment (DoE) *Potentially Contaminating Activities, Industries and Land Uses* document (2004a), and as such require investigation for potential contamination in accordance with the Department of Environment and Conservation (DEC) (formerly Department of Environment) 2001-2006 *Contaminated Sites Management Series*. Infrastructure associated with the WWTP at Lots 32 and 33 includes a fenced area containing two wastewater treatment ponds (a lined settlement pond and an unlined overflow infiltration pond), a fenced weather station which was installed in 2006 and two groundwater monitoring bores located to the north-west and east of the WWTP. No fuel storage has ever been undertaken at the site.

Although historical certificates of title indicate that Lots 32 and 33 were owned by farmers, graziers and orchardists through their history, there are no indications in the historical aerial photographs or from consultation with persons knowledgeable of historical site activities, of orchards or agricultural activities been undertaken at any time at these lots.

3.9.2 Lot 8

The site history has indicated that the western portion of Lot 8 has remained undeveloped coastal dunes covered in natural vegetation until the present day. Although the lot has historically been owned by a number of farmers, graziers and orchardists, landuses across the central and eastern portions of the lot appear to have been limited to quarrying and grazing. Lime quarrying commenced in 1977, with most of the excavation works being undertaken on the central portion of the lot, and the eastern section primarily been utilised for stockpiling of the quarried lime. Infrastructure associated with the quarry appears to have been limited to an unmanned office and automatic weigh-



bridge. Grazing appears to have been undertaken across the southern and eastern portions of the lot.

Although quarrying is not recognised as a potentially contaminating land use, fuel storage and refuelling infrastructure, which are frequently associated with quarries, are recognised as being potentially contaminating. However, the site history has indicated that although a refuelling facility associated with the quarry was initially planned, there is no evidence that one was ever constructed. Shire of Harvey records and communications with the site owner indicate that a mobile fuel service was used instead.

Although historical certificates of title indicate that Lot 8 was owned by farmers, graziers and orchardists through its history, there are no indications in the historical aerial photographs or from consultation with persons knowledgeable of historical site activities, of orchards or agricultural activities been undertaken at any time at this lot.



4. Assessment Criteria

4.1. Soil Contamination Assessment Criteria

Assessment of site contamination in Western Australia is based on the DEC (2001-2006) *Contaminated Sites Management Guideline Series*. The guidelines include Health Based Soil Guidelines for various exposure settings (HIL) and Ecological Investigation Levels (EIL).

Based on the proposed land use for the site, the soil analysis results from this investigation were compared with the following criteria presented in DEC (2003) *Assessment Levels for Soil, Sediment and Water*:

- Ecological Investigation Level - EIL.
- Human Health Investigation Level 'F' (HIL-F) for Commercial/Industrial Land Use.

4.2. Site Specific Groundwater Assessment Criteria

Groundwater analysis results were compared to the DEC guidelines for Marine Water, Fresh Water and Drinking Water as presented in the DoE (2003) *Assessment Levels for Soil, Sediment and Water*. These guidelines are considered the most appropriate, considering the close proximity to the Indian Ocean, superficial aquifer beneath the site, the presence of a wetland and a groundwater bore on the southern portion of Lot 8. The recommended criteria have been developed based on the risk-based approach in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000).

Guidelines for Total Petroleum Hydrocarbons (TPH) in site groundwater have been sourced from the ANZECC/ARMCANZ (2000) low-reliability trigger value for marine ecosystems. As the guideline value provided ($7 \mu\text{g/L}$) is below the practical quantitation limit for standard TPH fractionation analysis, levels of TPH in site groundwater are also compared to data from Tsvetnenko (1998) reproduced in ANZECC/ARMCANZ (2000) which provides a range of concentrations outside which levels may cause acute toxicity to a wide range of marine organisms.

Total alkalinity:sulphate ratios and sulphate:chloride ratios were compared with the Swedish EPA (2002) guideline value of 5 or greater and Mulvey



(1993) value of 0.5 or less respectively, as per recommendation in the DoE(2004b) *Guidance for Groundwater Management of Urban Areas on Acid Sulphate Soils* document. These parameters provide a potential indicator of the occurrence of sulphide oxidation in the soils.

Enterococci concentrations were compared with the National Health and Medical Research Council (2006) *Guidelines for Managing Risks in Recreational Water* guideline level of 40 CFU/100 mL, which is the 95% percentile for intestinal enterococci/100, which relates to an average probability of less than one case of gastroenteritis in every 100 exposures.



5. Conceptual Site Model

5.1. Potential Sources of Environmental Concern

Identified areas of potential sources of environmental concern across Lots 32 and 33 were limited to the fenced area containing the WWTP and included the following:

- The effluent/sludge ponds where effluent can potentially overflow onto the soil and seep into the groundwater.
- The pipe leading into and out of the WWTP has the potential to leak effluent through cracks.

Identified areas of potential sources of environmental concern across Lot 8 were focused on the portion of the lot associated with former quarrying activities, and included the following:

- Stockpiles of lime spoil and gravelly fill material located across the centre of the lot.
- The former unmanned site office and weighbridge area.

5.2. Chemicals of Concern and Areas of Association at the Site

Potential chemicals of concern identified at the site and the areas they are associated with are summarised below.

Analyte	Rational	Areas of Association within the Site
Metals (aluminium, arsenic, cadmium, copper, cobalt, chromium, lead, nickel, zinc mercury)	Commonly associated with sewage treatment plants and with refuelling facilities.	Surface soils and groundwater within the vicinity of the WWTP site at Lots 32 and 33. Surface soils and groundwater within the vicinity of the former quarry at Lot 8.
Nutrients (phosphorus, potassium, nitrogen).	Commonly associated with sewage treatment plants.	Surface soils and groundwater within the vicinity of the WWTP site at Lots 32 and 33.



