resource and environmental management

Aquifer Storage and Recovery Potential for Buckland Park

Final Report

Prepared for

Walker Corporation Pty Ltd

Level 50, Governor Phillip Tower,
1 Farrer Place,
SYDNEY NSW 2000
30 October 2008

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1 INTRODUCTION

The Walker Corporation Pty Ltd engaged Resource & Environmental Management Pty Ltd (REM) to investigate various groundwater issues as part of the preparation of an Environmental Impact Statement (EIS) for the Buckland Park proposal. The site is 1,308 hectares situated 32km north of Adelaide, adjacent to the Gawler River, west of Port Wakefield Road (Figure 1).

One component of this work entailed a desktop review of the potential for aquifer storage and recovery (ASR) at Buckland Park. ASR is a process whereby stormwater (typically urban or creek flow) is harvested during winter months, injected and stored in aquifers, and then subsequently recovered during periods of high demand in summer. If feasible, ASR has the potential to decrease the consumptive use of potable water for non-potable applications (e.g. irrigation) and to supplement or bank water to protect against future uncertainties in availability that may occur as a result of prolonged drought conditions.

This report outlines a desktop evaluation of the potential for ASR within the catchment area of the Buckland Park site. The study focuses on the capacity of the major aquifers beneath the site as, at this stage, the potential magnitude of ASR demand at the site is unknown.

1.1 Objectives

The objectives of this investigation are to assess the:

- feasibility of ASR at Buckland Park through a desktop review of the local hydrogeology, taking into account the likely influence of water policy and regulations;
- potential impact of the proposed ASR scheme on regional aquifer pressure and water quality; and
- to describe ASR management and monitoring requirements, taking into account the likely influence of water policy and regulations.

1.2 Scope of work

The desktop investigation draws upon existing work and available data to determine the likely capacity of the aquifer to receive and store water. The results presented are preliminary and further work would be required to fully evaluate the feasibility of ASR at Buckland Park. The scope of work for this investigation includes:

- a review of local and regional groundwater conditions, aquifer type (confined or unconfined), depths and groundwater quality;
- estimation of the potential storage capacities of the major aquifers beneath Buckland Park;
- description of the likely legislative, management, and monitoring requirements of an ASR scheme at Buckland Park.

2 BACKGROUND

2.1 What is ASR?

The term ASR was defined by Pyne (1995) as “the storage of water in a suitable aquifer through a well during times when water is available, and recovery of the water from the same well during times when it is needed”. The concept is depicted in Figure 2.

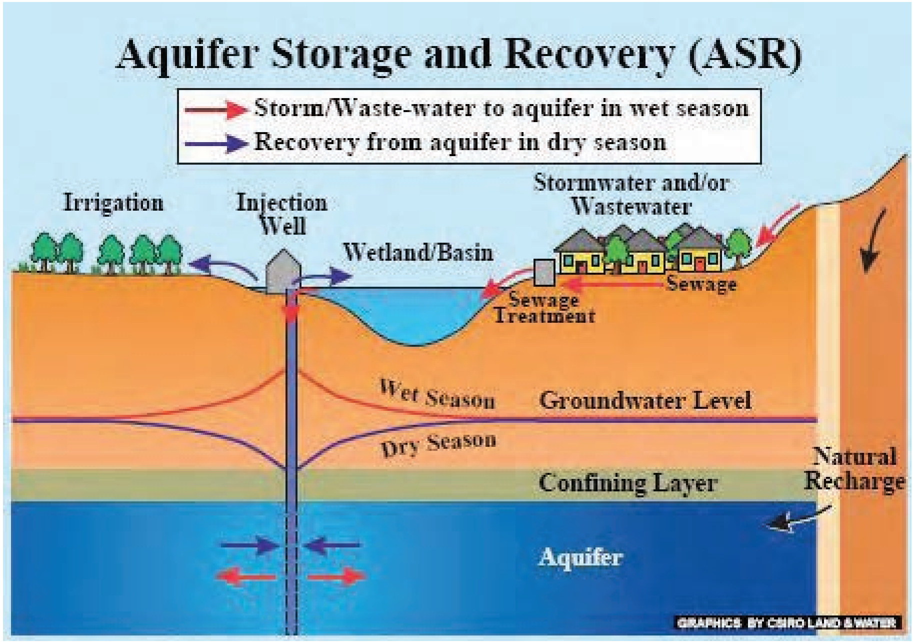

Figure 2. Schematic depiction of the ASR process (after Martin and Dillon, 2002).

While there are a range of methods whereby groundwater recharge can be artificially increased, ASR by injection wells has developed as the main form of recharge enhancement in the Adelaide region. This is due to the presence of suitable confined aquifers at depth, restricted space, and a lack of suitable watertable aquifers (Hodgkin, 2004). Typically, ASR by recharge wells involves the harvesting of treated stormwater and/or wastewater during winter months (when rainfall is highest, and demand for water low) for injection into purpose-built wells. The same wells are used to extract water in times of high demand (summer months) where it is used for non-potable uses (e.g. irrigation) or it can be treated and purified for potable supply.

ASR can be used as a resource management tool where water from a source is treated and then stored underground (Figure 2). Large volumes of water may be stored underground thereby reducing the need to construct expensive surface reservoirs. ASR can also replenish aquifers that have experienced long-term declines in water levels as a result of concentrated and heavy pumping (Martin and Dillon, 2002).

2.2 Previous investigations

There have been a number of previous investigations into ASR in the Adelaide region, which were reviewed by Martin and Dillon (2002) and Hodgkin (2004). The confined aquifers of the Northern Adelaide Plains (NAP), where Buckland Park is located, were identified as having a high potential for ASR developments (Martin and Dillon, 2002). This view was supported for the Buckland Park area in a preliminary investigation by Australian Water Environments (AWE, 2007), which concluded that the T2 Tertiary aquifer had suitable properties and sufficient permeability to allow for ASR with injection rates of 10 to 12 L/s possible. The study also suggested the injection of water would be beneficial by lowering the native groundwater salinity, and that other aquifers and confining layers would not be adversely affected by the increased pressure associated with injection.

A number of nearby ASR schemes, south of the Buckland Park area, are currently in operation or are in the planning stage (Figure 1). Some of these schemes are proposed to operate with artesian conditions that may impact irrigators within 2.5 kilometre radius of the ASR injection well.

3 REGIONAL HYDROGEOLOGY

3.1 Hydrostratigraphy

The Adelaide Plains consist of Tertiary and Quaternary sediments up to 600 m thick that host up to ten aquifer systems, which overly Precambrian bedrock. Generally, the Tertiary sedimentary aquifers constitute the largest and most important groundwater resource of this region, whilst the Quaternary aquifers are relatively thin and of limited extent.

Buckland Park is within the Adelaide Plains Sub-Basin where the hydrostratigraphy is relatively simple due to the uniformity and extent of the key geological units. Figures 3 and 4 depict the regional hydrostratigraphy of the Northern Adelaide Plains. Recent broad-scale investigations of the area (Evans, 1990; Gerges, 1996, 1999, 2001; and Zulfic, 2002) are summarised in Hodgkin (2004) from which much of this section has been sourced.

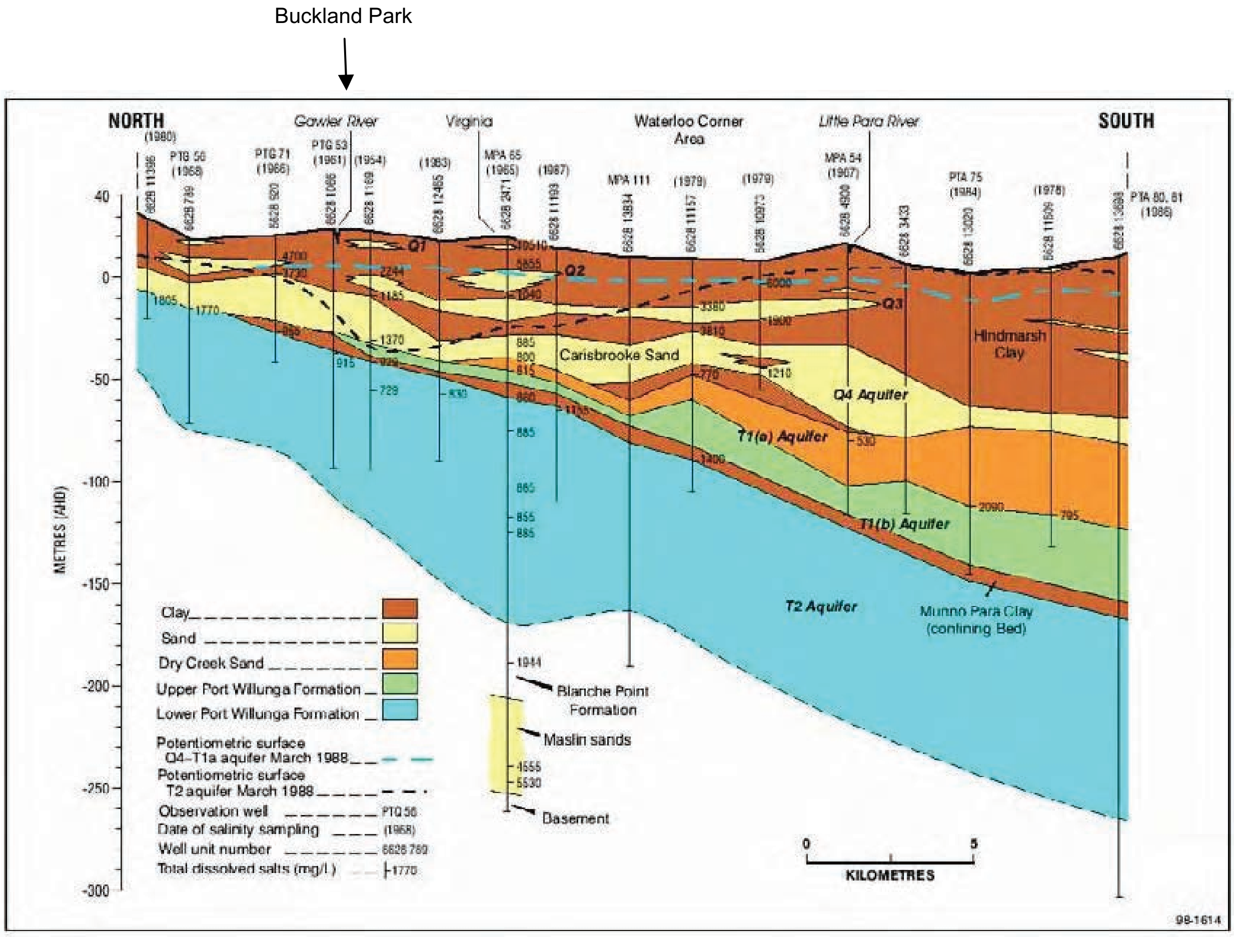

Figure 3. North-south hydrogeological cross-section, Northern Adelaide Plains (after Zulfic, 2002). The arrow indicates the approximate position of Buckland Park.

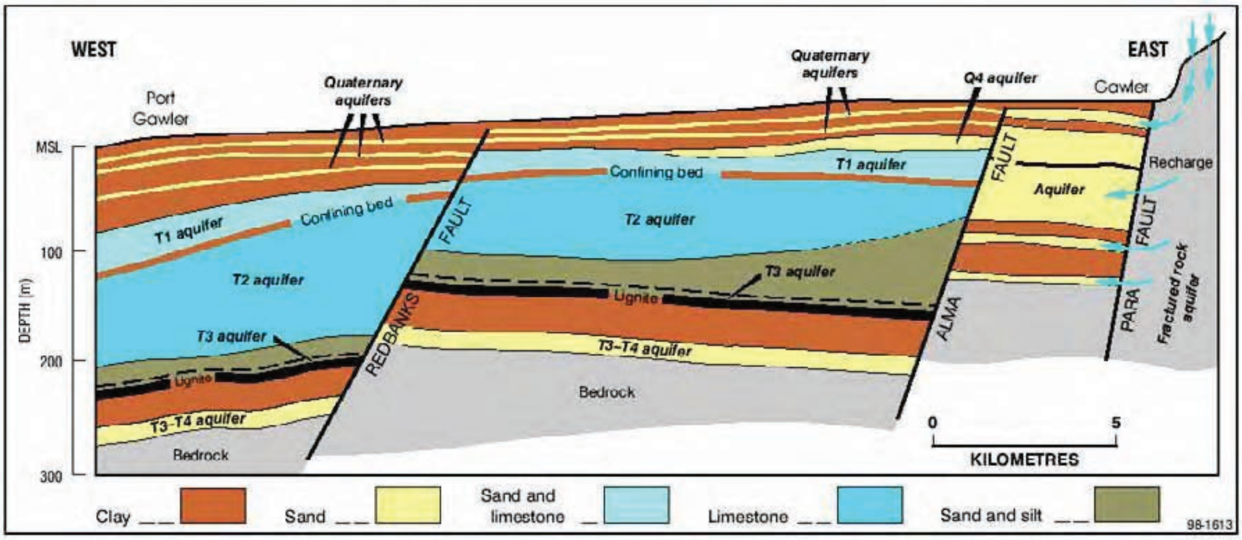

Figure 4. West-east hydrogeological cross-section along Gawler River, Northern Adelaide Plains (after Zulfic, 2002). Buckland Park is located west of the Redbanks Fault.

3.1.1 Quaternary aquifers

In the NAP region, three Quaternary aquifers (Q1 to Q3) are generally present with thicknesses ranging from 3 to 15 m. They can be quite discontinuous with lateral extents often less than 2 km. The Hindmarsh Clay unit encloses these aquifers and thins to the northern limit of the NAP PWA, where it can be as little as 20-30 m. Clay underlies the Q3 aquifer and forms a confining bed above the Q4 aquifer, although there are localised occurrences of the Q3 aquifer directly overlying the Q4 aquifer.

3.1.2 Q4 (Carisbrooke Sand) Aquifer

The Q4 aquifer is a sandy confined aquifer that is present throughout most of the region, but is absent near of the coast, north of St Kilda. In the NAP region, it is comprised solely of the Carisbrooke Sand and averages about 20 m thickness. It consists of multi-coloured, poorly sorted, fine to medium grained quartz and and silt, with some clay and thin gravel beds. Wells completed within Q4 are typically low yielding and require screening and extensive development to minimise the production of fine sands. At Buckland Park, the Q4 aquifer directly overlies the T1 aquifer, and is absent within 2-4 km of the coast (Figure 5). It is likely that it thins and expires (pinches out) near the western side of the site.

3.1.3 T1 Aquifer

The T1 aquifer is generally considered to be two sub-aquifers separated by the glauconitic silts and sands of the Croyden Facies, which act as a weak semi-confining bed. The upper most sub-aquifer, T1a, consists of the Hallet Cove Sandstone and Dry Creek Sand that are of shallow marine origin and comprise shelly, dark grey to brown sand, silt and clay.

The T1a sub-aquifer is absent in the northern parts of the Buckland Park site, where the Q4 directly overlies the T1b. This sub-aquifer consists of the upper fossiliferous sands and limestones of the Port Willunga Formation. It is a confined aquifer that often enables high-yielding wells with open-hole production intervals, making it suitable for ASR projects.

The thickness of the T1 aquifer is about 75 m in the south-eastern NAP PWA and thins out and disappears toward the north, 8 km north of the Gawler River. Drillhole logs taken from the Buckland Park area suggest it is quite thin in this region (<10m thick). The depth to the top of T1 aquifer is about 50 m near the Gawler River and gradually deepens toward the south-east. It is encountered at about 150 m below ground level just west of the Para Fault near Salisbury (Hodgkin, 2004).

Hydraulic conductivities in the T1b aquifer vary between 1 and 2 m/day for ten aquifer tests undertaken in the southern area of the NAP PWA. Aquifer tests have not been conducted in the T1 aquifer more than one kilometre north of Waterloo Corner. The transmissivity (T) and the storativity (S) of the T1 aquifer are reported to range between 60 and 150 m^2/d and 2.5×10^{-4} to 5×10^{-4} respectively (Gerges, 2001).

The T1 aquifer sits above the Munno Para Clay Member, which is a blue-grey, fossiliferous, highly plastic clay that acts as an aquitard. The Munno Para clay has an average thickness of around 10 metres and contains two thin layers of white to grey limestone.

3.1.4 T2 Aquifer

Throughout most of the Adelaide Plains Sub-basin, the T2 aquifer consists of well-cemented limestones of the lower Port Willunga Formation. Gerges (2001) recognised three sub-divisions of the T2 Aquifer in the NAP region based on lithological characteristics:

• T2A Sub-aquifer – mostly pale-grey to white well cemented limestone/sandstone.

• T2B Sub-aquifer – a pale yellow to orange brown limestone/sandstone, friable to moderately cemented and occasionally interbedded with highly calcareous fossiliferous sand.

• T2C Sub-aquifer – mainly interbedded sand and very friable limestone with occasional silt and clay.

In the metropolitan area, very few wells intersect the T2 Aquifer, whereas in the NAP PWA, the upper section of the T2 Aquifer forms the main groundwater supply.

The T2 aquifer varies in thickness from 20 m in the area near Kangaroo Flat to 100 m near Virginia, Milner, and along the southern boundary of the NAP PWA. At its shallowest point, the top of the T2 aquifer is 30 m below ground level along the central region of the northern boundary of the NAP PWA (Hodgkin, 2004). The depth to the top of the T2 aquifer deepens toward the south-east, where its deepest point within the NAP PWA is 210 m below ground level.

Aquifer tests have been conducted in the T2 aquifer in at least eight locations within the NAP PWA. These tests show that the hydraulic conductivity of the T2 aquifer typically ranges between 1 and 3 m/day. The transmissivity and the storativity of the T2 aquifer are reported to range from 80-125 m^2/d and 1.9 - 5.6×10^{-4} respectively (Gerges, 2001).

The T2 aquifer is underlain by the Ruwarung and Aldinga members of the Port Willunga Formation. These units are predominantly fine grained marine sediments that act as confining beds and have a combined thickness that varies between about 50-150 m.

3.1.5 T3 and T4 aquifers

The T3 aquifer is thin (5m in the NAP region) and formed by sandy sections of the Aldinga member or the underlying Chinamen Gully Formation. It is not significantly hydraulically connected to the T2 aquifer and is separated from the T4 aquifer by the thick confining beds of the Blanche Point Formation.

The T4 aquifer consists mainly of South Maslin Sands and sometimes North Maslin Sands. It is of uncertain thickness, but Gerges (2001) indicates it ranges from about 20-60 m thick south of the Little Parra River.

The T3 and T4 aquifers are saline. Levels as high as 80,000 mg/L TDS have been recorded in the deeper T4 aquifer (Hodgkin, 2004).

3.1.6 Significance of the Buckland Fault

While the exact position of the Buckland Fault is unknown, it is thought to occur near the western boundary of the site (Figure 5). The fault has caused the downward displacement of the geological strata on its western side of the order of 70 m, and it is believed that the Munno Para Clay Member has been eroded to the west of the fault, thus providing a direct connection between the T1 and T2 aquifer.

3.2 Groundwater levels

Depth to groundwater maps are provided for the Q4, T1 and T2 aquifers (Figures 5, 6 and 7 respectively). Extraction from the T2 aquifer has created a deep cone of depression that is centred between Virginia and the Gawler River (Figure 6) from which the majority of groundwater extraction occurs in this region.

Depth to groundwater is an important consideration for ASR schemes, because it has a large control on the potential volumes of water that can be stored within an aquifer. Injection into aquifers with quite shallow groundwater levels may lead to the creation of artesian or free-flowing conditions in nearby wells unless they are fitted with appropriate headworks. Indeed, prior to the extensive extraction of groundwater resources for irrigation, the main Tertiary aquifers were sufficiently pressurised to ensure most wells west of Port Wakefield Rd were artesian. At the Buckland Park site (Figures 5, 6 and 7), the groundwater levels are quite shallow (<10 m) in the Q4 and T1 aquifers and this may present a problem for ASR schemes. Groundwater levels are deeper in the T2 aquifer, although they are more shallow west of the Buckland Park fault near the coast.

Seasonal changes in groundwater levels are also relevant for ASR considerations as injection typically occurs in winter months (May-September) and extraction occurs in summer (October-April). Seasonal changes in groundwater levels within the T1 and T2 aquifers can be seen in Figures 6 and 7 with separate depth to water contours for March 2003 and September 2001. In the T1 aquifer within the project area, the depth to groundwater drops from a relatively flat 5 m in late winter to localised drawdown cones of around 10 m in late summer (presumably due to groundwater extraction). In the T2 aquifer, depth to groundwater contours have a similar shape in both late summer and winter, but the cone of depression (centred between Virginia and Gawler) drops from 30 m in late winter to 60 m in late summer. The impact of this drawdown decreases with distance from the centre of the cone. Thus in the western part of the project area groundwater levels drop only a few metres in summer, compared to 30m in the eastern part of the project area.

3.3 Groundwater flows

The general flow direction is towards the coast for the Q4 and T1 aquifers, but the cone of depression has reversed this flow path in the T2 aquifer and groundwater flows radially towards the centre of the depression in this aquifer. While hydraulic gradients are more pronounced in summer, the general direction of groundwater flow does not change seasonally.

3.4 Groundwater salinity

Regional groundwater salinity maps (from Hodgkin, 2004) are provided for the Q4, T1 and T2 aquifers respectively (Figures 8, 9, 10). There is a general trend of increasing salinity to the north west. Groundwater salinity may be affected by extraction with higher levels in the Q4 and T1 aquifers evident in the cone of depression, north of Virginia.

There is a big range in groundwater salinity across the NAP; it ranges from 1000 to > 5000 mg/L in the Q4 and T2 aquifer, from 1000 to > 4000 mg/L in the T1 aquifer. Within the project area, the salinity is generally lower and more favourable for irrigation in the T2 aquifer, where it is < 1000 mg/L. The salinity of the T1 aquifer is also attractive for ASR, being <1000 mg/L for large portion of the site.

4 PROJECT AREA ASR POTENTIAL

4.1 Local hydrogeology

4.1.1 Groundwater levels

Maps of the most recent groundwater levels (September 2007) in the Q4, T1 and T2 aquifer at Buckland Park were generated using data from monitoring wells (Figures 11, 12, 13). Data is lacking for the Q4 within the project area with few wells completed here, although it is likely that the depth to water is minimal (<5 m). The depth to water in the T1 is around 7 m. There are deeper water levels in the T2 (7-20 m), which are due to the cone of depression caused by groundwater extraction from this aquifer.

4.1.2 Groundwater salinity

Maps of the most recent groundwater salinities in the T1 and T2 aquifer are presented in Figures 14 and 15. While there are few data points within the site, nearby wells indicate salinities of around 1000-1500 mg/L in the T1 and <1000 mg/L in the T2. This confirms findings from regional datasets (Figures 9, 10) which identified both of these aquifers as having salinities favourable for ASR.

4.1.3 Aquifer yields

Recorded yields in the Q4, T1 and T2 aquifers are presented in Figure 16. The Q4 aquifer appears to have limited yields and hence injection rates. The T1 aquifer has yields that are generally high and favourable for ASR although there is some variation- there are two known cases of low yields (<2.5 L/s) within the proposed development area, whilst within 2 km of the north-west boundary there are several yields in excess of 15 L/s (equivalent to 473 ML/year if continuously pumped). Yields within the T2 aquifer are favourably high, typically in the range of 5 to >15 L/s.

4.1.4 Groundwater extraction

Groundwater extraction maps for 2006/07 are presented for the Q4, T1 and T2 aquifers (Figures 17, 18, 19). There is limited extraction from the Q4 aquifer, and there are relatively few surrounding users of the T1 aquifer, which mitigates the likelihood of ‘interfering’ with adjoining wells under artesian storage conditions for these aquifers. By contrast there are numerous existing T2 wells/users within 2 km of the project boundary. This may become a constraint on the potential amount of water that could be injected.

4.2 Aquifer properties

Table 4.2 presents a summary of the aquifer characteristics as determined from the available published data.

Table 1 Summary of Q4, T1 and T2 aquifer characteristics at Buckland Park

Aquifer	Q4	T1	T2
Description	Sandy, confined aquifer of limited thickness and extent at project site	Fossiliferous sands and limestones	Cemented limestones
Thickness	<20 m	10-35 m	80-100 m
Groundwater salinity	3,000-5,000 mg/L TDS	< 1,000 mg/L TDS	< 1,000 mg/L TDS
Transmissivity (T)		60 - 150 m^2/day	80 - 125 m^2/day
Aquifer yield	<2.5 L/s	<2.5 to > 15 L/s	5 to >15 L/s
Storativity (S)		2.5×10^{-4} to 5×10^{-4}	1.9×10^{-4} - 5.6×10^{-4}

4.3 Aquifer storage capacities

The capacity of an aquifer to store additional water is a function of the aquifer storativity and increased potentiometric head (available head). The additional volume for a confined aquifer is defined as:

$$\Delta V = (A \,.\, h \,.\, b \,.\, S_s)/1000$$

where ΔV = aquifer storage (ML), A = area (m^2), h = available head (m), b = aquifer thickness (m), and S_s = specific storage (m^{-1}).

The available heads and aquifer thicknesses were previously calculated at 50 m intervals across the Adelaide Plains by Hodgkin (2004) based on groundwater levels for Autumn 2003. This data was imported into ArcGIS software for spatial analysis and applied to the Buckland Park site. Groundwater levels at the end of the irrigation season (autumn) were used as this is where groundwater levels would normally be at the start of an injection period. Generating new contours and information based on more recent data was not within the scope of this project.

Aquifer storage capacities are presented in Table 2. An upper and a lower value of S_s (1.2×10^{-5} and 6×10^{-6}) were used to calculate an upper and lower estimate. The sub-artesian volume is the available storage if heads are to remain 2 m below ground level so as to avoid causing neighbouring wells screened in the same aquifer from overflowing during winter/spring. The calculated artesian volume assumes that groundwater levels/pressures can be raised above ground level up to 50% of the theoretical maximum (before physical rupture of the sediments overlying the aquifer).

If ASR is to remain sub-artesian at Buckland Park, there is limited capacity in the Q4 and T1 aquifers. The T2 aquifer, however, is able to store between 96 and 193 ML whilst maintaining groundwater levels at least 2 m below ground level. Additional storage is available if artesian conditions are allowed. This would entail additional infrastructure and costs to install the necessary headworks on the project wells and potentially on some wells in the site's vicinity.

The greater storage capacity of the T2 aquifer is primarily due to the significantly greater thickness compared to the Q4 and T1 at Buckland Park (see Figures 14, 15). However, the high sub-artesian storage in the T2 is partly a reflection of the site's position within the cone of depression caused by irrigators extracting water from the T2 over many years.

Table 2 Estimates of artesian and sub-artesian storages (ML) for the Q4, T1 and T2 aquifers at Buckland Park

Aquifer	Aquifer Storage Capacities, ΔV (ML)	
	Sub-artesian	Artesian
Q4		11 - 23
T1a	0.8 – 1.7	8.9 – 18
T1b	1.6 – 3.3	112 - 224
T2	97 – 193	525 - 1,050

These preliminary estimates assume that storage occurs only over the extent of the Buckland Park site to a fixed level. This is not realistic as injection into a well produces a conical shape of water level changes. Furthermore, local variations in aquifer hydraulic properties are likely to reduce or increase the potential storage. Similarly, groundwater salinity may reduce the potential recharge volume and area if there are areas of high ambient salinity. Such areas should be avoided to minimise losses associated with mixing with the native saline groundwater.

If however, the ASR scheme was to be operated whereby groundwater levels were some 50 to 70 m above ground surface (artesian), which is typical of ASR schemes operated by City of Salisbury and Playford, the storage capacity of the T2 and T1 aquifers beneath future urban areas shown in the Master plan, using the lower approximate of specific storage, is estimated to be around 500 ML/yr and 200 ML/yr respectively. The estimated volume that could potentially be stored at the Buckland Park site is consistent with the volumes that the City of Salisbury and Playford ASR schemes are proposing or currently injecting.

4.4 Summary

The Q4 aquifer at Buckland Park represents a relatively poor target for ASR. The aquifer is thin and may not cover the entire site, there is limited storage even under artesian conditions, groundwater salinity is relatively brackish (3,000-5,000 mg/L), and the unconsolidated sandy nature of the aquifer means injection wells may be less efficient and have more maintenance problems than holes completed in more stable formations. In brief, the Q4 aquifer has too many limitations and does not warrant further investigation unless a small ASR scheme (say <5 ML/yr) is envisaged.

The T1 aquifer represents a reasonable ASR target but is significantly less prospective than the underlying T2 aquifer. Groundwater salinity is favourable (<1000 mg/L), yields (injection rates) are generally high, and the limestones at the base of the T1 should support relatively efficient open hole well completions. However the sub-artesian storage is minimal within the site boundaries (2.4 - 5.0 ML) due to shallow depths to groundwater and relatively limited aquifer thickness.

Significantly greater storages can be obtained (112 - 224 ML) under artesian conditions. The general lack of surrounding users of the T1 supports the feasibility of such an approach.

The T2 aquifer represents the most attractive aquifer in terms of maximum storage capacity and probably also for the maximum injection rates as reflected by many high yielding bores within the site's vicinity. Under sub-artesian conditions, the storage capacity is in the order of 96-193 ML. It is significantly higher under artesian conditions (525-1,050 ML), although the practicality of artesian storage may be limited by the large number of existing T2 wells/users within two kilometres of the site. The salinity of the aquifer is also favourable (<1000 mg/L).

5 POTENTIAL IMPACTS OF ASR

5.1 Groundwater levels

Given that the T2 aquifer represents the most obvious target for ASR at Buckland Park, some preliminary calculations were performed to assess the impact of an ASR scheme on groundwater levels in the T2 aquifer. The water demand for such a scheme is unknown so the calculations were performed using storage volumes of 50 and 100 ML/year.

Well-Z, a 2-D groundwater model, was used to approximate head build-up due to injection into a single ASR well, located arbitrarily at the centre of the site. The calculations simulate the impact of injection into this well, assuming constant injection rates for a period of 100 days. Four different scenarios were modelled using this method; an ASR scheme of either 50 or 100 ML/year, using the either the highest or lowest values for transmissivity (T) and storativity (S) from the published ranges (Table 3). In essence, Scenario A simulates the maximum expected head build-up from an ASR scheme (with the highest pumping rates and the lowest T and S values), while Scenario D simulates the least expected head build-up due to lower pumping rates and the highest T and S values. Scenarios B and C are between these two extremes. Figures 20, 21, 22 and 23 depict Scenarios A, B, C and D respectively. The predicted head build-up is plotted over recent groundwater levels (September 2004), to show the likelihood of artesian conditions being encountered if these injection rates were used.

Table 3 Scenarios modelled to simulate the impact of ASR on groundwater levels at Buckland Park

Scenario	ASR Storage (ML/year)	Transmissivity (m^2/day)	Storage Coefficient
A	100	80	1.9×10^{-4}
B	100	125	5.6×10^{-4}
C	50	80	1.9×10^{-4}
D	50	125	5.6×10^{-4}

Scenario A (Figure 20) demonstrates that while the predicted head build-up is large near the injection well for a 100 ML/year ASR scheme with 50 m^2/d transmissivity, the impact on groundwater levels outside of the site is minimal (<3 m). Some artesian conditions may be encountered in the site under this scenario – the ground surface is 3 mAHD in the southwest corner and gradually rises to 11 mAHD in the northeast corner. However, these conditions would be confined to the immediate vicinity of the well and perhaps the southwest corner of the site where the ground surface is lower.

The impact of a 50 ML/year ASR scheme with higher transmissivity is much less, with groundwater levels rising by only about 1 m within the site (Scenario D, Figure 23). The impact of groundwater levels in Scenarios B and C (Figures 21, 22) are similar.

While the Well-Z calculations provide some indication of the possible impact of an ASR scheme, the results have some limitations due to the assumptions used by the software and the simplification of actual hydrogeological conditions. Well-Z is a 2-D model attempting to simulate a complex 3-D flow regime. It assumes a flat groundwater level as an input and does not consider any variations in groundwater level due to seasonality or extraction from neighbouring wells. Therefore the results should be viewed as qualitative rather than quantitative.

5.2 Groundwater quality

Assuming that urban runoff/stormwater is to be harvested for injection into an ASR scheme at Buckland Park, this water would need to be treated either mechanically or via a wetland. This is to ensure pollutants do not enter the aquifer and adversely affect down-gradient users, such as those pumping from the T2 near Virginia. Pollutants typically associated with urban runoff include sediment, heavy metals, nutrients, bacteria, oil, grease, toxic chemicals, pesticides and other contaminants. The source water must meet EPA guidelines (see next section) before injection can occur. Injected water should contain very low levels of suspended solids to prevent aquifer clogging during injection.

In terms of salinity, the impact of ASR on groundwater quality can often be favourable with the injection of fresh urban runoff lowering the salinity of groundwater and producing a buffer zone of low salinity water near the injection well. The size and behaviour of this buffer zone is affected by the ratio of injected to recovered volumes, the timing of injection/recovery, and the ratio of the salinity of the injection water to the native groundwater. Managing the buffer zone is important if certain criteria for recovered groundwater quality are to be met.

6 ASR MANAGEMENT ISSUES

6.1 Legislation

Given the size of the site and an assumed intent to harvest urban runoff from over 1 ha, any ASR scheme at Buckland Park would have to be licensed by the EPA. The operation of an aquifer recharge scheme is subject to the *Environment Protection Act 1993*, which is concerned with the quality of water stored in and recovered from aquifers. Aquifer recharge must comply with the *Environment Protection Act 1993* (the Act) and the *Environment Protection (Water Quality) Policy 2003* (EPP Water Quality) administered by the SA EPA. The SA EPA may issue an authorisation in the form of a licence to operate an ASR scheme once development approval has been granted from the local planning authority (if required). Under section 47(2) of the Environment Protection Act, the EPA must grant an authorisation if development approval has been given. Under the referral system in the Development Act, the EPA may direct that the development be refused if it is not satisfied with the assessed environmental impact. To be granted a licence, the proponent will need to demonstrate effective Managed Aquifer Recharge (MAR) operational skills and that the MAR proposal will not cause environmental harm. When the EPA is satisfied that the proposal will allow compliance with the Act, it may grant a licence, to which will be attached operational and reporting conditions.

A DWLBC permit would be required for injection (or drainage) of water into a well and a DWLBC license for ‘recharge allocation’ would also be required to enable recovery of the injected water.

The Adelaide and Mt Lofty NRM Board plays a key role in the development and operation of ASR. The site is within the Northern Adelaide Plains Prescribed Well Area, which is governed by the terms of a Water Allocation Plan (WAP). The WAP is being revised, but currently applies several ASR specific rules; these include 1) the recharge allocation will generally be no more than 80% of the injected water volume; 2) unused recharge entitlements can be carried over for up to 5 years; and 3) water cannot be allocated where doing so will adversely affect the groundwater resource, the land, or nearby groundwater users (wells).

The ASR approvals process is currently under review and all future ASR activities may be administered through DWLBC who will, where required, refer the application to the EPA for comment.

Before the current WAP review for the NAP PWA is concluded, clarification should be sought from DWLBC concerning ASR within the project area so that any appropriate amendments to the WAP can be considered.

6.2 Monitoring requirements

Regulatory requirements, as stipulated by the NRMB, for establishing and operating an ASR scheme in the Northern Adelaide Plains are still evolving. Recent discussion ideas for ASR (Adelaide and Mount Lofty Ranges NRM Board, 2006) suggest that the following monitoring requirements may become implemented in the future:

- Water quality testing before operation commences: proposed policy would require both the source water and the existing groundwater to be tested. The source water would need to meet the guidelines of the EPA Water Quality Policy.

- Ongoing water quality testing: the proposed policy would require groundwater to be sampled once a year. Sampling requirements of the source water would depend on source of the water and the volume being recharged. For example, roof runoff would not require on-going monitoring if early testing showed it to be clean, while other urban runoff would require on-going monitoring (once a year for <20 ML/year injected, more than once a year if >20 ML/year).

- Additional testing and notification to domestic groundwater users within a 1 km radius of the ASR well: domestic users within a 1 km radius of the proposed ASR site will have to be notified and additional testing may be required if one or more domestic users are located within this zone.

For groundwater levels, each ASR injection well should have a dedicated T2 monitoring well close enough to pump-test the injection well to obtain accurate hydraulic properties (T and S) and to act as an ongoing monitoring well. Any suitable existing T2 monitoring wells should also be used to monitor the impact of the ASR scheme.

6.3 Risks

There are numerous complexities that need to be investigated further prior to establishing an ASR scheme to service the Buckland Park proposal. There are differing levels of risk and management required, largely depending on the source water for the ASR scheme. For example, should the ASR scheme ever plan to inject reclaimed water into the aquifer, then more intensive investigations and rigorous on-going monitoring would be required. The method of delivery to users will also influence the final design and number of injection/extraction wells. The following key risks have been identified and need to be evaluated further in the context of any proposed ASR schemes at Buckland Park:

- loss of recovery volume through mixing if the injection well field extends into the more brackish/saline parts of the aquifer;
- poor recovery efficiency if the injected water moves outside the capture radius of the recovery well;
- impacts to existing groundwater users of the Tertiary aquifers;
- groundwater users who may be adversely affected by the ASR scheme;
- setting of aquifer environmental values for the aquifer that may preclude the use of stormwater or reclaimed water as a source for injection;
- third party users that may use groundwater for potable purposes which may preclude reclaimed wastewater or stormwater as a potential source of water for injection; and
- in the absence of the Munno Para Clay there is greater potential for upward leakage from the Tertiary aquifers which may impact on the shallow watertable.

6.4 Impacts associated with operating under artesian conditions

If the ASR scheme is to be operated under pressurised (artesian) conditions potential impacts may include:

- Extraction from the ASR well introduces a new demand into the area which can result in well interference between the ASR well existing users. This is likely to occur if the existing user's wells are completed in the upper most section of the aquifer and the ASR well is completed over a deeper section.
- During injection existing operational wells which are not appropriately sealed around the headworks may begin to flow.
- Potential failure of the overlying confining bed if injection pressures are too high.
- Poor performance of pumps in existing users wells because of a greater depth of submergence at the start of the irrigation season.