Analyte	Rational	Areas of Association within the Site
Phenols	Commonly associated with sewage treatment plants and with refuelling facilities.	Surface soils and groundwater within the vicinity of the WWTP site at Lots 32 and 33 and the former quarry at Lot 8.
Pathogens (e-coli, enterococci, thermotolerant coliforms)	Commonly associated with sewerage treatment plants.	Surface soils and groundwater within the vicinity of the WWTP site at Lots 32 and 33.
Total Petroleum Hydrocarbons (TPH) Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX) Polycyclic Aromatic Hydrocarbons	Commonly associated with fuel storage and oil leaks.	Surface soils and groundwater within the vicinity of the former quarry at Lot 8.

5.3. Exposure Pathways, Potential Receptors of Concern and Risk Levels

For the purpose of this assessment, possible exposure pathways are identified as natural and/or manmade pathways for chemicals of concern in the liquid or gaseous state, and receptors include persons, ecological receptors such as wetlands, creeks and other surface water bodies, shallow groundwater, infrastructure and utilities, and groundwater abstraction bores that are, or may be adversely impacted by the chemicals of concern.

Potential chemicals of concern identified at the site from the site history and detailed site inspection, the areas they are associated with, the possible exposure pathways, potential environmental receptors and associated risks identified at the site are summarised below.

Source	Pathway	Receptor	Risk
<p>Surface soil impacted by pathogens, nutrients, metals and hydrocarbons.</p>	<ul style="list-style-type: none"> • Migration via wind mobilization of particulates and volatilization of hydrocarbons. • Migration via surface runoff. • Migration of thermotolerant coliforms from soil down to the water table via infiltration and percolation of rainwater through the fine to medium grained sandy fill and natural soils which may act as preferential pathways. Migration through vertical movement through the vadose zone via aquifer fluctuations. 	<ul style="list-style-type: none"> • Current or future site users may come into dermal contact, accidentally ingest potentially impacted soils or inhale particulates and vapours. • Occupants of adjacent areas through inhalation of particulates and fumes. • Vegetation. • Groundwater. • Construction phase workers during remedial or excavation works may come into dermal contact with or accidentally ingest potentially impacted soils. 	<ul style="list-style-type: none"> • Moderate risk where surface soils remain and no cap present. • Low risk where concrete or asphalt capping present. • Low to negligible risk. • Low – existing vegetation appears in good conditions. • Moderate – groundwater is very shallow (<3 m bgl) across the site. • Moderate risk.

Source	Pathway	Receptor	Risk
<p>Groundwater impacted by petroleum hydrocarbons, phenolic compounds and metals in the vicinity of the former quarry at Lot 8.</p>	<ul style="list-style-type: none"> • Direct contact and ingestion, dermal contact with abstracted water, inhalation of vapours. • Migration via natural or induced groundwater flow. • Movement of gas through soils from the volatilisation of hydrocarbons in impacted groundwater. • Migration via natural or induced groundwater flow. • Migration via natural or induced groundwater flow. • Migration via natural or induced groundwater flow. • Direct contact and ingestion, dermal contact with abstracted water, inhalation of vapours. 	<ul style="list-style-type: none"> • Current or future site users may come into dermal contact with or accidentally ingest potentially impacted groundwater, or inhale hydrocarbon vapours. • Occupants of adjacent areas may come into dermal contact with or accidentally ingest potentially impacted groundwater, or inhale hydrocarbon vapours. • Future buildings and infrastructure. • Registered groundwater abstraction bores located in vicinity of site. • Conservation Category Wetland and offsite Multiple Use Wetland • Indian Ocean • Construction phase workers during remedial or excavation works. 	<ul style="list-style-type: none"> • Moderate – The likelihood of dermal contact is moderate due to shallow groundwater levels and ponding of groundwater at surface. • Low risk. Site immediately hydraulically down-gradient of Lot 8 is Lot 32 which is mostly unoccupied and undeveloped sand dunes and native vegetation. Area around WWTP is only visited sporadically. Other adjacent lots are generally at notable distances from the former quarry area. • Low risk. • Low risk - at sufficient distance from and not hydraulically down-gradient of former quarry site. • Low risk. Both wetlands are at a sufficient distance from and hydraulically adjacent to former quarry area. • Low risk. Indian Ocean is at a notable distance from the former quarry site. • Moderate – The risk of dermal contact is moderate due to shallow groundwater levels and ponding of groundwater at surface.

Source	Pathway	Receptor	Risk
<p>Groundwater impacted by nutrients, pathogens, phenolic compounds and metals in the vicinity of the WWTF at Lots 33 and 34.</p>	<ul style="list-style-type: none"> • Direct contact and ingestion, dermal contact with abstracted water, inhalation of particulates. • Migration via natural or induced groundwater flow. • Migration via natural or induced groundwater flow. • Migration via natural or induced groundwater flow. • Migration via natural or induced groundwater flow. • Direct contact and ingestion, dermal contact with abstracted water, inhalation of vapours. 	<ul style="list-style-type: none"> • Current or future site users may come into dermal contact with or accidentally ingest potentially impacted groundwater. • Occupants of adjacent areas may come into dermal contact with or accidentally ingest potentially impacted groundwater. • Future buildings and infrastructure. • Registered groundwater abstraction bores located in vicinity of site. • Conservation Category Wetland and offsite Multiple Use Wetland • Indian Ocean • Construction phase workers during remedial or excavation works. 	<ul style="list-style-type: none"> • Moderate – The likelihood of dermal contact is moderate due to shallow groundwater levels and the two wastewater pond at the WWTP. • Low risk. Site immediately hydraulically down-gradient of the WWTP is a large portion of Lot 33 which is mostly unoccupied and undeveloped sand dunes and native vegetation. Other adjacent lots are generally at notable distances from the WWTP. • Low risk. • Low risk - at sufficient distance from and not hydraulically down-gradient of the WWTP. • Low risk. Both wetlands are at a sufficient distance from and hydraulically adjacent to the WWTP. • Low risk. Indian Ocean is at a notable distance from the WWTP. • Moderate – The risk of dermal contact is moderate due to shallow groundwater levels and ponding of groundwater at surface.



6. Field Investigations and Laboratory Analysis Program

6.1. Soil Sampling and Analysis Plan

The soil sampling regime was designed on the basis of the findings of the site history study and the site conceptual model. The sampling methodology was based on those detailed in the DEC (2001-2006) *Contaminated Sites Management Series*. A summary of the Sampling and Analysis Plan is presented in Table 2.

The numbers of soil sampling locations established across Lots 32 and 33 (6 boreholes) and Lot 8 (8 boreholes) do not meet the sampling frequency recommended in the DEC (2003-2006) *Contaminated Sites Management Series* for 41 and 40 hectare site respectively, as the assessment was for due diligence purposes only. The objective of the sampling programs was to target areas of environmental concern. At Lot 8 this was associated with the former lime quarry over the central and eastern portions of the site, and at Lots 32 and 33 the area at the site containing the settlement pond and overflow infiltration pond.

Soil boreholes were strategically located to target areas of concern, and were generally extended to a depth of 1.5 mbgl. Soil samples were scheduled for analysis based on the site history and potential contaminants of concern commonly associated with the historical uses of portions of the site (Table 2).

Nine groundwater monitoring bores were installed at the site (four across Lots 32 and 33, and five across Lot 8) in accordance with DoE (2001) requirements to ascertain groundwater quality and flow across the site. Justification for the locations for each of the nine groundwater wells was:

- MW1 – located in the centre of the northern portion of Lot 32, hydraulically up-gradient of the WWTP, to assess the quality of groundwater entering the WWTP.
- MW2 – located on the southern perimeter of the WWTP on the boundary between Lots 32 and 33 and hydraulically adjacent to the WWTP. Bore installed to assess the quality of groundwater in the immediate vicinity of the ponds.



- MW3 – located on the northern perimeter of the WWTP on the boundary between Lots 32 and 33 and hydraulically adjacent to the site. The bore was installed to assess the quality of groundwater in the immediate vicinity of the ponds.
- MW4 – located on the western perimeter of the WWTP in the north-eastern corner of Lot 33 and hydraulically down-gradient of the WWTP. The bore was installed to assess the quality of groundwater leaving the WWTP.
- DS1 – located on northern perimeter of Lot 8 and the former quarry, and hydraulically adjacent to the site. The bore was installed to assess water quality entering or leaving this portion of the site.
- DS3 – located in the centre of Lot 8 and on the western perimeter of the former quarry area – hydraulically down-gradient of the quarry. This bore was installed to provide information on the quality of groundwater leaving the former quarry area.
- DS4 – located on the eastern half of Lot 8, in the centre of the former quarry area to provide information on groundwater quality immediately beneath the quarry site.
- DS5 – located on the eastern perimeter of Lot 8 and hydraulically –up-gradient of the site and the former quarry. Bore installed to provide information on the quality of groundwater entering Lot 8 and the quarry area.
- DS8 – located on the southern perimeter of Lot 8 and hydraulically adjacent to the site. The bore was installed to assess water quality entering or leaving the site this portion of the site.

6.2. Soil Sampling

Field investigations were undertaken on 3 August 2007 across Lots 32 and 33, and on 9 November 2007 across Lot 8, and included the establishment of 19 soil boreholes in total, using a bobcat mounted 50mm Push Probe. Fieldwork was directed by a 360 Environmental scientist who identified the sampling locations based on the Sampling and Analysis Plan, coordinated the environmental sampling and QA/QC procedures and logged the sub-surface conditions. Soil sample locations are shown on Figure 5 and soil profile borelogs are contained in Appendix F.

Soil sample locations were chosen to target areas of environmental concern across the site. At Lots 32 and 33 these were areas around the WWTP

perimeters and within the WWTP boundaries, in particular the area of the site containing the settlement pond and overflow infiltration pond, and at Lot 8 within the footprint of the former quarry and stockpiling areas, including the area around the former weighbridge and transportable office. Soil sample locations were recorded using a handheld GPS unit. Following inspection of the profile during drilling, soil samples were recovered at the surface (indicatively 0 to 0.15m) and then at approximately 0.5 m intervals for the duration of the borehole. All samples were placed into clean, laboratory-supplied glass sample jars and labelled with the sample number, date and company name. The sample jars were placed in an ice-chilled cooler for transportation to the laboratory and kept chilled at all times. Samples were dispatched to the nominated analytical laboratories (Australian Laboratory Services) under 360 Environmental chain-of-custody documentation (Appendix G).

New, clean gloves were worn for the collection of each sample to reduce the risk of cross contamination. All pieces of equipment re-used between sample locations were rinsed with a phosphate-free decontaminant solution (Extran), a scrubbing brush and deionised water prior to sampling and between sample locations.

6.3. Monitoring Bore Installation and Development

Groundwater monitoring bores were installed at nine locations across the site (shown on Figure 5), using a 75mm solid stem auger drill rig. The constructed bores were cased with Class 18 machine-threaded 50 mm PVC casing. The bore annulus surrounding the screened interval was filled with washed, graded (0.8 to 1.2 mm) gravel pack. The annulus above the filter pack was sealed with bentonite granules and grouted to the surface. The bores were capped with an envirocap and cased with a steel riser. Soil samples were collected from the groundwater bore locations.

The constructed groundwater bores were developed following installation to remove excess fine sediments in the filter pack and surrounding formation. Approximately 100 litres was pumped from each bore until groundwater was consistent and clear in appearance and stabilised pH, EC, temperature and DO readings were recorded. Following installation, well locations were surveyed using a handheld GPS.

The construction borelogs of the nine groundwater bores are featured in Appendix F.