The ASR schemes operated by the Cities of Salisbury and Playford also have the potential to impact on existing users (REM 2008) where pressure injection results in groundwater levels rising some 50 to 70 m above ground surface.

To mitigate this potential issue the City of Salisbury has actively sought to purchase water allocation licences from existing users within close proximity to their operational ASR schemes and decommission those wells.

6.4.1 Existing groundwater users

Modelling carried out for the Cities of Salisbury, Playford and Tea Tree Gully predicted that the impacts of operating ASR schemes with a 50 to 70 m pressure head are likely to cause most wells within a 1.5 to 2 km radius from the injection wells to also become artesian during winter. Figure 24 and Figure 25 illustrate the location of existing licensed groundwater users who abstract irrigation supplies from the T2 and T1 aquifer respectively within the Buckland Park/Virginia area.

If the T2 aquifer is the primary target, and 500 ML or more is the proposed injection volume, up to 287 existing users within a 3 km radius from Buckland Park (Figure 24) could potentially be impacted if an ASR scheme is operated under artesian conditions. Well headworks would need to be modified and sealed to prevent wells flowing during winter at an estimated cost of between $1,000 and $2,500 per well depending on the existing headworks configuration.

It should be noted that these predictions are dependent on the local aquifer hydraulic properties. The potential for artesian conditions and areal extent may be less than predicted because as there is the potential that the large cone of depression centred on Virginia caused by irrigators extracting water from the T2 over many years may buffer the impacts. This would need to be confirmed by further investigations following drilling and testing at the Buckland Park site.

7 KEY FINDINGS AND RECOMMENDATIONS

7.1 Key findings

Based on a review of the local hydrogeology there is strong potential for a successful ASR scheme with around 50+ ML/yr to be developed at Buckland Park within the T2 aquifer. The T2 aquifer represents the most attractive aquifer in terms of maximum storage capacity and probably also for maximum injection rates. Preliminary calculations suggest an ASR scheme in the T2 would have minimal impact on groundwater levels in the area surrounding the proposed development.

Salisbury and Playford Councils are proposing ASR schemes with potential storage volumes of the order of 200 to 500 ML/yr. Preliminary evaluations (REM, 2008) have indicated that injection at this rate has the potential to cause aquifers to become artesian within 1.5 to 2.0 kilometres of the injection well. The estimation of a 50+ ML/yr scheme for the Buckland Park site is conservative and will maintain sub-artesian conditions at the site. Operating at artesian conditions will allow greater volumes of water to be stored (potentially greater than 200 ML/yr) but impacts to other groundwater users and shallow watertables will need to be considered in more detail.

There may also be opportunities to operate an ASR scheme across a footprint that is larger than the Buckland Park site, thereby increasing the storage capacity. This initiative would require discussions with City of Playford.

If the ASR scheme targets the T1 aquifer and operated under artesian conditions (50 to 70 m head above ground surface) up to 44 existing users (Figure 25) could potentially be impacted and their wells would need to be sealed.

Injection of greater than 500 ML/year into the T2 aquifer may potentially cause a large number (up to 287) of existing users wells to become artesian during winter. Modifications to seal those wells that may potentially be impacted would be required. Cost to modify the headworks is estimated to be between $1,000 and $2,500 per well depending on the configuration of the existing headworks.

The T1 aquifer may be a more prospective target at the Buckland Park site because there are only 44 existing users within a 3 km radius and therefore costs associated with modifying well headworks to prevent them from flowing during injection is likely to be considerably less than for the number of existing T2 users.

Conjunctive use of the T1 and T2 aquifers could nominally achieve a total injection volume of approximately 400 ML/yr with the smallest number of existing users impacted if artesian conditions result.

The actual volumes of injection into the T1 and T2 aquifer are contingent on the physical aquifer hydraulic properties at the site which should be confirmed through a drilling and testing program.

7.2 Recommendations

To proceed with an ASR scheme at Buckland Park, the following recommendations are made:

- Determine the likely water demand and urban runoff capture volumes. (If water demand is low, use of the T1 aquifer should be re-considered).

- A further constraint to implementing ASR on the Buckland Park site is the potential to store the captured storm water. Two options are proposed:

    - Pipe captured storm water to the City of Playford ASR site at Munno Para/Andrews Farm, a distance of approximately 10 km. In summer, using the same pipeline, deliver the water back to Buckland Park.

    - Identify potential areas where storages could be constructed in closer proximity to the Buckland Park site (In the early stages storm water could be managed on-site.

  It is recommend that a cost benefit analysis be carried out to identify which of the above two options are the most economically viable.

- Investigate the potential for harvesting stream runoff from the Gawler River if urban runoff supply is less than demand.

- Discuss preliminary ASR plans with DWLBC and the Adelaide and Mount Lofty Ranges NRM Board for feedback in relation to any ASR requirements currently being considered within the WAP revision process.

- If ASR investigations are to progress, then a field-based second stage program is necessary, which should include:

    - a local groundwater use survey;

    - installation of test ASR injection/recovery and monitoring wells;

    - aquifer discharge test(s) utilising the injection/recovery well to confirm aquifer hydraulic properties, and to provide an indication of the potential injection/recovery performance;

    - analysis of groundwater quality from the target aquifer;

    - an injection and recovery trial (if the site proves feasible) to evaluate the operational performance and potential recovery efficiency of the scheme; and

    - development of final concept design and cost.

- If operating the ASR scheme under artesian conditions is likely then ASR investigations should also include:

- Construction of a production and monitoring well to quantify aquifer properties of the T2 aquifer through aquifer discharge testing at the Buckland Park site.
- Construction of a production and monitoring well to quantify aquifer properties of the T1 aquifer through aquifer discharge testing at the Buckland Park site.
- Preliminary injection and recovery testing to quantify aquifer response during injection and recovery.
- Source water and groundwater sampling and water quality analysis.
- Basic groundwater modelling to quantify the potential impacts to third parties supported by the information obtained from the construction and testing of the investigation wells in the T1 and T2 aquifers.
- Modelling to predict if the T1 and T2 aquifers could be used simultaneously and the maximum injection volumes that could be achieved that would minimise impacts to existing users. Approval would be sought from the Adelaide and Mount Lofty Ranges Natural Resources Management Board to use the model developed by REM for this testing.
- Review options for conjunctive injection into the T1 and T2 aquifers following confirmation of the aquifer hydraulic properties through drilling and testing at the Buckland Park site.
- Risk assessment aimed at evaluating nay remaining uncertainty that may be associated with the ASR scheme including the regulatory framework.
- Identification of preventative measures preventative measures (e.g. operational procedures, critical control points and contingency plans) that may be required to mitigate any residual risk.

8 REFERENCES

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9 STATEMENT OF LIMITATIONS

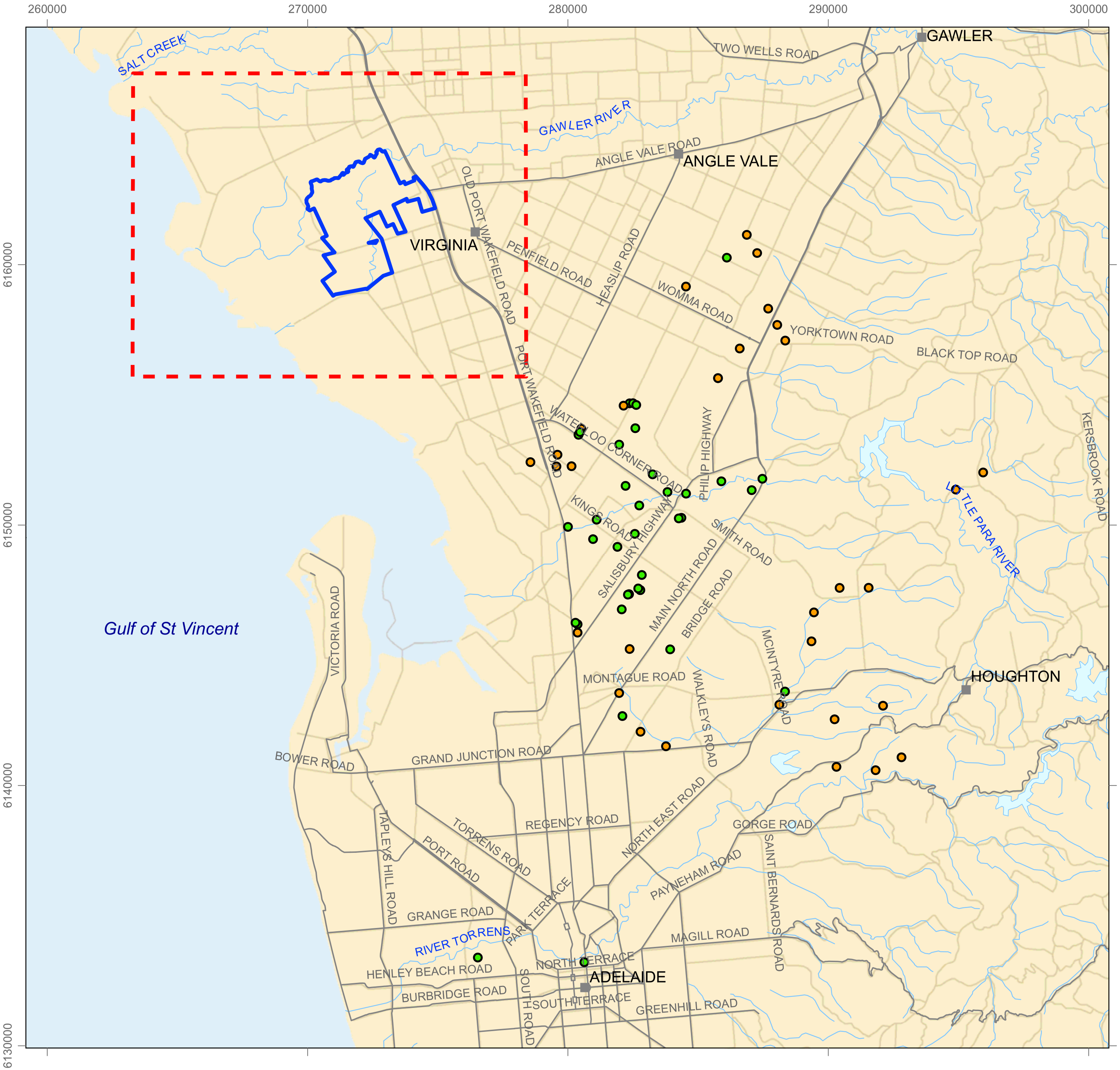
The services performed by REM have been conducted in a manner consistent with the level of quality and skills generally exercised by members of its profession and consulting practice

This report is solely for the use of Walker Corporation Pty Ltd and may not contain sufficient information for purposes of other parties or for other uses. Any reliance on this report by third parties shall be at such parties' sole risk.

The information in this report is considered to be accurate with respect to information provided and conditions encountered at the site at the time of investigation.

REM has used the methodology and sources of information outlined within this report and have made no independent verification of this information beyond the agreed scope of works. REM assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that the information provided to REM was false.

Figures



Legend

- Placenames
- Site
- Major Roads
- Watercourses
- Reservoirs
- Study Area

ASR Wells

- Operating
- Planned

0 5 10 km

Buckland Park ASR Potential

Project Location and Existing ASR Wells

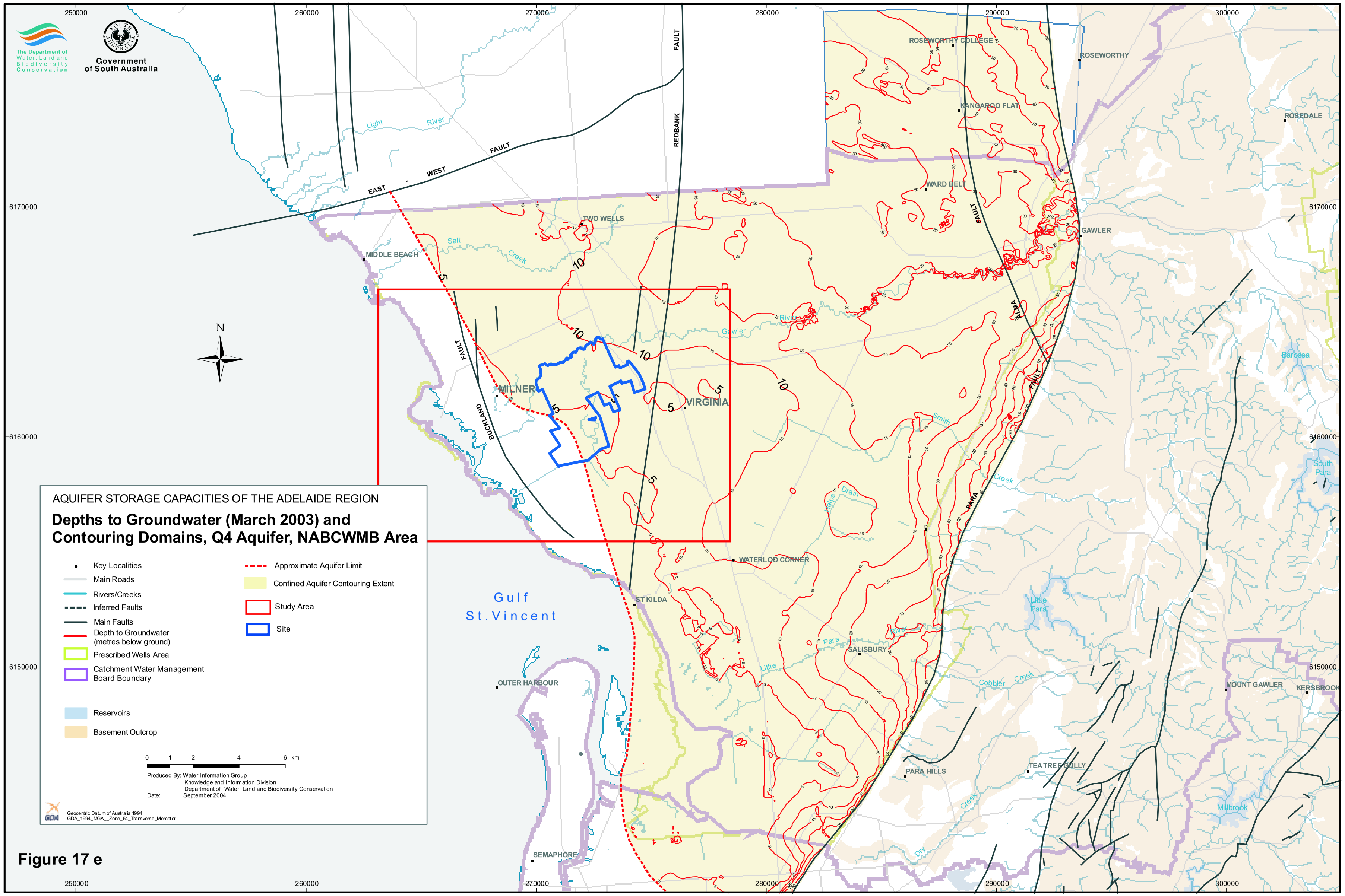
rem

Figure

1

December-2007

R:\GIS\Walker Corporation (GM)\(01) Buckland Park\Maps\Development\Existing ASR Bores.mxd



BUCKLAND PARK ASR POTENTIAL

Depth to groundwater- Q4 Aquifer

FIGURE 5

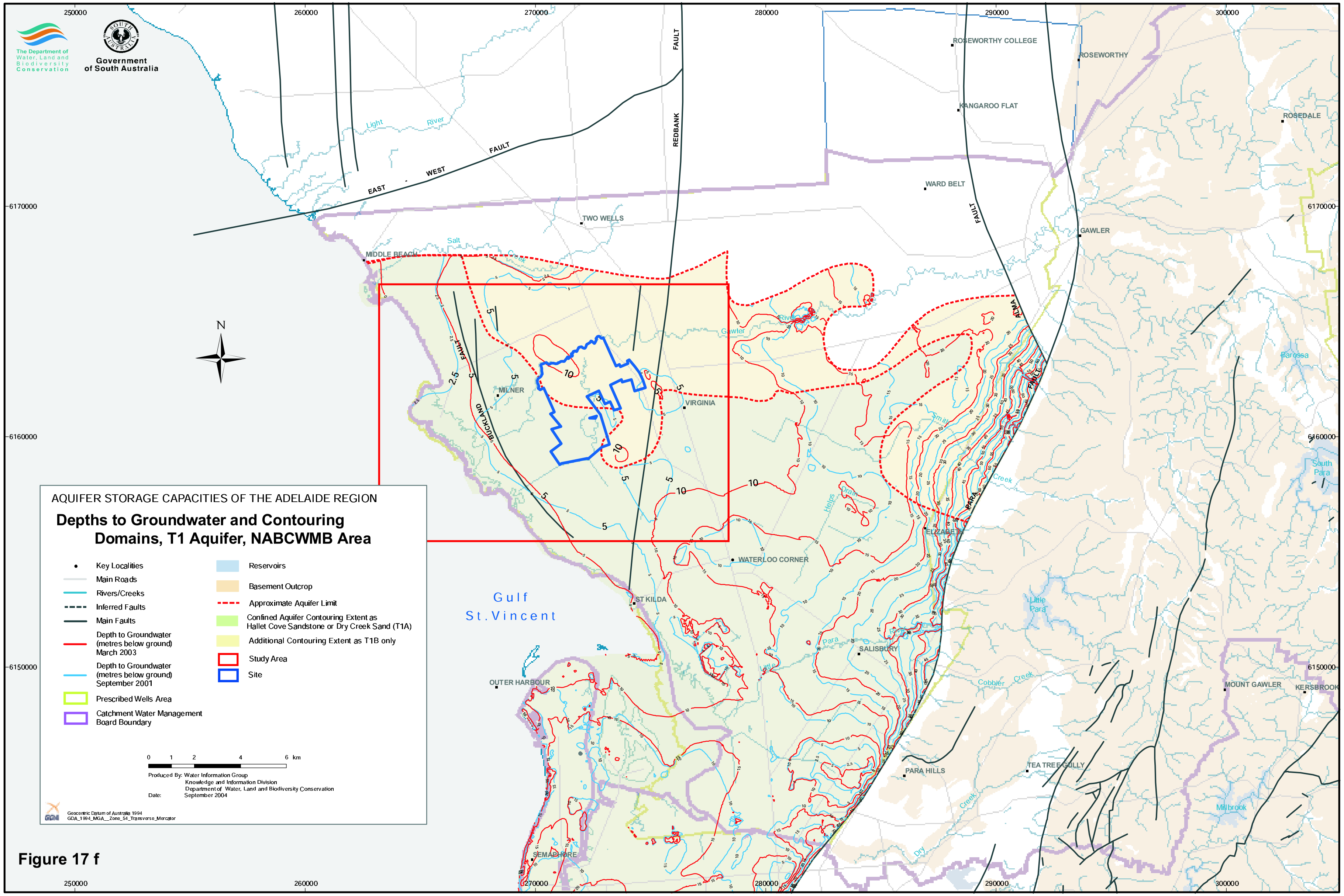


Figure 17 f

After Hodgkin (2004)

BUCKLAND PARK ASR POTENTIAL

Depth to groundwater- T1 Aquifer

FIGURE 6

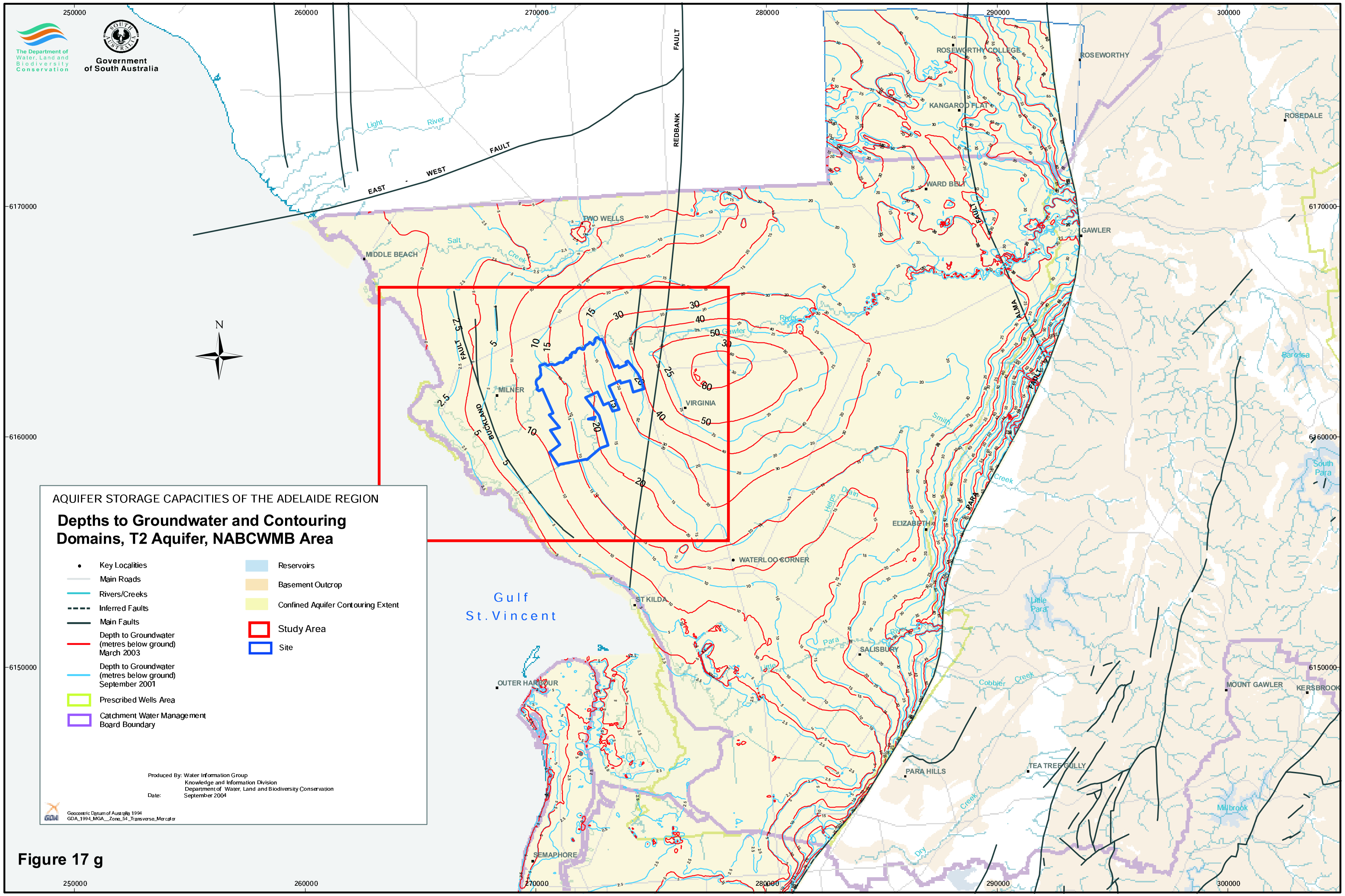


Figure 17 g

After Hodgkin (2004)

BUCKLAND PARK ASR POTENTIAL
Depth to groundwater- T2 Aquifer

FIGURE
7

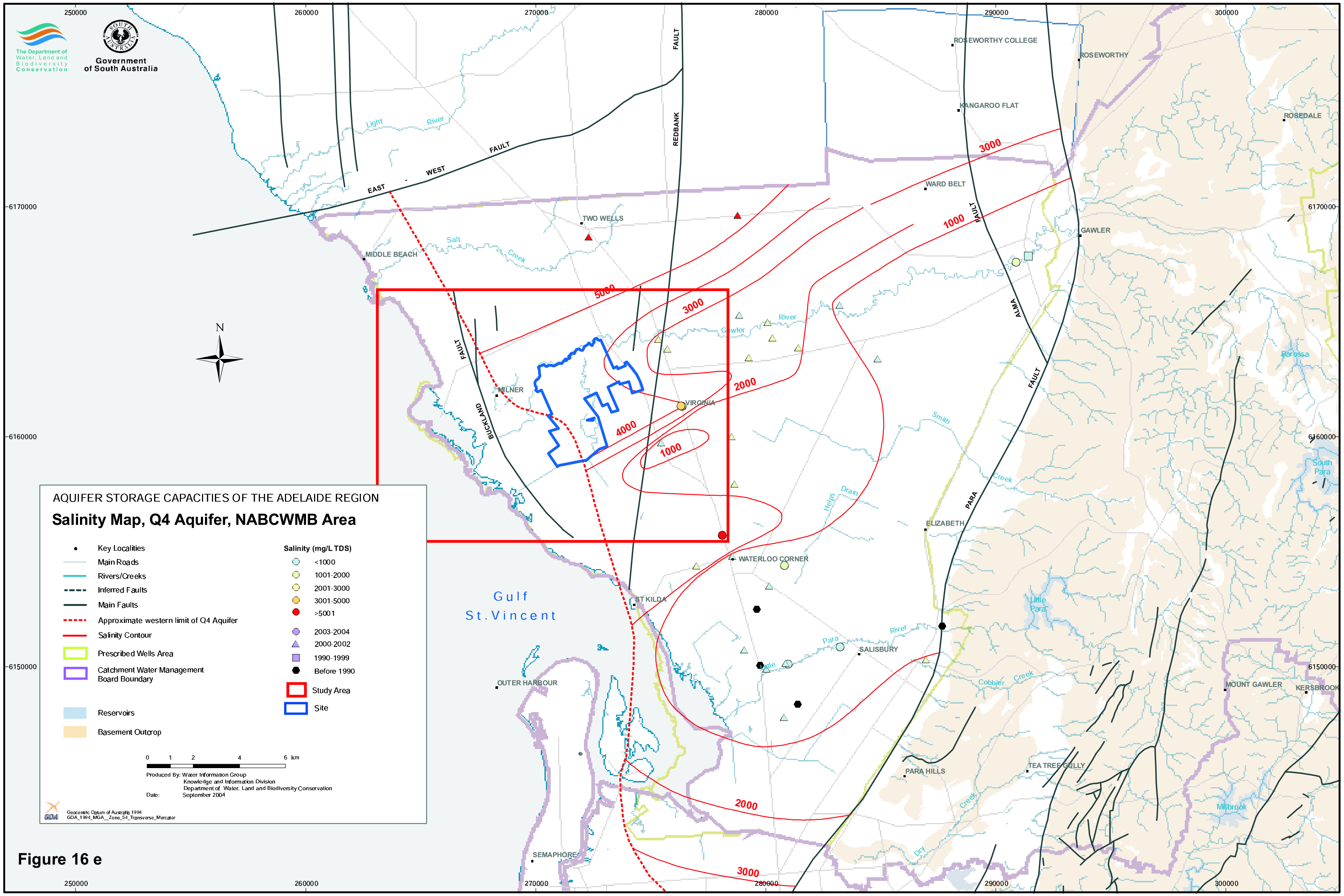


Figure 16 e

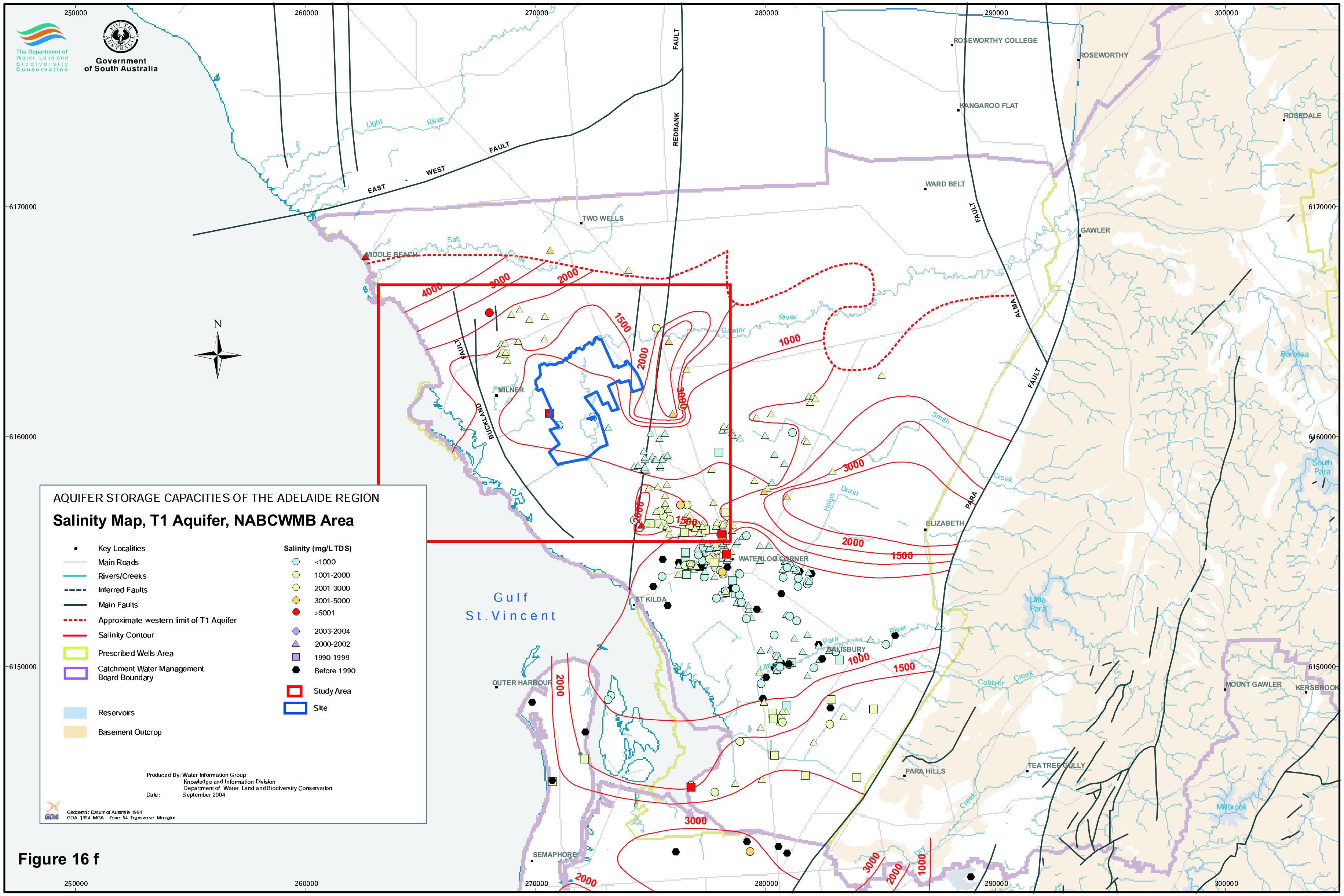
R:\Walker Corporation (GM)\(01) Buckland Park\Maps\ASR Evaluation\Maps from Hodgkin_2004\TDS_Q4.cdr

After Hodgkin (2004)

rem

BUCKLAND PARK ASR POTENTIAL
Groundwater Salinity- Q4 Aquifer

FIGURE
8



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After Hodgkin (2004)

rem

BUCKLAND PARK ASR POTENTIAL

Groundwater Salinity- T1 Aquifer

FIGURE 9

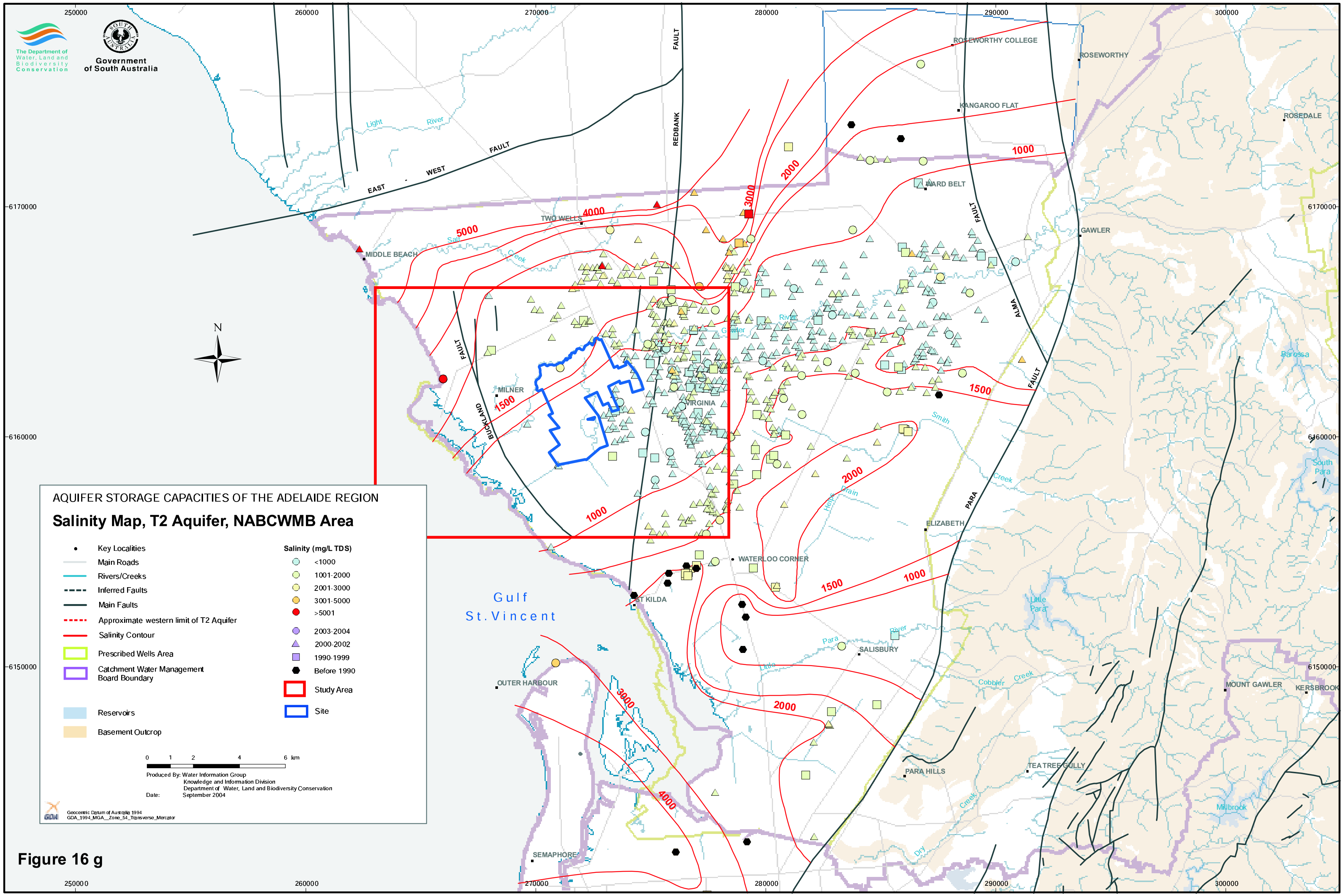

Figure 16 g

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After Hodgkin (2004)

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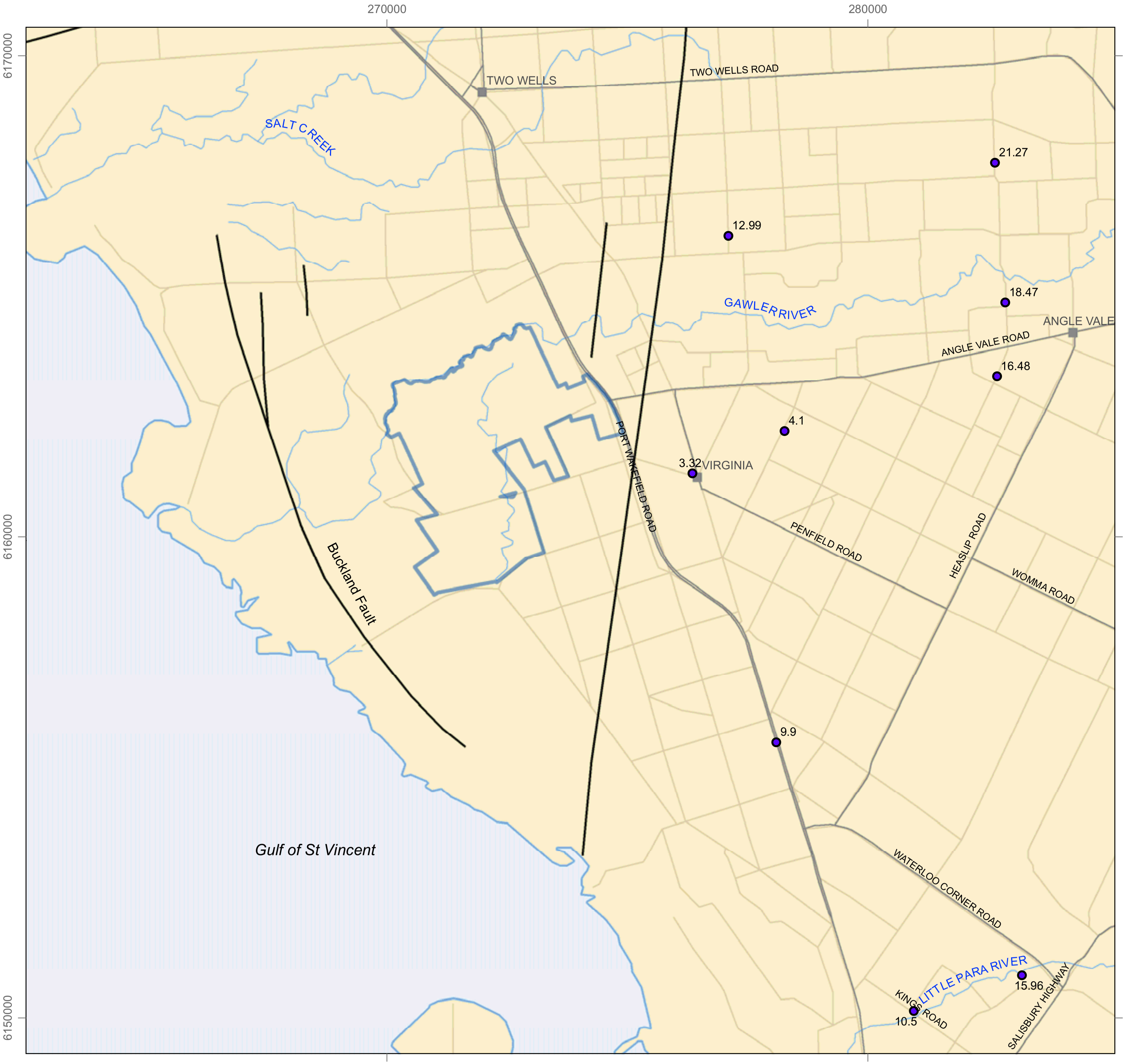
BUCKLAND PARK ASR POTENTIAL
Groundwater Salinity- T2 Aquifer