6.4. Groundwater Sampling

In accordance with industry protocols, groundwater monitoring was undertaken at the nine newly constructed monitoring bores at least one week following installation and development. Groundwater samples were collected from monitoring bores across Lot 32 and 33 on 16 August 2007, and from monitoring bores across Lot 8 on 16 November 2007. A groundwater sample was also collected from an existing Water Corporation bore GW2, which is located on the eastern boundary of Lot 32 to provide water quality data on groundwater entering the lot. A sample was not collected from the second Water Corporation bore GW1/WC1, located on the western boundary of Lot 32, as the monitoring bore was dry at the time the sampling was undertaken.

A second round of sampling was carried out at selected monitoring bores on 21 January 2008, to confirm the laboratory analytical results obtained from the first sampling round. Re-sampled monitoring bores included MW1 to MW4 and GW1/WC1 located around the WTPF, and groundwater bores DS3, DS4 and DS8 established across Lot 8.

The standing water level in each of the bores was measured and then purged using a low-flow peristaltic pump, with approximately 5 bore volumes purged. Field water quality parameters (pH, temperature, dissolved oxygen (DO), redox potential and electrical conductivity [EC]) were recorded during purging and sampling to assess water quality and to ensure the bores had been adequately purged. The results of groundwater monitoring bore field recordings for purging and sampling are contained in Appendix H.

Samples were collected and placed in laboratory-supplied containers for the required analytes and kept chilled on ice for storage and transport to the analytical laboratory. Groundwater samples were filtered in the field for metals analyses using disposable 0.45 μm syringe filters.

The collection container and the probe used for field measurements were decontaminated between each sample location using a phosphate-free detergent (extran), and rinsed with distilled water. Dedicated water tubing was used at each monitoring bore. The water quality meter was calibrated prior to use and the calibration certificate is contained in Appendix I.

6.5. Laboratory Analysis

All soil and groundwater samples were analysed by the NATA-accredited Australian Laboratory Services (ALS) using NATA-accredited methods.





Scheduled analysis of soil and groundwater samples was based on site history and site conceptual model findings. The nominated analysis regimes for Lot 8 and for Lots 32 and 33 are discussed below:

6.5.1 Lot 8

Selected soil samples from each of the nine locations established across Lot 8 were analysed for identified potential contaminants of concern. Specifically, all surface soil samples from DS1- DS9 were analysed for metals, TPH, BTEX, PAHs and phenols. Similarly, all five groundwater samples collected from monitoring bores located across Lot 8 were analysed for metals, TPH, BTEX, PAHs, phenols, nutrients and major cations.

6.5.2 Lot 32 and 33

Selected soil samples from each of the ten locations established across Lots 32 and 33 were analysed for metals, nutrients (phosphorus, potassium, nitrogen, TKN, nitrates + nitrites), phenols and pathogens (e-coli, enterococci and thermotolerant coliforms). All surface soil samples from BH1- BH4 and soils at depth from BH5 and BH6 were analysed for all of the above constituents, whereas soil samples collected at locations MW1 – MW4 at a greater distance from the WWTP, were analysed for metals only. Samples selected for analysis from locations BH5 and BH6, situated between the two waste water treatment ponds and in the middle of the unlined infiltration pond, were collected from deeper in the soil profile to capture any potential leaks from the ponds, and analysed for the constituents listed above.

All five groundwater samples collected from monitoring bore located across Lots 32 and 33 were analysed for metals, nutrients, phenols and pathogens (e-coli, enterococci and thermotolerant coliforms).

6.5.3 Second Round of Groundwater Monitoring

Samples collected from monitoring bores DS4 and DS8 (located in the central and southern portions of the former quarry on Lot 8 respectively) in January 2008, were all analysed for dissolved cadmium, whilst the sample from DS3 (western boundary of the former quarry) was analysed for TPH.

All five groundwater samples collected from monitoring bore located across Lots 32 and 33 were analysed for pathogens including e-coli, enterococci and thermotolerant coliforms.



6.6. Quality Assurance and Quality Control

Quality assurance/quality control (QA/QC) measures were adopted during soil sampling in accordance with the DEC (2001-2006) *Contaminated Site Management Series* and Australian Standard AS4482.1. QA/QC measures are detailed in the 360 Environmental QA/QC Report contained in Appendix J.

Work was carried out by experienced environmental scientists in accordance with accepted industry standards. Prior to commencement of field investigations, all soil augers and sampling equipment were cleaned with water and phosphate-free detergent and rinsed with deionised water. Field quality control samples included soil duplicate samples and rinsate samples.

All samples were transported under 360 Environmental chain-of-custody procedures. Chain-of-custody documentation and laboratory sample receipt advice reports for all sampling is presented in Appendix G.

ALS's internal QA/QC measures included spike analyses, method blanks, laboratory control samples and laboratory duplicates. Their quality control reports are contained in Appendix K.

6.7. Data Usability

An assessment of the usability of the laboratory data has been made by considering field and laboratory procedures and comparing against pre-determined qualitative criteria. Appendix J - Quality Assurance/Quality Control Data Assessment Report presents the results of the assessment and the implications of the findings on the final data usability. Based on the assessment, it is considered that the laboratory tests reasonably represent the conditions at the sampling points at the time of sampling. The sampling and laboratory procedures are considered satisfactory.



7. Results

7.1. Site Stratigraphy

The subsurface conditions encountered across the site during the drilling programs are described below and soil borelogs are contained in Appendix F. Soils around the WWTP, located in the north-western and north-eastern portions of Lots 32 and 33 respectively, were generally consistent across this section of the site, comprised of fine to medium grained, brown sands underlain by light grey, light brown and black, fine to medium grained sands. Organics were encountered in the top 0.30-0.35 mbgl at some of the locations, especially soil bores established on the west, south-west and south of the WWTP ponds.

Thin lenses of limestone cap rock were encountered in several bores at depths ranging from 1.0 mbgl north of the ponds (MW5) to 3.6 mbgl south of the ponds (MW2). In addition, clayey soils of medium plasticity were intercepted at a depth of 5.4 mbgl at MW2 and continued to the completion of the bore at 7.0 metres. No fill material was encountered at any of the sampling locations established across Lots 32 and 33.

Surface soils across the eastern half of Lot 8 were generally comprised of brown, fine to medium grained sandy fill material, with some organics, ranging in thickness from 0.4 m (DS1) to 0.7 m (DS2 and DS6). White, fine grained sands occurring at DS3, and light yellow, medium grained sands with limestone gravels at DS4, both extending to a depth of 0.3 m were the exceptions.

Underlying the fine grained sands were mostly light yellow to brown, medium grained sands with frequent limestone fragments, ranging in thickness from 0.3 m (DS2) to 3.3 m (DS3). In boreholes located in the southern portion of Lot 8 (DS6, DS7 and DS8), shell fragments were also encountered in this unit. At DS2 and DS4 this unit was immediately underlain by a layer of limestone, with a thickness of 0.65 and 0.6 m respectively, and at DS6 and DS7 by a unit of orange, medium to coarse grained sands with shell fragments. At all remaining bores the underlying unit was comprised of light yellow, medium grained sands.

7.2. Soil Analytical Results

Tables 3 to 5 present the results of analytical soil sampling and compare results with applicable guidelines presented in DoE (2003) *Assessment Levels for Soil, Sediment and Water*. The laboratory analytical reports are presented in Appendix L and the findings are discussed in the following sections.

7.2.1 Metals

Concentrations of all metals in the 19 soil samples analysed from Lots 8, 32 and 33 were below the recommended guidelines levels (EIL and HIL-F for industrial/commercial land use), with the majority below respective laboratory Limits of Reporting (LOR).

7.2.2 Nutrients and Pathogens

Surface soil samples collected from six bore locations (BH1-BH6) in and around the WWTP on Lots 32 and 33 were analysed for nutrients and pathogens, including nitrite and nitrate, TKN, total phosphorus, potassium, e-coli, enterococci and thermotolerant coliforms.

Whilst no guidelines are provided for nutrients or pathogens in soil, a comparative assessment of the data for the six samples analysed for these parameters was undertaken. Findings of the assessment indicated the following:

- Nitrite + nitrate concentrations ranged from 0.0.169 mg/kg (BH6-3) to 0.742 mg/kg (BH2-1) with an average value of 0.422 mg/kg.
- TKN levels ranged between 20 mg/kg in sample BH5-5 and 180 mg/kg in sample BH3-1 with an average concentration of 112 mg/kg. Concentrations at BH5 and BH6 were approximately a third to a quarter of concentrations at the remaining four locations.
- Total phosphorus concentrations were lowest in soil sample BH5-5 with a value of 30 mg/kg, and highest in soil sample BH2-1 at 106 mg/kg. As with TKN levels, total phosphorus concentrations in soil samples BH5-5 and BH6-3 were lower than levels measured in the remaining four soil samples. The median value for total phosphorus was 69 mg/kg.
- Potassium concentrations were relatively steady in the six soil samples analysed for this parameter, ranging from 50 mg/kg in soil sample BH2-1 to 80 mg/kg in soil samples BH1-1 and BH4-1.

- E-coli and enterococci levels were below the laboratory detection of reporting (LOR) in all six samples analysed.
- Concentrations of thermotolerant coliforms were below the LOR in nearly all six soil samples analysed, with a concentration of 4 Colony Forming Units (CFU)/100 mL in soil sample BH1, marginally above the LOR of 3 CFU/100 mL, being the exception. The localised and low level presence of the pathogen at this location is considered likely a result of physical human transfer of maintenance staff (on footwear and machinery) accessing the site or from animals (kangaroos, foxes, rabbits, etc).

7.2.3 TPH/BTEX/PAHs

Concentrations of TPH, BTEX and PAHs in all nine soil samples analysed were below respective laboratory LOR and recommended guideline levels.

7.2.4 Phenolic Compounds

Concentrations of phenolic compounds in all 15 soil samples analysed were below respective laboratory LOR and recommended guideline levels.

7.3. Groundwater Analytical Results

Tables 6 to 10 present the results of analytical groundwater sampling and compare results with applicable guidelines presented in DoE (2003) *Assessment Levels for Soil, Sediment and Water* and Tsvetnenko (1998). The laboratory analytical reports are presented in Appendix L and the findings are discussed in the following sections.

7.3.1 Field Parameters

Lot 32 and 33

Field parameters measured at the five monitoring bores located across Lots 32 and 33 during the groundwater sampling event carried out on 16 August 2007 and 21 January 2008 are shown in Table 6 and indicate the following:

- Purged water was clear and colourless in all five groundwater monitoring bores during the sampling round undertaken on 16 August 2007, but mostly slightly turbid, with a light grey colour on 21 January 2008. No odours were detected at any of the monitoring bores during either monitoring event.



- Standing water levels across the lot varied between approximately 2.71 and 4.42 metres below top of casing (mbtoc).
- pH levels measured in groundwater at the five monitoring bores ranged between 6.82 (MW1 and MW4) and 7.47 (MW3) over the two monitoring events. However, pH levels declined at all five monitoring bores between the first and second monitoring rounds, with decreases ranging from 0.02 pH units at MW1 to 0.42 pH units at MW3. Although all values conformed to the *DoE 2003 Freshwater* and ANZECC/ARMCANZ 2000 recommended guideline levels of 6.5-8.5, all levels were below the *DoE 2003 Marine Water* guideline levels of 8.0 – 8.4.
- EC levels at the five monitoring bores ranged from 756 $\mu\text{S cm}^{-1}$ at MW3 to 1464 $\mu\text{S cm}^{-1}$ at MW1, with values generally higher in bores on the eastern side of the WWTP than those on the western side. Notable changes in EC levels occurred at three of the monitoring bores between the two monitoring rounds, including declines at MW1 and MW2 and an increase at GW1/WC1. Nonetheless, all EC readings indicate that groundwater at the site is fresh.
- Dissolved oxygen concentrations at the five monitoring bores ranged from 5.91 mg/L at MW3 (western perimeter of WWTP) to 11.23 mg/L at MW2 (southern perimeter of the WWTP), indicating that groundwater at the site is generally moderately to highly oxygenated. Notable declines in DO concentrations occurred MW2, MW3 and GW1/WC1 between the first and second monitoring events.
- Redox values at the five bores across Lots 32 and 33 were relatively steady, ranging between 105 mV at MW1 and 165 mV at MW1, indicating that groundwater conditions at Lots 32 and 33 are moderately oxygenating. Redox values at all monitoring bores declined between the two monitoring events, although some by marginal increments only.