FIGURE 10



Legend

- SWL in the Q4 Aquifer (mbgl)
- Site
- Major roads
- Watercourses
- Placenames

0 3 6 km

Buckland Park ASR Potential

SWL in the Q4 Aquifer - September 2007

Figure 11

December-2007

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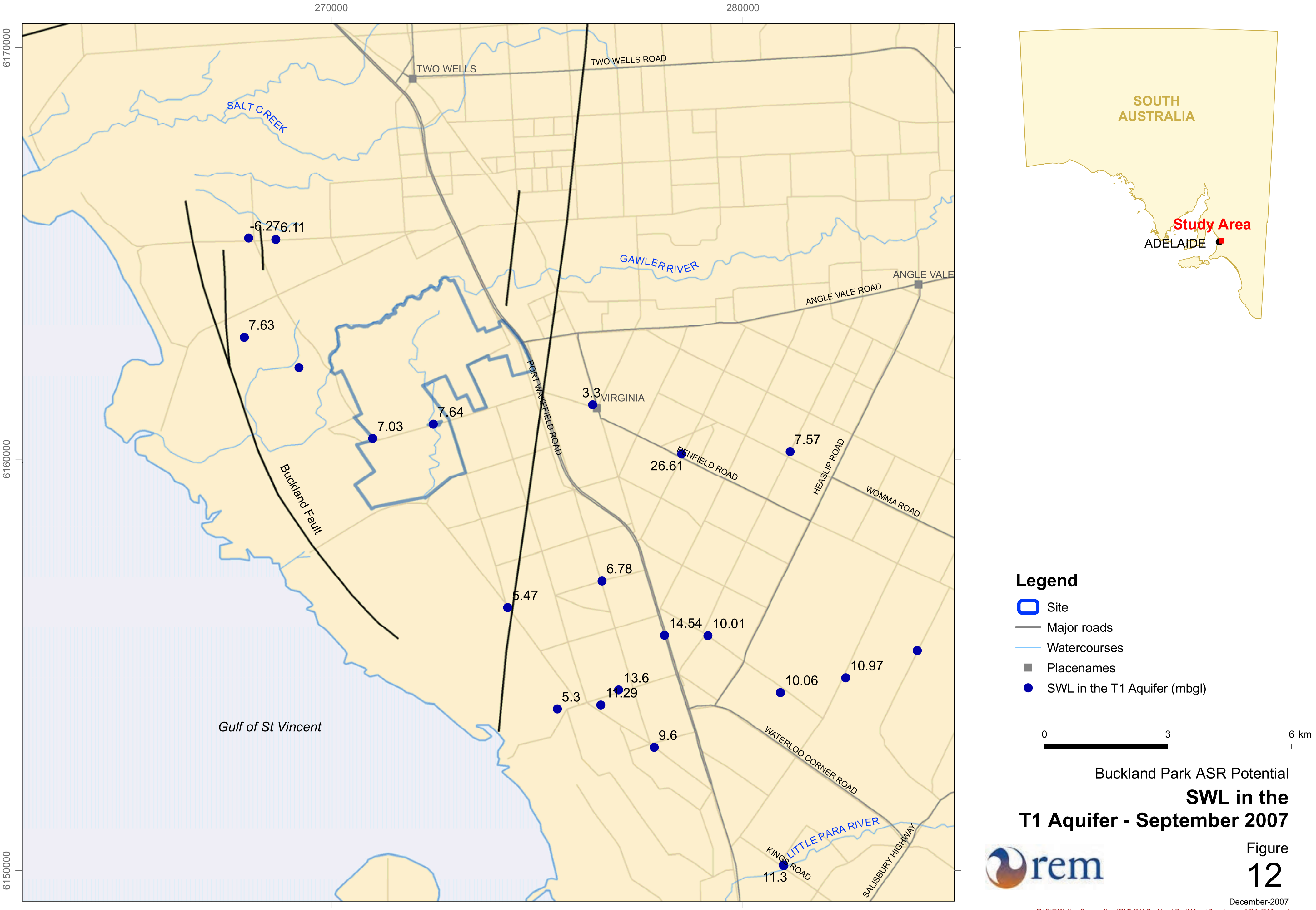

Buckland Park ASR Potential

SWL in the T1 Aquifer - September 2007

Figure 12

December-2007

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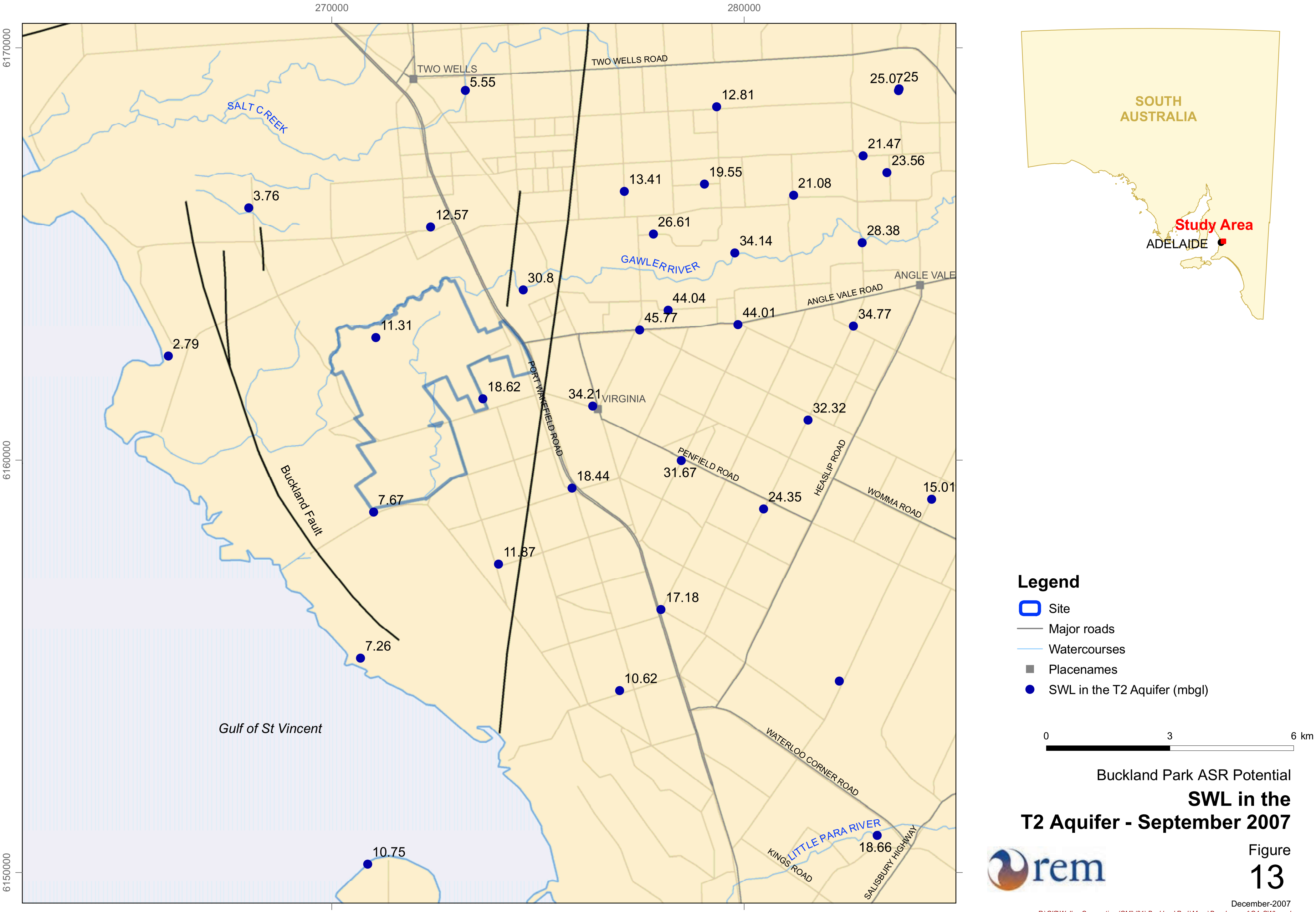


Legend

- Site
- Major roads
- Watercourses
- Placenames
- SWL in the T2 Aquifer (mbgl)

0 3 6 km

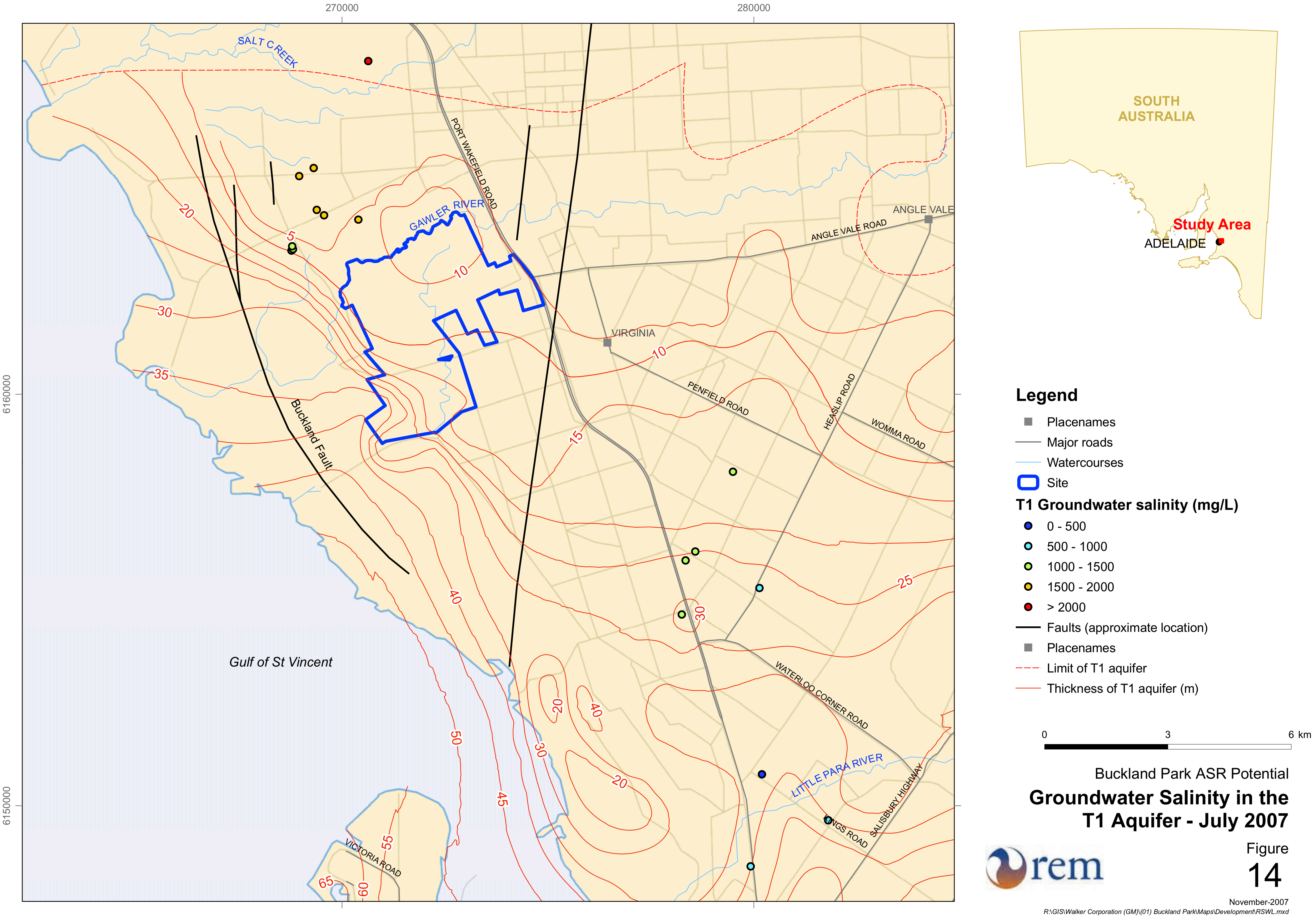
Buckland Park ASR Potential

SWL in the T2 Aquifer - September 2007

Figure 13

December-2007

R:\GIS\Walker Corporation (GM)\(01) Buckland Park\Maps\Development\Q4_SWL.mxd



Buckland Park ASR Potential

Groundwater Salinity in the T1 Aquifer - July 2007

Figure 14

November-2007

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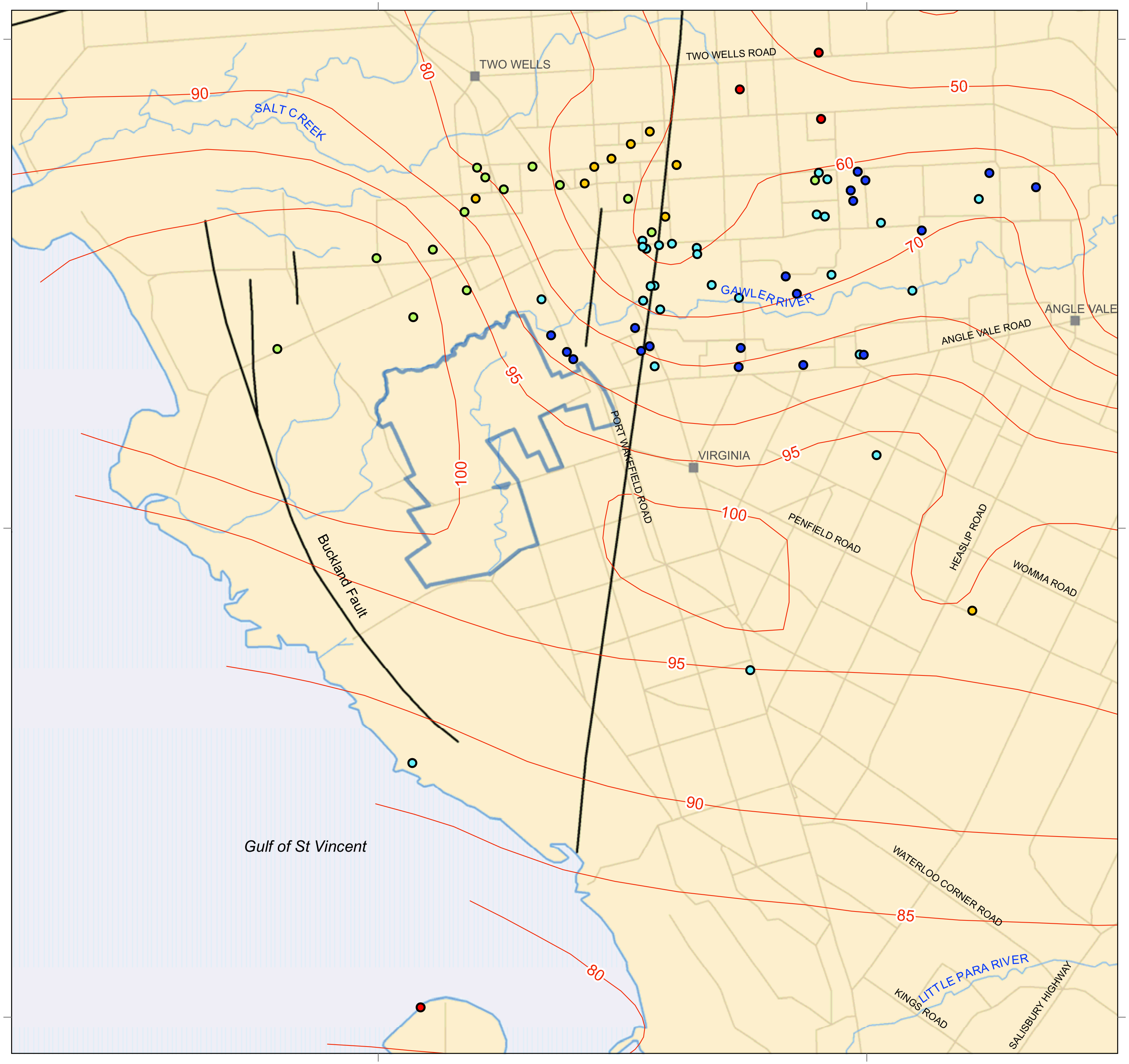

Legend

- Placenames
- Major roads
- Watercourses
- Site
- Faults (approximate location)

T2 groundwater salinity (mg/L)

- 0 - 1000
- 1000 - 1500
- 1500 - 2000
- 2000 - 3000
- > 3000
- Thickness of T2 aquifer (m)

0 3 6 km

Buckland Park ASR Potential

Groundwater Salinity in the T2 Aquifer - July 2007

rem

Figure 15

November-2007

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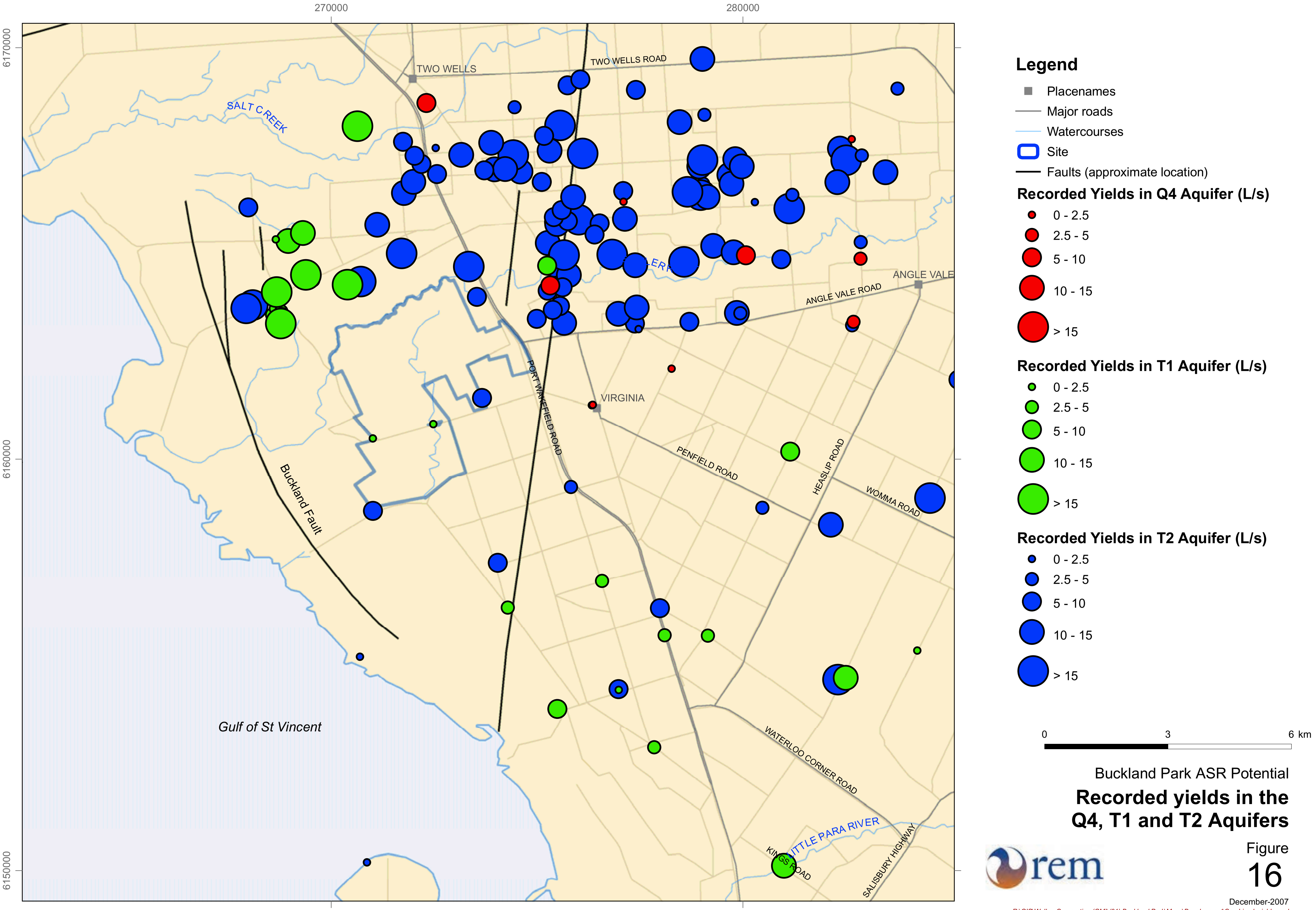