Lot 8

Field parameters measured at the five monitoring bores located across Lot 8 during the groundwater sampling event carried on 16 November 2007 and 21 January 2008 are shown in Table 6 and indicate the following:

- Purged water was clear and colourless in all five groundwater monitoring bores during both monitoring events.



- Standing water levels across the lot were generally shallower with respect to ground level than at Lots 32 and 33, with measurements ranging between 0.92 and 1.91 mbtoc.
- pH levels measured in groundwater at the five monitoring bores ranged between 7.02 (DS8) and 7.77 (DS4). As with pH levels in groundwater at Lots 32 and 33, all values conformed to DoE (2003) Freshwater Guideline and ANZECC/ARMCANZ 2000 recommended guideline levels of between 6.5-8.5, but were below the DoE (2003) Marine Water guideline levels of 8.0 – 8.4.
- EC levels at the five monitoring bores ranged from 590 $\mu\text{S cm}^{-1}$ at DS3 (on the western perimeter of the quarry) to 1620 $\mu\text{S cm}^{-1}$ at DS8 (on the southern perimeter of the quarry). EC levels at DS3 and DS4 increased by notable increments between the two monitoring events, whilst those at DS8 declined significantly. However, all EC readings indicate that groundwater at the site is fresh.
- Dissolved oxygen concentrations in groundwater across Lot 8 ranges from 3.37 mg/L at DS8, (southern perimeter of the former quarry) measured on 16 November 2007, to 8.55 mg/L measured at the same monitoring bore measured on 21 January 2008. These results indicate that groundwater at Lot 8 is poorly to moderately oxygenated.
- Redox values at the five bores across Lot 8 ranged between -1 mV at DS4 (centre of the former quarry – measured on 16 November 2007) to 175 mV at DS3 (western perimeter of the quarry – measured on 21 January 2008), indicating that groundwater conditions at the site are slightly reducing at the centre of the site, and slightly to moderately oxygenating from the centre out to the lot boundaries. It is noted however, that at all three monitoring locations re-sampled, redox values increased by notable increments between the first and second monitoring events.

7.3.2 Metals

Assessment of groundwater monitoring results indicates that nearly all levels of dissolved metals, including aluminium, arsenic, chromium, cobalt, copper lead, manganese, mercury, nickel, selenium and zinc, were below the DoE (2003) recommended guideline levels for Marine Water, Fresh Water and Drinking Water in all monitoring bores. Exceptions occurred at several monitoring bores across Lot 8, included the following:



- Dissolved cadmium concentrations of 0.3 µg/L at DS4 (centre of the former quarry) and DS8 (southern perimeter of the former quarry) marginally above the DoE (2003) Fresh Water guideline level of 0.2 µg/L. However, these concentrations were below the DoE 2003 Marine Water guideline level of 0.7 µg/L and the Drinking Water guideline levels of 2 µg/L.
- A dissolved iron concentration of 420 µg/L at DS8 (southern perimeter of former quarry) above the DoE 2003 Drinking Water (Aesthetic) guideline level of 300 µg/L.
- Total aluminium concentrations in groundwater at all monitoring bores exceeded the DoE Freshwater guideline level of 55 µg/L by up to 36 times. Concentrations at MW1, DS1, DS4, DS5 and DS6 also exceeded the DoE 2003 Drinking Water Aesthetic guideline level of 200 µg/L. Of note, total aluminium concentrations in groundwater at Lot 8 were generally higher than those measured at Lot 32 and 33.
- All total zinc concentrations in groundwater at Lot 8 exceeded the DoE 2003 Freshwater guideline level of 8 µg/L with values ranging from 11 µg/L (DS5) to 37 µg/L (DS4). However, with the exception of the level at DS4, most concentrations conformed to the Marine Water and Drinking Water guideline levels of 15 µg/L and 3000 µg/L respectively. Of note, total zinc concentrations in groundwater at all bores located across Lots 32 and 33 conformed to all nominated guideline levels.
- Concentrations of total iron were above the DoE 2003 Drinking Water guideline level of 300 µg/L in groundwater at most monitoring bores across the site, with elevated levels ranging from 340 µg/L at GW1/WC1 (located to the north-west of the WWTP) to 1280 µg/L at DS8 (southern perimeter of the former quarry on Lot 8). Levels conforming to the DoE Drinking Water guideline were limited to groundwater monitoring bores on the southern and western perimeters of the WWTP (MW2 and MW3) and those on the northern and western perimeters of the former quarry on Lot 8 (DS1 and DS3).

Due to the close proximity of monitoring bores DS4 and DS8 to the Conservation Category wetland located on the southern portion of Lot 8, the two monitoring bores were re-sampled for dissolved cadmium. Results from the second round of monitoring indicated that cadmium concentrations were below the laboratory limits of reporting.

7.3.3 TPH

Nearly all concentrations of TPH in groundwater at the five monitoring bores established across Lot 8, were below guideline levels and laboratory limits of reporting. A C₂₅-C₂₈ concentration of 100 µg/L just on the LOR in groundwater at DS3 (located on the western perimeter of the former quarry) was the exception. A second round of sampling and analysis at this monitoring bore was undertaken to verify this detection, and identical results were obtained. No phase separated hydrocarbons (PSH) were detected using the oil-water phase separator nor any surface sheen observed during either sampling event.

The level of TPH recorded in site groundwater at DS3 was greater than the low-reliability trigger value in ANZECC 2000; however, the guideline level (7 µg/L) is below the practical quantitation limit for standard TPH fractionation analysis. Of note, the detected concentration of C₁₅-C₂₈ fraction of TPH at DS3 was on the limit of reporting and well below the trigger levels suggested by Tsvetnenko (1998) which may cause acute toxicity to a wide range of marine organisms (300 to 4500 µg/L). The C₁₅-C₂₈ fraction may be associated with diesel and/or lubricating or heavy waste or fuel oil. It is noted that TPH was not detected in any of the soil samples collected from across Lot 8.

7.3.4 BTEX and PAHs

Concentrations of all PAHs and BTEX in the five groundwater samples analysed (collected from the Lot 8 monitoring bores) were below respective LORs and all nominated guideline levels.

7.3.5 Phenolic Compounds

Concentrations of all phenolic compounds in the ten groundwater samples analysed (collected from the ten monitoring bores across the site) were below respective LORs and all nominated guideline levels.

7.3.6 Nutrients and Pathogens

Table 7 presents concentrations of nutrient and potability analytes measured in groundwater at the site. These results indicated the following:

- Total suspended solid (TSS) concentrations were low to moderate with values ranging from 5 mg/L at GW1/WC1 to 105 mg/L at DS4.

- Total alkalinity levels were slightly higher in groundwater at Lots 32 and 33 (222 to 460 mg/L) than in groundwater at Lot 8 (152 to 303 mg/L). Most concentrations were above the DoE 2003 Drinking Water – Aesthetics guideline level of 200 mg/L.
- Total acidity concentrations at Lots 32 and 33 ranged <1 to 8 mg/L whilst those at Lot 8 were notably higher ranging from 11 to 27 mg/L. The difference is attributed to the calcareous sands located across Lots 32, 33 and the western portion of Lot 8, which would assist in reducing acidity in groundwater in these areas.
- Sulphate concentrations ranging from 17 to 49 mg/L in groundwater across Lots 32 and 33, were generally lower than levels in groundwater across Lot 8, which ranged from 57 to 177 mg/L.
- Sulphur levels were on average lower in groundwater across Lots 32 and 33 with values ranging from 6 to 16 mg/L, than those in groundwater at Lot 8, with concentrations between 19 to 59 mg/L.
- Chloride concentrations in groundwater across the site ranged from 52.4 mg/L at DS3 to 203 mg/L at DS8. All concentrations conformed to the DoE (2003) Drinking Water – Aesthetic guideline level of 250 mg/L.
- Ratios of total alkalinity:sulphate were below 5 at all monitoring bores located across Lot 8, with values ranging from 1.49 (DS5) to 3.54 (DS1), indicating the potential impact of acid sulphate soils in groundwater across this lot (Swedish EPA, 2002). Conversely, all total alkalinity:sulphate ratios in monitoring bores across Lots 32 and 33 conformed to the nominated guideline, ranging from 7.84 (MW2) to 14.41 (GW1/WC1).
- Sulphate:chloride ratios in groundwater at Lot 8 were all above 0.5, ranging between 0.63 (DS4) and 1.55 (DS3), and thus potentially indicative of acid sulphate soil impact on the groundwater across this lot (Mulvey, 1993). Sulphate:chloride ratios in groundwater at Lots 32 and 33 ranged between 0.18 (GW1/WC1) and 0.34 (MW3).
- Nitrate + nitrite concentrations in groundwater across Lots 32 and 33 ranged from 3.59 (GW1/WC1) to 17.9 mg/L (MW4), whilst across Lot 8 concentrations were between 0.019 (DS3) and 15.4 (DS5).



- TKN concentrations were measured in groundwater monitoring bores located across Lots 32 and 33, and ranged from 0.60 mg/L (GW1/WC1) to 1.2 mg/L (MW1 and MW4).
- Total nitrogen concentrations measured in groundwater monitoring bores across Lots 32 and 33 ranged from 4.2 mg/L at GW1/WC1 to 19.0 mg/L at MW4.
- Total phosphorus concentrations were measured in groundwater monitoring bores located across Lots 32 and 33, and were consistently low, ranging from 0.04 mg/L (GW1/WC1) to 0.07 mg/L (MW1 and MW4) only.
- Calcium concentrations across the site ranged from 55 mg/L (DS4) to 164 mg/L (DS8) and were generally higher in groundwater at Lots 32 and 33 than at Lot 8.
- Magnesium levels in groundwater across the site ranged from 11 mg/L (GW1/WC1) to 29 mg/L (DS8).
- Sodium concentrations ranged from 38 mg/L (DS3) to 160 mg/L (MW1) in groundwater across the site.
- Potassium levels in groundwater were between 2 mg/L (GW1/WC1 and DS3) and 21 mg/L (DS8).
- Concentrations of thermotolerant coliforms and E.coli from both monitoring events were below the LOR in all samples analysed for both monitoring events.
- Levels of enterococci were below the LOR in nearly all groundwater samples analysed during the first monitoring event undertaken on 18 August 2007, with the exception of a concentration of 7 CFU detected at MW4. Confirmatory sampling and analysis in January 2008 indicated that levels were below the LOR at nearly all monitoring bores including MW4. A concentration of 70 CFU/100 mL at MW1 was the exception, with this value exceeding the nominated NHMRC 2006 guideline level of 40 CFU/100 mL.

8. Conclusions and Recommendations

The outcome of the contamination assessment of soils across the site has indicated that levels of metals, TPH, BTEX, PAHs and phenolic compounds in all soils samples collected and analysed from Lot 8, are below recommended guideline levels (EIL and HIL-F guidelines (commercial/industrial landuse)). These results indicate that the impact of potentially contaminating activities undertaken at the site associated with the quarry appears to have been minimal on surrounding soils.