Buckland Park ASR Potential

Recorded yields in the Q4, T1 and T2 Aquifers

rem

Figure 16

December-2007

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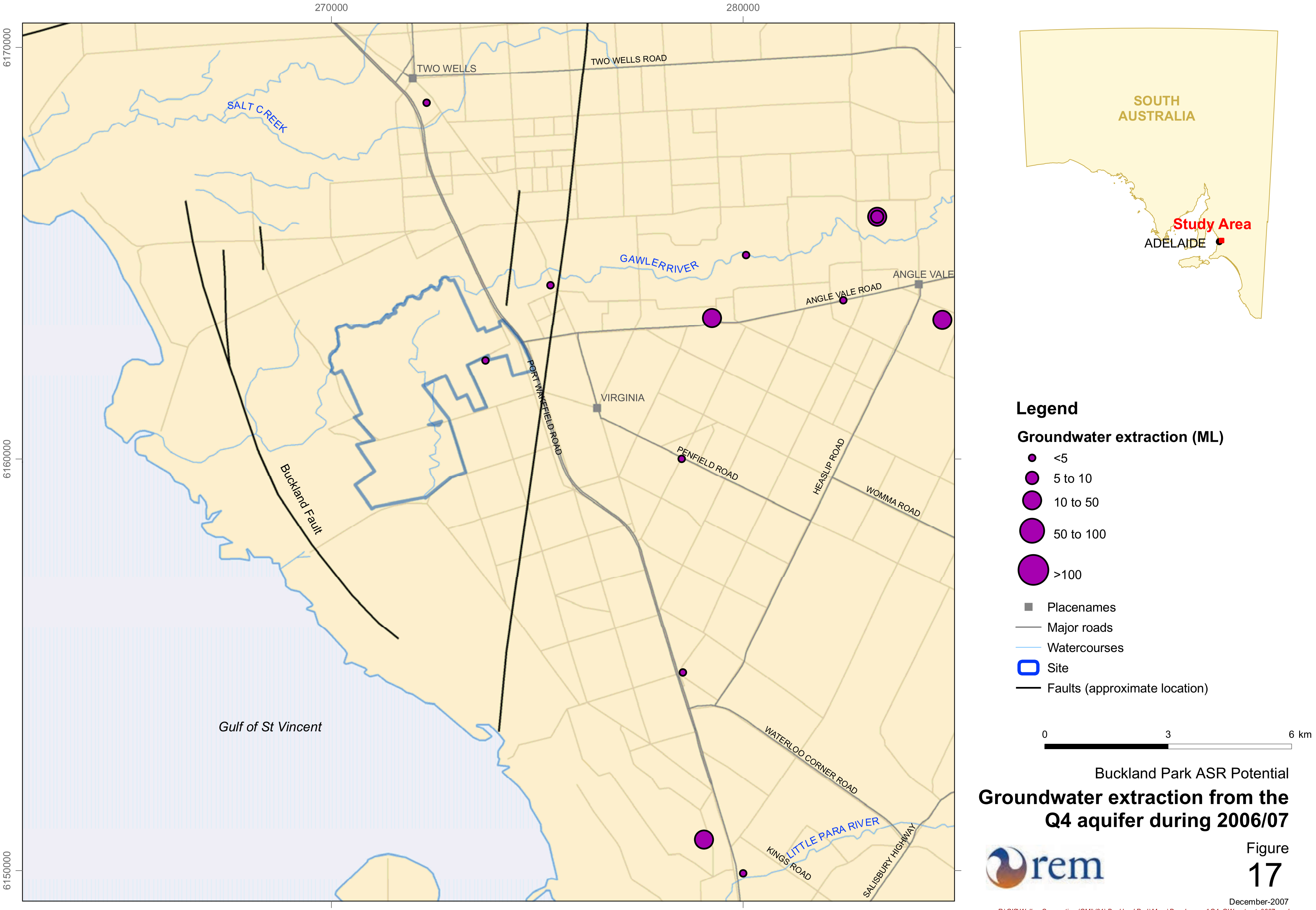

Buckland Park ASR Potential

Groundwater extraction from the Q4 aquifer during 2006/07

rem

Figure 17

December-2007

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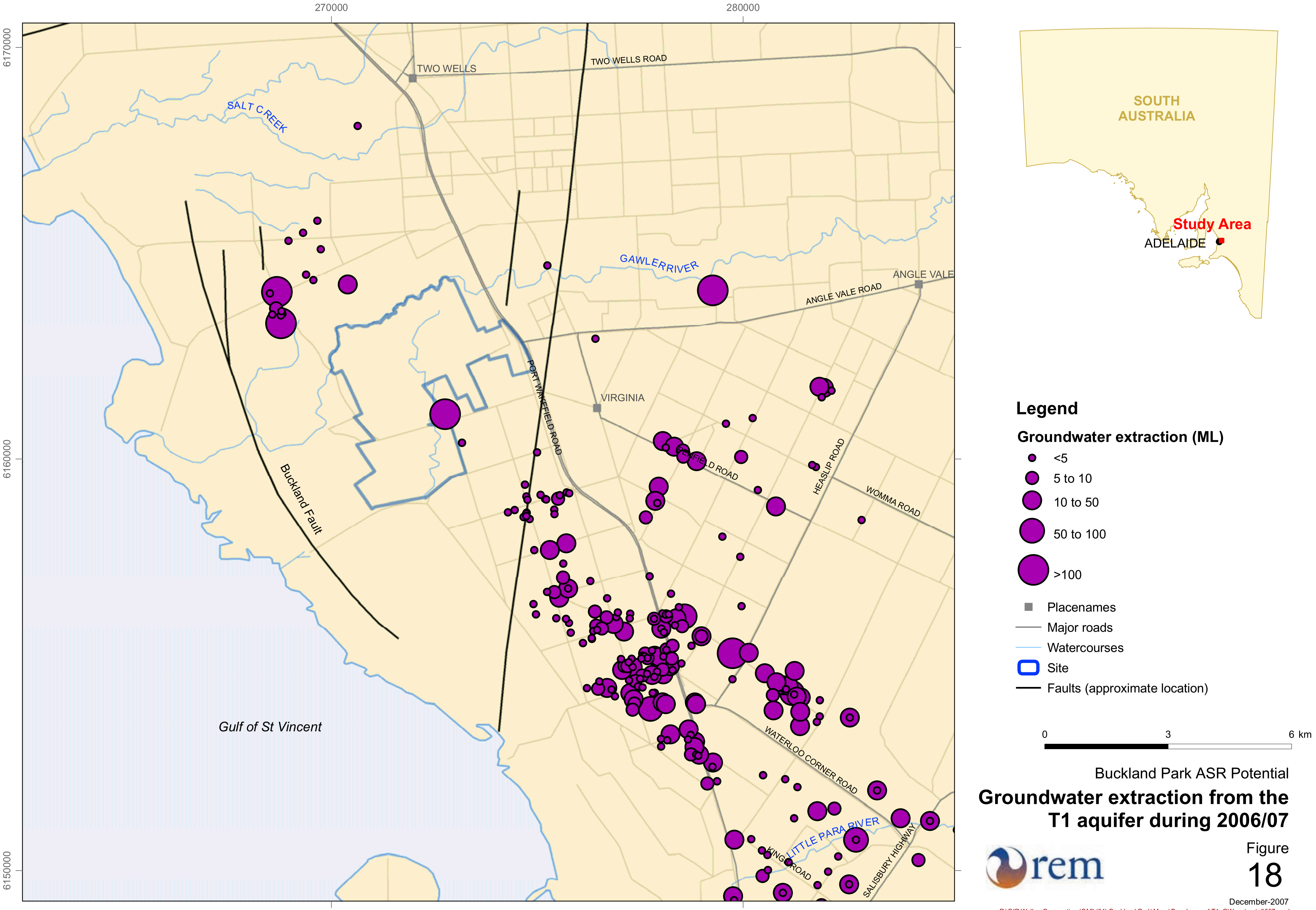

Legend

Groundwater extraction (ML)

- <5
- 5 to 10
- 10 to 50
- 50 to 100
- >100
- Placenames
- Major roads
- Watercourses
- Site
- Faults (approximate location)

0 3 6 km

Buckland Park ASR Potential

Groundwater extraction from the T1 aquifer during 2006/07

rem

Figure 18

December-2007

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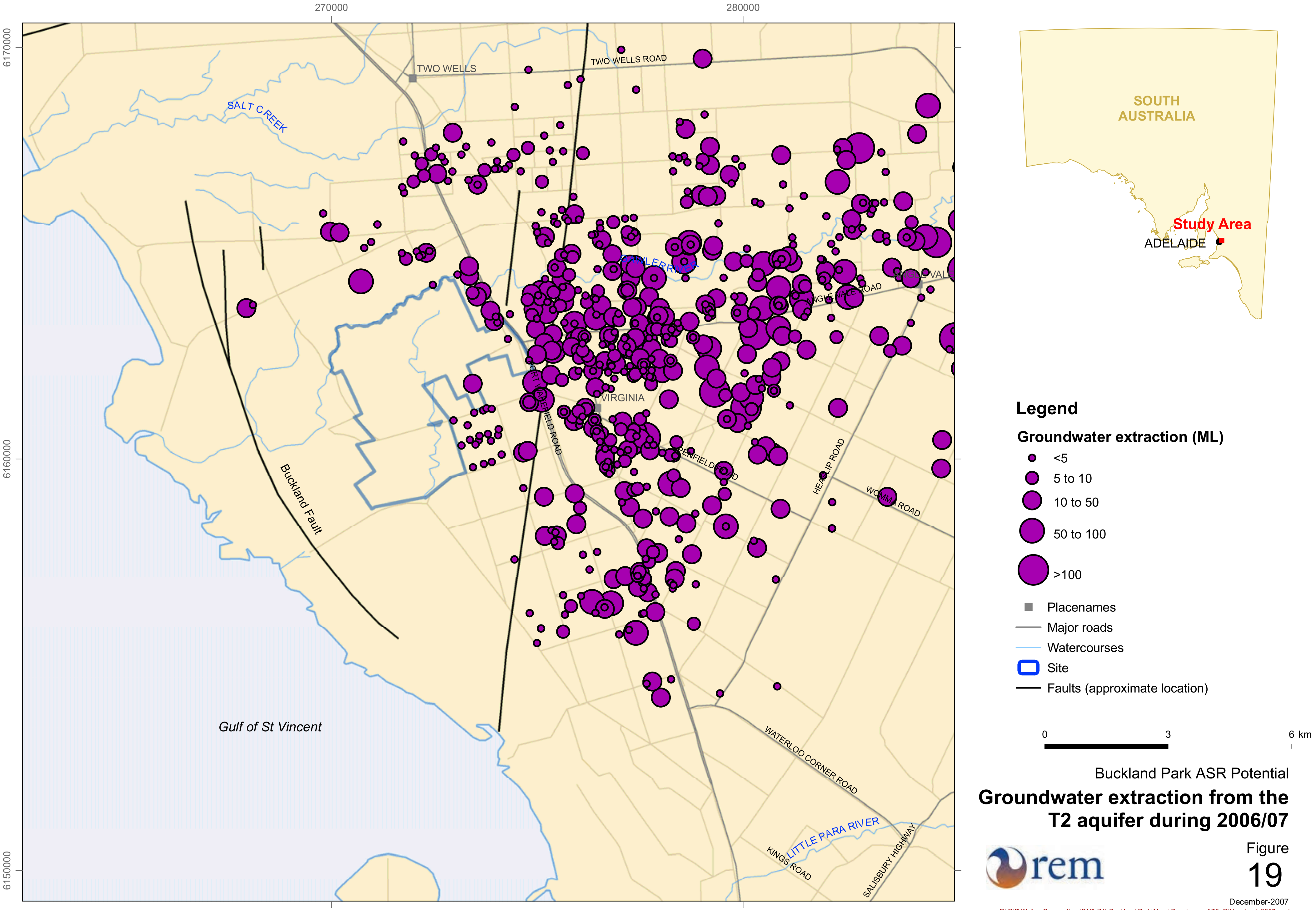

Buckland Park ASR Potential

Groundwater extraction from the T2 aquifer during 2006/07

Figure 19

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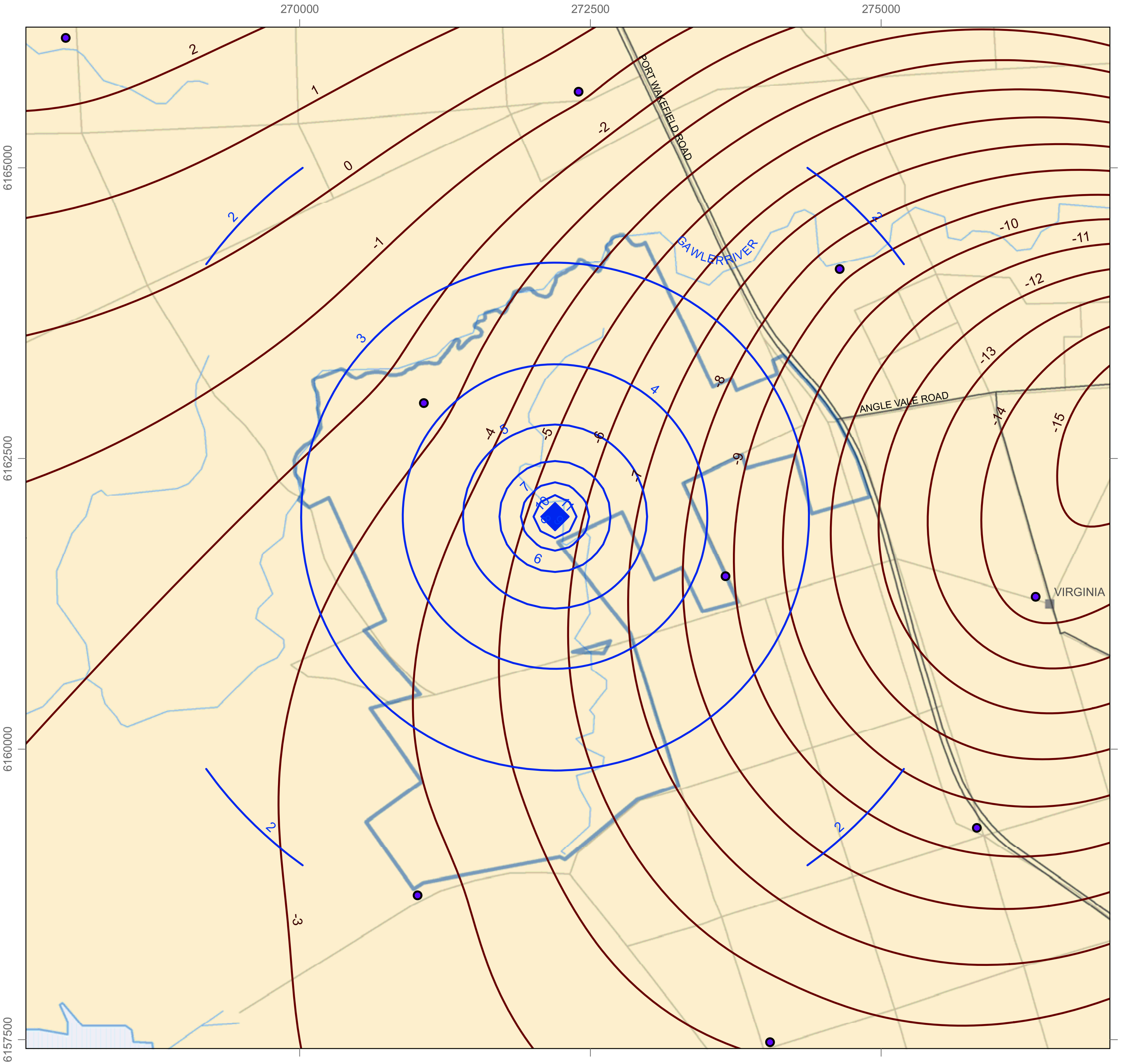

Buckland Park ASR Potential

Predicted head build-up from ASR in the T2 Aquifer- Scenario A

Figure 20

January-2008

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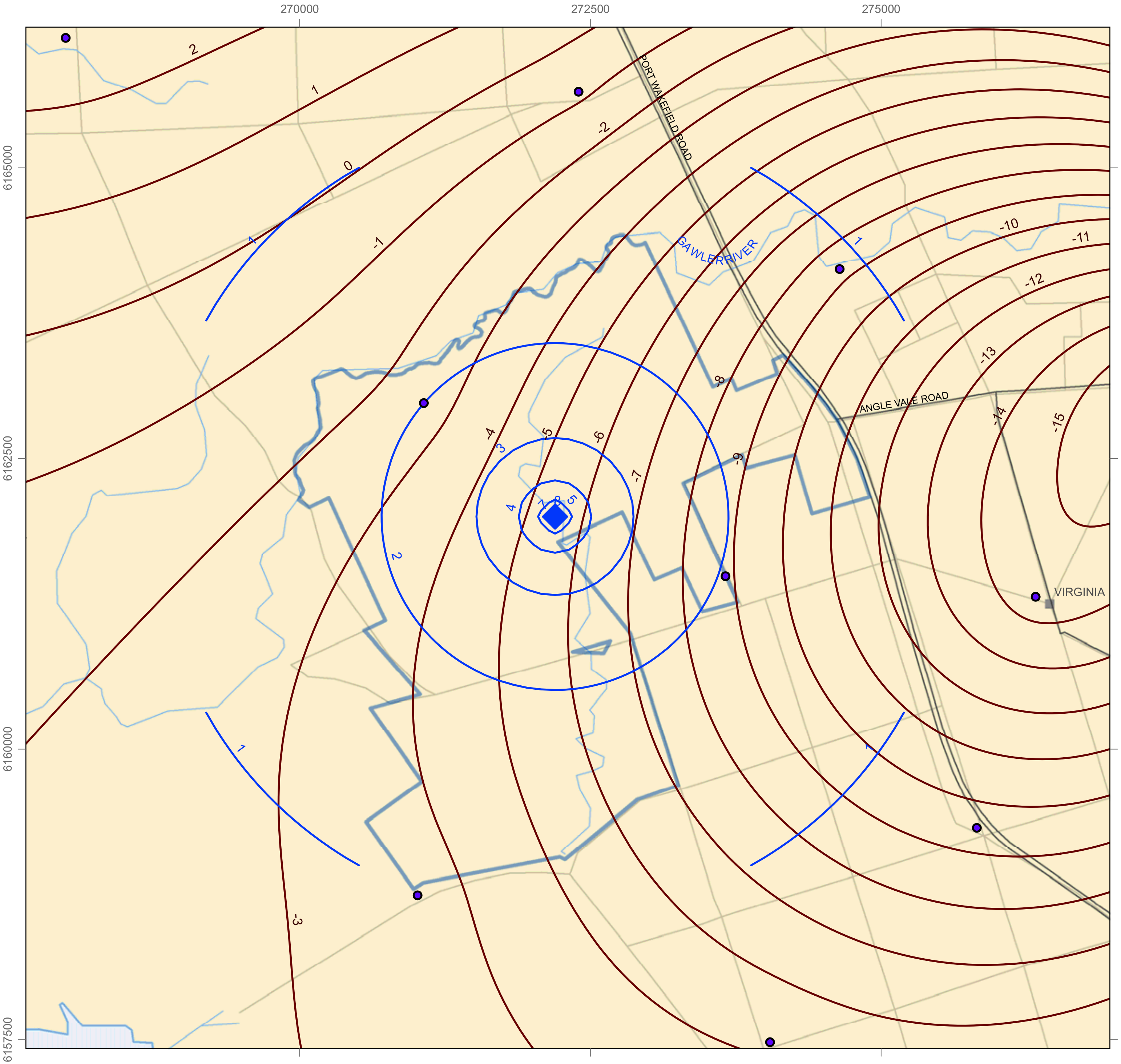