Levels of metals, nutrients and phenolic compounds in all soils samples collected and analysed from Lots 32 and 33 are below recommended guidelines; however, a low level detection of thermotolerant coliforms occurred in a surface soil sample at BH1. The localised and low level presence of the pathogen at this location is considered likely a result of physical human transfer of maintenance staff (on footwear and machinery) accessing the site or from roaming animals (kangaroos, foxes, rabbits, etc).

All remaining pathogens analysed were below respective LORs. These results indicate that soils in the north-eastern corner of the WWTP may potentially be impacted by faecal contamination likely originating from the WWTP.

Whilst the concentrations of most metals in groundwater at the site are below DoE (2003) *Marine Water, Freshwater and Drinking Water Guidelines*, some exceedences occurred, particularly in groundwater at Lot 8. These included:

- Dissolved cadmium at DS4 and DS8 marginally exceeded the Freshwater guideline level of 0.2 µg/L. However, a second round of monitoring at DS4 and DS8 for dissolved cadmium indicated that concentrations at these two monitoring bores were below the LOR.
- A dissolved iron concentration of 420 µg/L at DS8 exceeded the DoE (2003) *Drinking Water – Aesthetic* guideline level of 300 µg/L.
- Total zinc at all five monitoring bores located at Lot 8 exceeded the DoE (2003) *Freshwater* guideline concentration of 8 µg/L, and a zinc level of 37 µg/L at DS4 also failed to meet the DoE (2003) *Marine Water* guideline level of 15 µg/L.
- Total aluminium concentrations at nearly all monitoring bores across



the site, with the exception of DS3, exceeded the DoE (2003) *Freshwater* guideline level of 55 µg/L, whilst concentrations at MW1, DS1, DS4, DS5 and DS8 also exceeded the Drinking Water – Aesthetic guideline level of 200 µg/L.

- Total iron at MW1, MW4, GW1/WC1, DS4, DS5 and DS8 all exceeded the DoE (2003) *Drinking Water –Aesthetic* guideline level of 300 µg/L, with concentrations in groundwater at Lot 8 generally higher than at Lots 32 and 33.

On the basis of high sulphate:chloride ratios and low total alkalinity:sulphate ratios in groundwater at the five bores located across Lot 8, the elevated metal concentrations occurring in groundwater at this lot are possibly attributable to the oxidation and conversion of ASS in high to moderate and moderate to low ASS risk areas located in the southern and eastern portions of Lot 8, and the likely subsequent acidification of the underlying groundwater some time earlier in the site's history.

A concentration of TPH C₁₅-C₂₈ fraction of 100 µg/L measured in site groundwater at DS3 and confirmed in a second monitoring event, was greater than the low-reliability trigger value in ANZECC 2000; however, it was well below the trigger level suggested by Tsvetnenko (1998) which may cause acute toxicity to a wide range of marine organisms (300 to 4500 µg/L). As TPH concentrations in all soil samples collected were below respective LORs and no indicators of a hydrocarbon spill or staining were observed during site visits, the source of the TPH detected at DS3 is not yet evident.

On the basis of the results of the soil and groundwater sampling program the following recommendations are made:

- Further investigations to delineate the extent of TPH impacted groundwater in the vicinity of DS3 should be carried out.
- Additional monitoring should be undertaken at all monitoring bores located in the vicinity of the WWTP to better understand the fluctuating levels of enterococci in these bores.
- Additional monitoring should be undertaken at monitoring bores DS4 and DS8 to monitor the fluctuating levels of dissolved cadmium in these bores, given the close proximity of the Conservation Category wetland.
- Due to the elevated levels of some metals in groundwater at Lot 8,



appropriate management strategies should be implemented during construction works and most particularly if any associated dewatering works are proposed across this portion of the site. Due consideration should be given and appropriate additional monitoring undertaken when considering future beneficial reuse of the groundwater at the site.

In conclusion, the contamination assessment has indicated that potentially contaminating activities undertaken at the site during its use as a quarry at Lot 8 and as a WWTP at Lots 32 and 33 may potentially have had some impact on the surrounding environment in the areas investigated, in particular metal, TPH and enterococci levels in the groundwater. Additional monitoring and investigations are recommended to assess potential risks to human health and the environment.



9. Limitations

This report is produced strictly in accordance with the scope of services set out in the contract or otherwise agreed in accordance with the contract. 360 Environmental makes no representations or warranties in relation to the nature and quality of soil and water other than the visual observation and analytical data in this report.

In the preparation of this report, 360 Environmental has relied upon documents, information, data and analyses (“client’s information”) provided by the client and other individuals and entities. In most cases where client’s information has been relied upon, such reliance has been indicated in this report. Unless expressly set out in this report, 360 Environmental has not verified that the client’s information is accurate, exhaustive or current and the validity and accuracy of any aspect of the report including, or based upon, any part of the client’s information is contingent upon the accuracy, exhaustiveness and currency of the client’s information. 360 Environmental shall not be liable to the client or any other person in connection with any invalid or inaccurate aspect of this report where that invalidity or inaccuracy arose because the client’s information was not accurate, exhaustive and current or arose because of any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to 360 Environmental.

Aspects of this report, including the opinions, conclusions and recommendations it contains, are based on the results of the investigation, sampling and testing set out in the contract and otherwise in accordance with normal practices and standards. The investigation, sampling and testing are designed to produce results that represent a reasonable interpretation of the general conditions of the site that is the subject of this report. However, due to the characteristics of the site, including natural variations in site conditions, the results of the investigation, sampling and testing may not accurately represent the actual state of the whole site at all points.

It is important to recognise that site conditions, including the extent and concentration of contaminants, can change with time. This is particularly relevant if this report, including the data, opinions, conclusions and recommendations it contains, are to be used a considerable time after it was prepared. In these circumstances, further investigation of the site may be necessary.



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