Legend

- Placenames
- Major roads
- Watercourses
- Site
- Existing T2 monitoring wells
- Groundwater levels- September 2004 (mAHD)
- Predicted head build-up (m) from ASR injection- 100ML scheme, maximum T & S assumed

0 1 2 3 km

Buckland Park ASR Potential

Predicted head build-up from ASR in the T2 Aquifer- Scenario B

rem

Figure 21

January-2008

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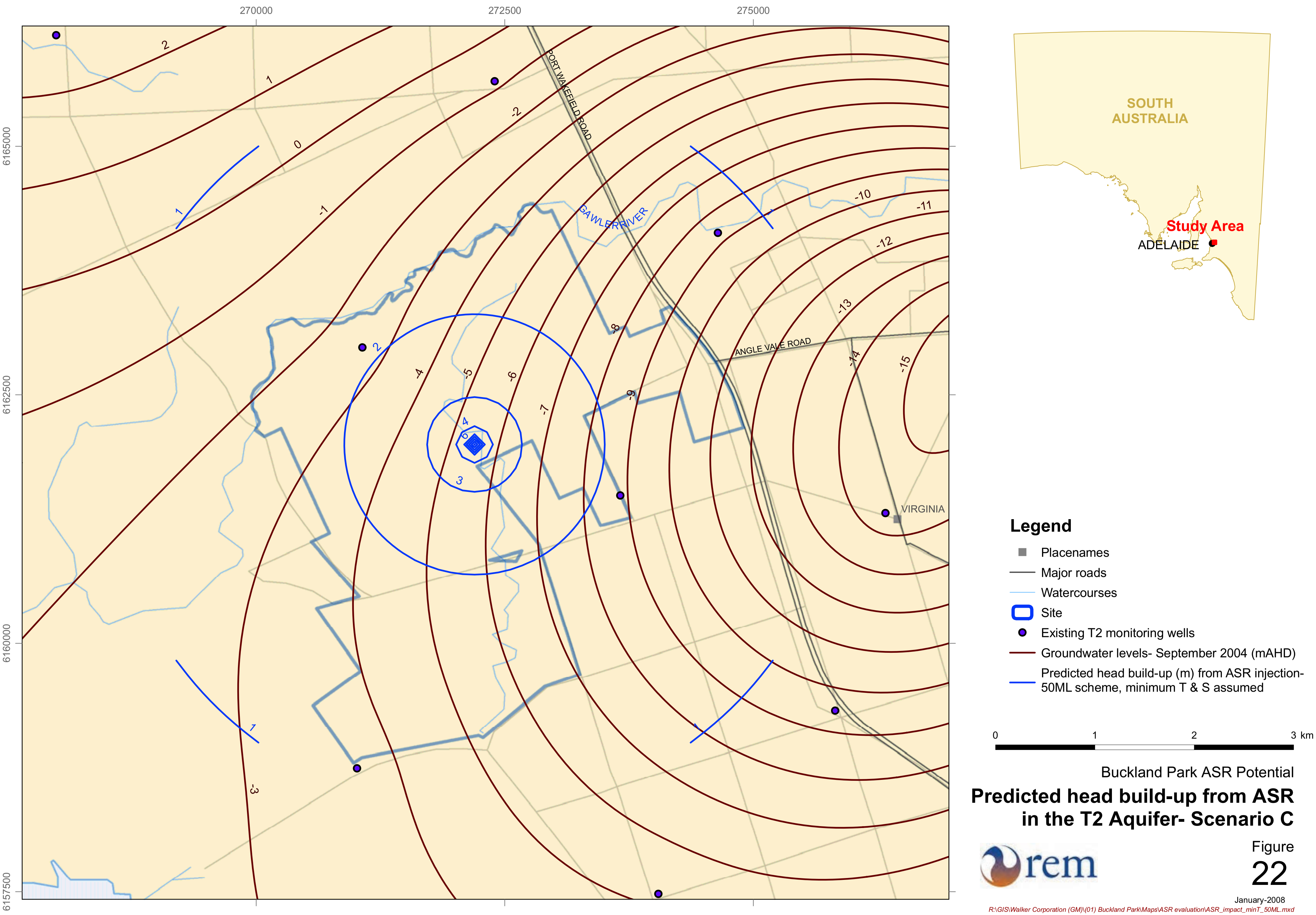

Buckland Park ASR Potential

Predicted head build-up from ASR in the T2 Aquifer- Scenario C

Figure 22

January-2008

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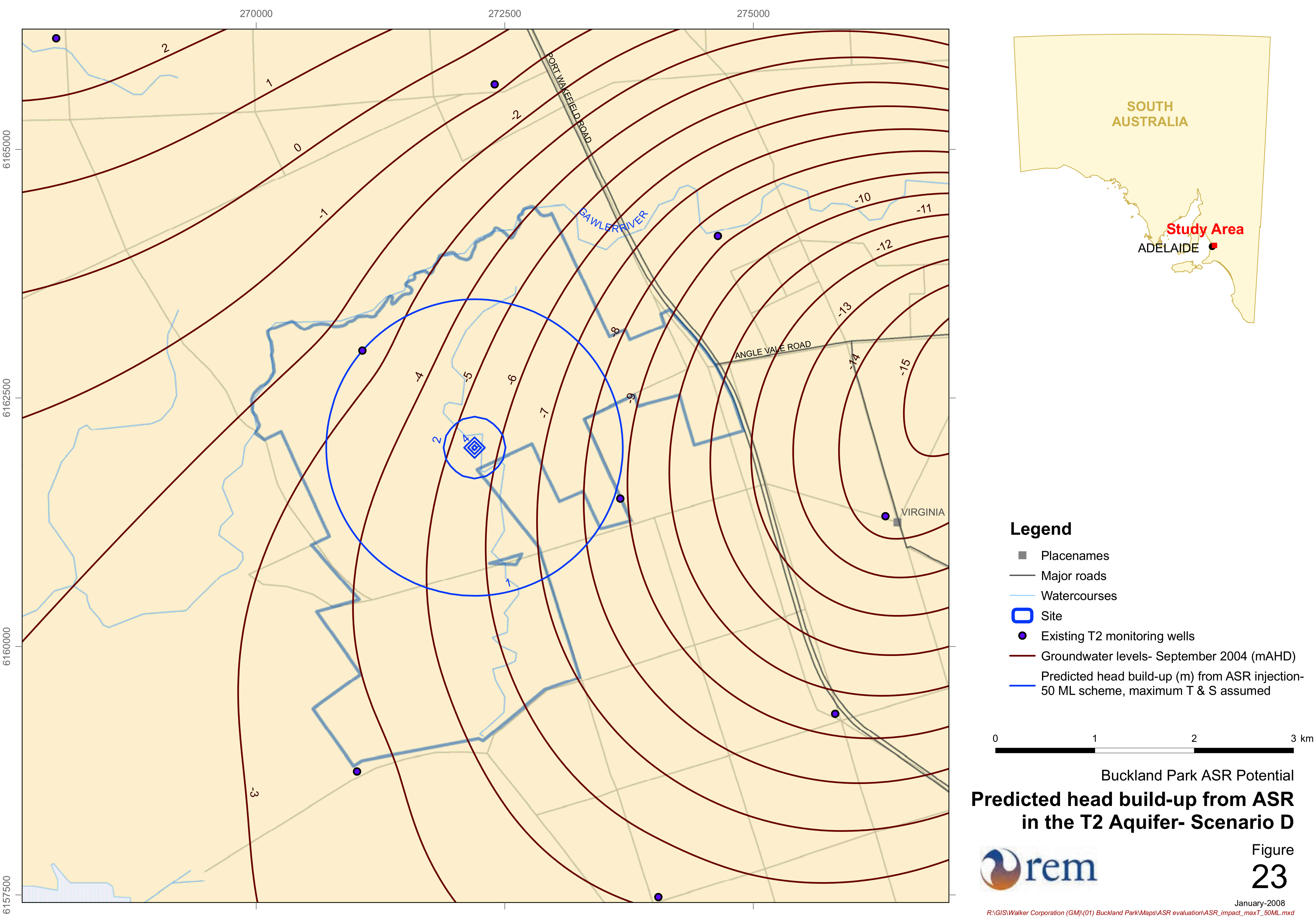

270000
272500
275000
6165000
6162500
6160000
6157500
PORT WAKEFIELD ROAD
GAWLER RIVER
ANGLE VALE ROAD
VIRGINIA
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
SOUTH AUSTRALIA
Study Area
ADELAIDE
Legend
Placenames
Major roads
Watercourses
Site
Existing T2 monitoring wells
Groundwater levels- September 2004 (mAHD)
Predicted head build-up (m) from ASR injection-
50 ML scheme, maximum T & S assumed
0
1
2
3 km
Buckland Park ASR Potential
Predicted head build-up from ASR
in the T2 Aquifer- Scenario D
rem
Figure
23
January-2008
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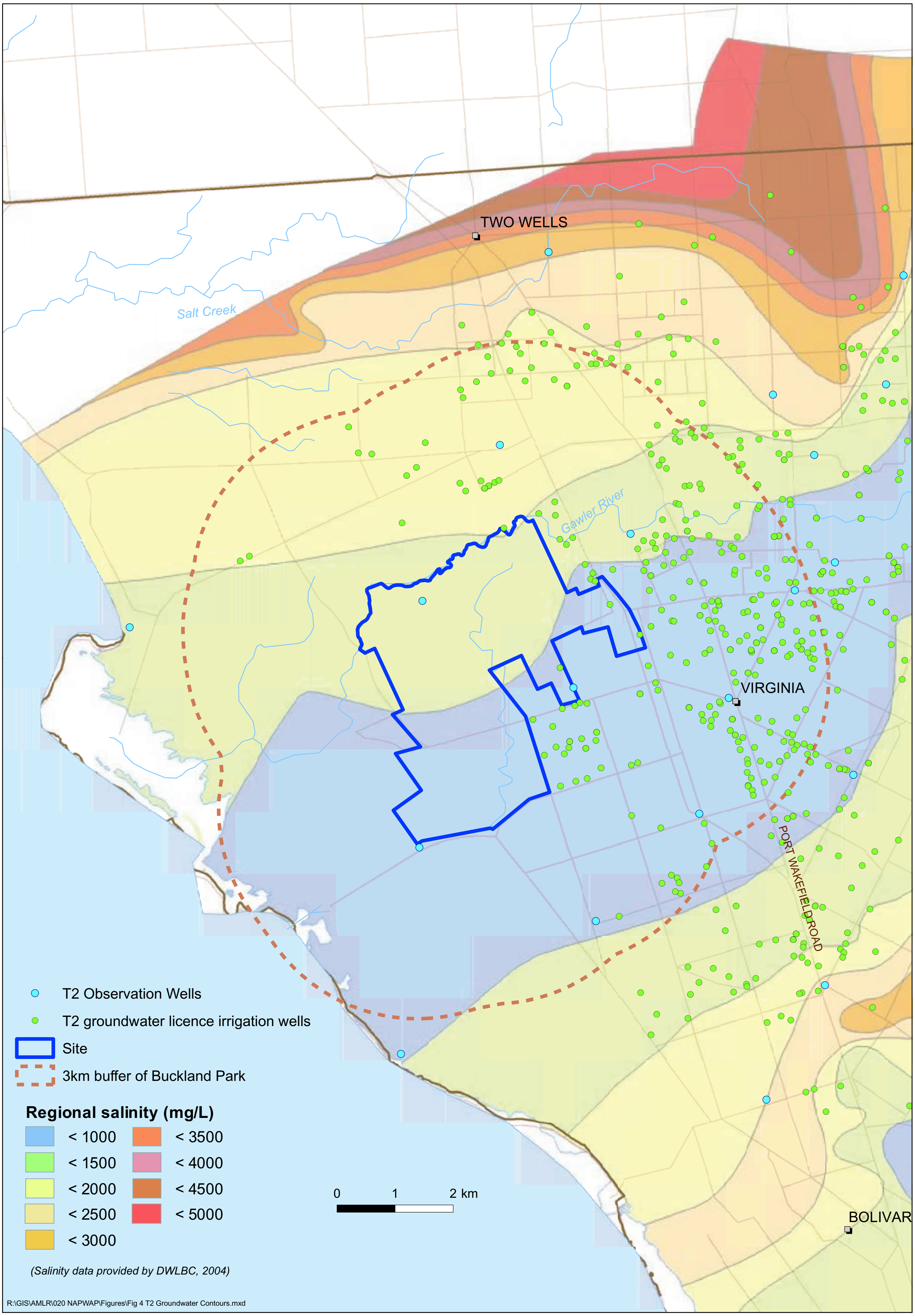

Licenced Groundwater users - T2 Aquifer Northern Adelaide Plains

Figure

24

July-08

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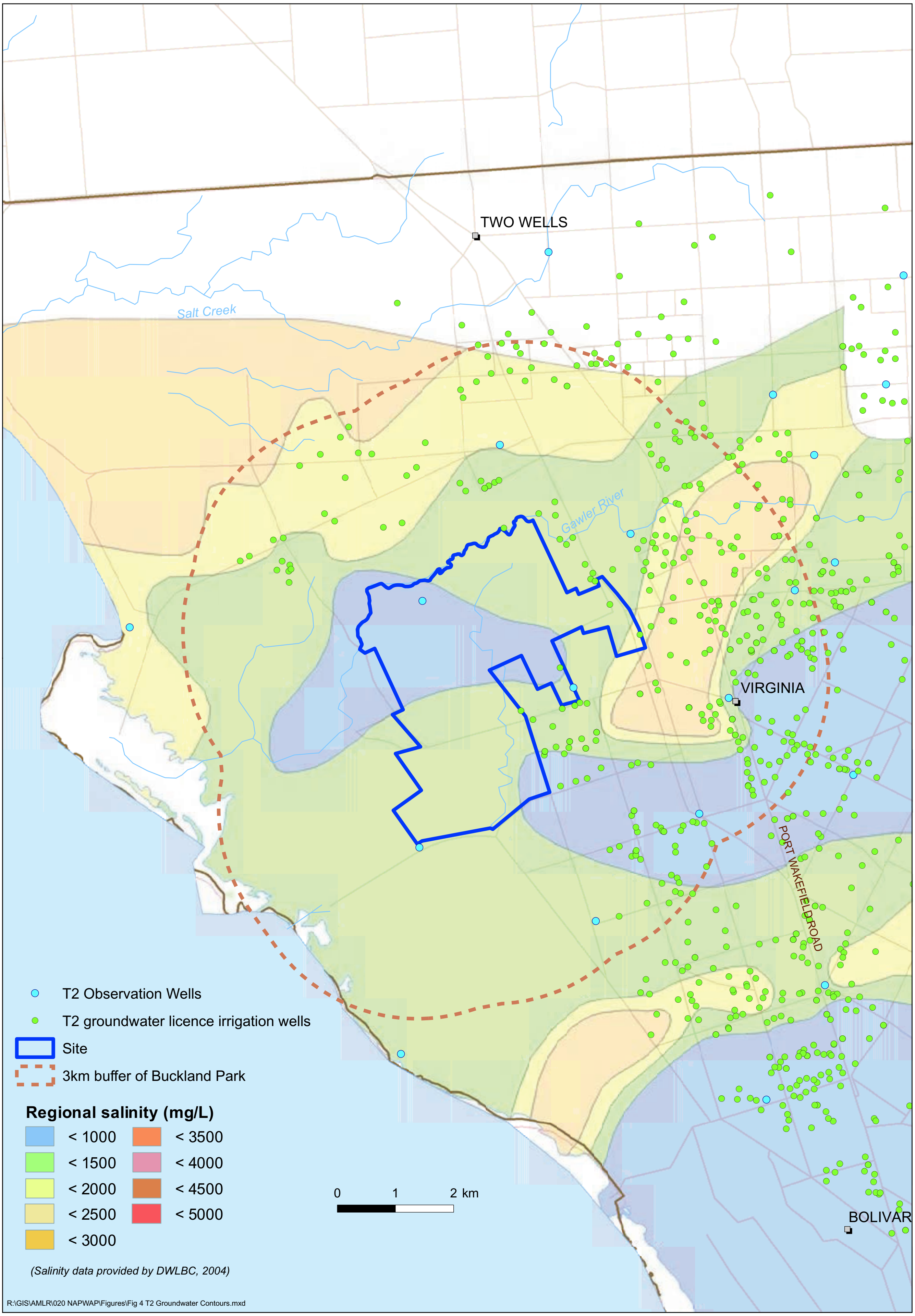

Licenced Groundwater users - T2 Aquifer Northern Adelaide Plains

Figure

25

July-08

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Appendix A: Buckland Park Development Proposal Overview

Walker Corporation

Buckland Park Proposal

Marine and Coastal Environment and Potential Impact Assessment

Cooe
Care Of Our Environment

Report Ref: WAL.BLP.1_v3

18 November 2008

Walker Corporation

Buckland Park Proposal

Marine and Coastal Environment and Potential Impact Assessment

18 November 2008

Prepared for

Walker Corporation

Prepared by

COOE (Care of Our Environment)

Formerly, Natural Resource Services Pty Ltd

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ABN 96 475 010 722

Job # WAL.BLP.12

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Appendix A: Comprehensive List of Coastal and Marine Fauna and Flora in the Buckland Park Area

Appendix B: Field Survey

Record of changes to this report:

Job ID.	Version	Draft #.	Date	Responsible Person	Comments
WAL.BLP.1	1	1	27-06-08	Joe Mifsud	Complete version first draft
WAL.BLP.1	1	2	9-07-08	Joe Mifsud	In-house edit and peer review and new marine vegetation map
WAL.BLP.1	2	3	10-10-08	Joe Mifsud	Rewritten to incorporate new information and phased development approach
WAL.BLP.1	2	4	6-11-08	Joe Mifsud	Rewritten to incorporate editorial by Sally Lewis

1. # Coastal and Marine Environment

1.1 Introduction;

The Buckland Park proposal is a joint venture of Walker Corporation and Daycorp. The site has an area of 1,308 hectares.

The site is located on Port Wakefield Road within the City of Playford, west of Virginia, and around 32 kilometres north of the Adelaide CBD and 14 kilometres from Elizabeth, see Figure 1.

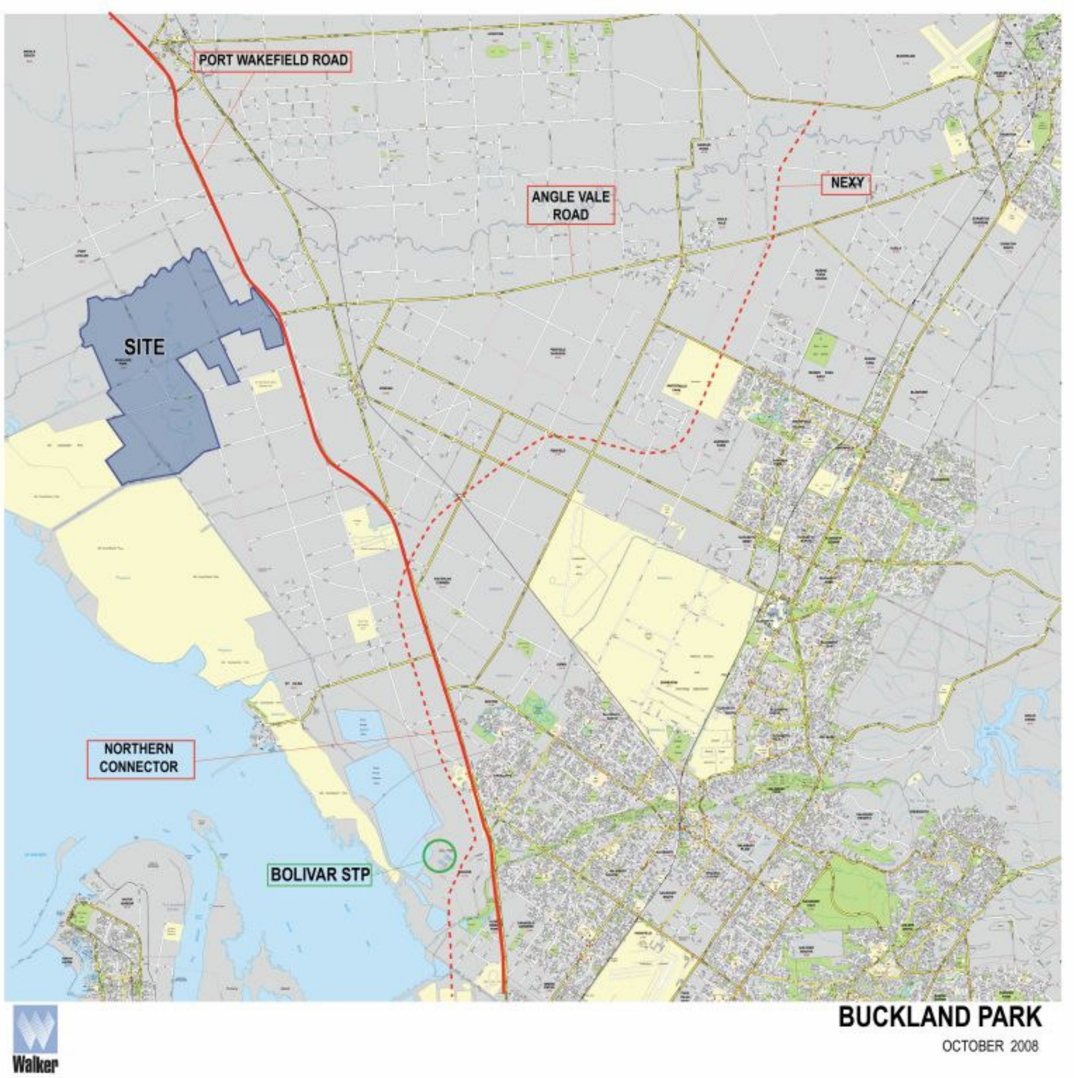


Figure 1: Buckland Park Locality Map

The site is bounded by Port Wakefield Road, the Gawler River, Cheetham Salt Limited saltpans and horticultural activities. The site is between 2.5 and 4 kilometres from the Gulf St Vincent coastline. The site is relatively flat arable land primarily used for low intensive grazing.

Remnant native vegetation occupies parts of the site's north west and south west portions, which can be seen on the aerial photograph in Figure 2.

Aerial photo supplied by Walker Corporation.

Figure 2: Site superimposed on aerial photograph

The Cheetham saltpans, adjoining the south west boundaries of the site are man made structures but are considered part of the coastal ecosystem, and provide a buffer between the site and the natural coastal and marine ecosystems.

These comprising of samphire flats, mangroves forest and algal mats fringing on tidal mud flats grading to sandy seabed supporting razorshell and seagrass habitats.

It is anticipated the proposal will comprise 12,000 residential allotments, with an average size of 500m^2, supported with multiple purpose open space, and commercial, retail, community and employment uses. The Proposal is illustrated in the Masterplan at Figure 3.

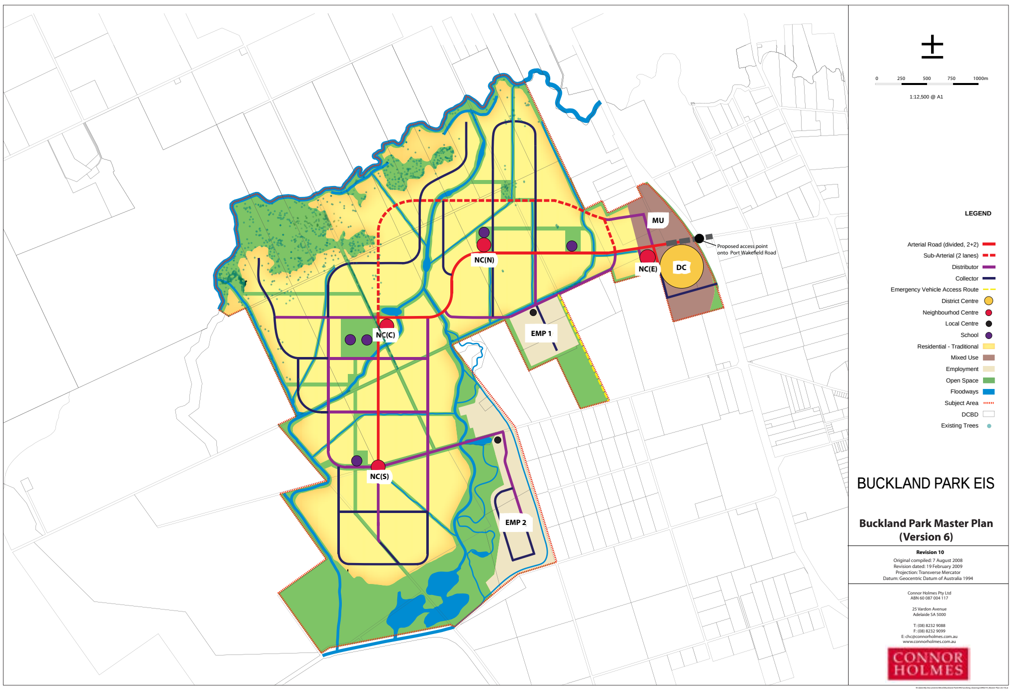


Figure 3: Master Plan of Buckland Park

The proposal will be implemented in stages over a period of 25 years, the first stage is planned for 2010 to 2016, as illustrated in the staging plan below Figure 4.

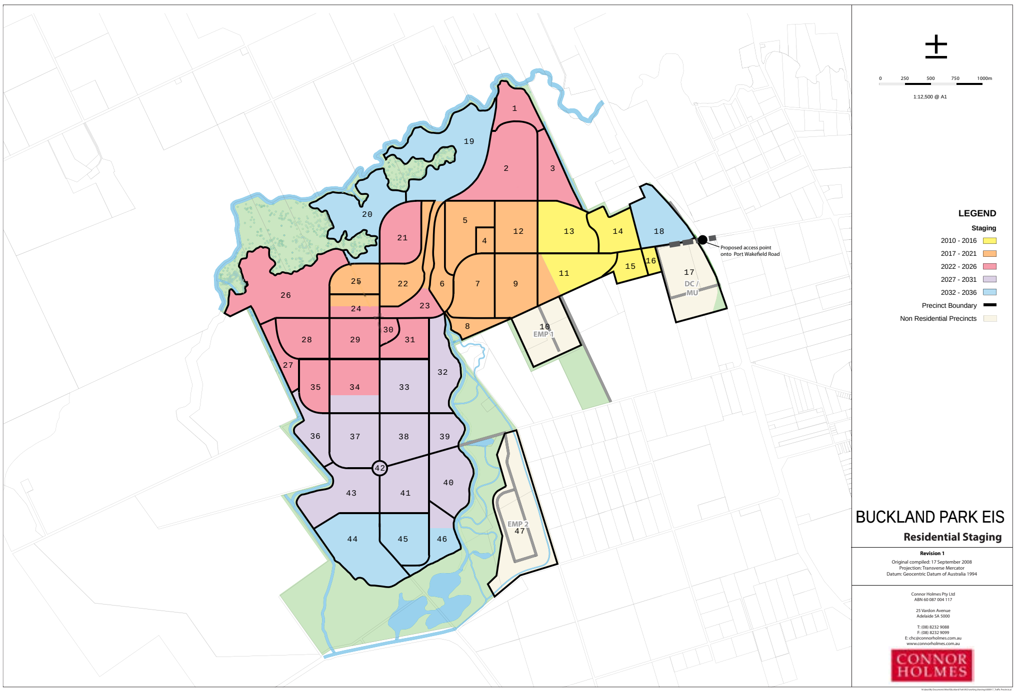


Figure 4: Proposal Staging

Walker Corporation commissioned COOE (formerly Natural Resource Services Pty Ltd) to assist with the coast and marine ecosystems assessment of the Environmental Impact Statement (EIS) for the Buckland Park proposal. This report is divided into four Sections:

Section 1 provides a desktop study of the coastal and marine ecosystems documenting habitats, plant and animal species of commercial importance and conservation significance within northern Gulf of St Vincent. This Section also describes the current and ongoing impacts of human habitation in the region.

Section 2 presents the findings of field surveys conducted in February 2008 to provide an overview of the current status of the samphire/saltmarsh and mangrove communities between the Cheetham salt pans and the coast.

Section 3 comprises of an environmental risk assessment to identify potential impacts the proposed development may have on the surrounding coastal ecosystem and presents control measures that will reduce the level of risk.

Section 4 outlines our conclusions.

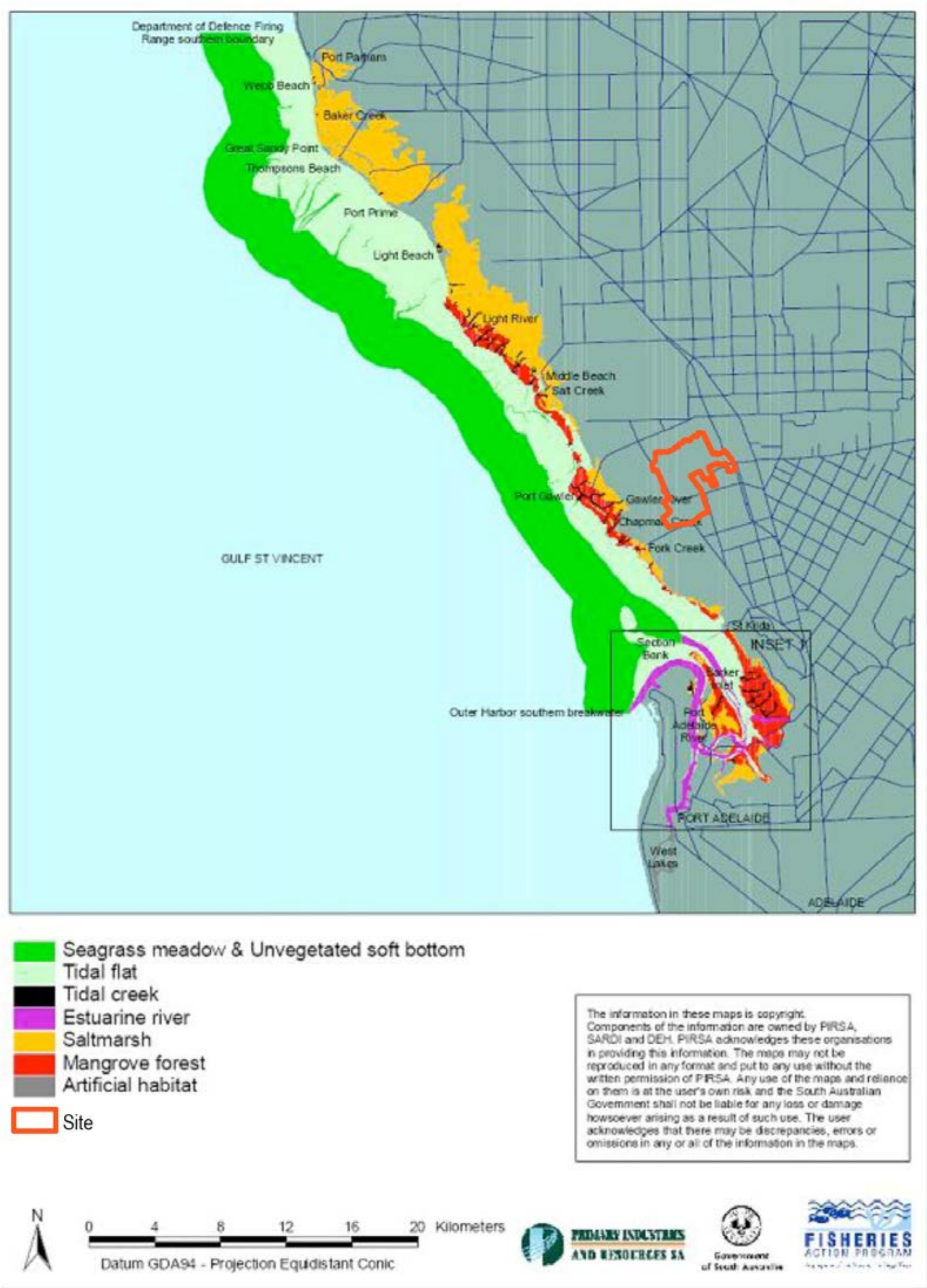
Coastal and marine background:

The Buckland Park proposal is located between Port Gawler and St. Kilda situated towards the southern end of the Clinton Biounit (Edyvane 1999a). This Biounit extends from Ardrossan on the eastern side of the Yorke Peninsula to just north of Hallett Cove, metropolitan Adelaide (Figure 5).

The Port Gawler area contains wetlands listed in the Commonwealth Directory of Wetlands of National Importance and features tidal flats with fringing mangrove forest intersected by several tidal channels and sand/shell grit ridges. Patches of seagrass meadows (*Amphibolis* and *Posidonia*) are found with unvegetated soft sediment seabed extending into the Gulf St Vincent.

The region is important for numerous birds including significant migratory species and marine fauna from protected dolphins and commercial fish and crustaceans, to the rare and endangered leafy seadragon and other members of the Pipefish family (Syngnathids).

The Cheetham Salt pans are unique and sensitive areas and are part of the internationally recognised St Kilda, Gawler River coastal wetlands particularly by birders (Cooper, Roy P. 1964 and 1980, Rix, C.E. 1978 and Day, F.A.G. 1994). These salt pans are well established and attract large numbers of waterbirds and animals and form an important feeding and roosting area for migratory birds. The salt pans themselves are teeming with aquatic life and demonstrate a variety of ecosystems functioning at different salinities.



Habitats based on Bryars (2003). Map reproduced with permission from PIRSA.

Figure5: The north-eastern area of the Gulf St Vincent bioregion

1.2 Regional Description

1.2.1 Oceanography & Dynamics

South Australia's semi-arid climate is characterised by minimal and irregular fresh water inputs through ephemeral creeks and storm water drains entering into the marine environment (Jackson & Jones 1999, Edyvane 1999a). The Gulf St Vincent is a tidally dominated inverse estuary, approximately 145 km long and 73 km wide, bordered by the Yorke Peninsula to the west and Fleurieu Peninsula to the south-east.

The large tidal range experienced by the Gulf St Vincent exposes intertidal areas with a horizontal extent of over 1,000m in some locations. Freshwater input into Gulf St Vincent occurs through Gawler, Torrens and Onkaparinga Rivers emptying into the Gulf St Vincent.

These contributing environmental factors define the dynamics of the Gulf St Vincent, where the headwaters of the estuary receive virtually no river discharge coupled with high evaporation rates during the summer months, creating high salinity (generally greater than 35 practical salinity unit (psu), up to 42 psu) and high water temperatures (between 12 °C and 26 °C) in the upper reaches of the gulf.

Suspended carbonate matter deriving from the southern ocean is transported in a northerly direction into the upper reaches of the gulf; this process contributes to higher turbidity in the upper gulf waters (Edyvane 1999b). Gulf St Vincent is identified as a low wave energy system characterised by weak tide currents moving clockwise.

Wind also drives currents within Gulf St Vincent predominantly clockwise (Bye 1976). Strong wind occurrences in the gulf can produce storm surges of up to 1m and tend to be more prominent in the upper gulf due to a wind funnelling effect.

The cooling of autumn months in South Australia creates an intensification of density fronts within the gulf, flushing the highly saline water accumulated during the summer months. These seasonal outflows of saline waters can be observed from April through until December.

1.2.2 Habitat Description Overview

The low lying tidal area of northern Gulf St Vincent is an important habitat supporting some of the largest areas of temperate ecosystems encompassing ecologically and economically[1] significant samphire, seagrass and mangrove communities (Edyvane 1999a) where the inter-tidal zones and areas of sub-littoral fringes are dominated by the grey mangrove forests (*Avicennia marina*). The supra-tidal samphire bands adjacent to the mangrove forests are comprised of extensive stretches of sand and mud flats. Within these communities, some samphire species coexist with mangroves but are generally found as separate bands of vegetation.

The soft sediments contained within the tidal flats support a variety of marine organisms, including burrowing crustaceans, polychaetes and molluscs that are an important food source for many commercial and non-commercial species including fish, prawns and birds (AMLR 2007, Edyvane 1999b).

The benthic sediments vary from fine in the deeper zones (due to slower currents allowing fine sediments to settle) to coarser sandy grains closer to the more energetic coastline (Grady & Brook 2000). Globally, soft-sediment strata comprise a large portion of the seafloor (Kingsford & Batershill 1995) that are modified by local abiotic factors such as tidal movements, organic particulates, oxygen and nutrient availability.

1.2.3 Coastal estuarine and freshwater habitats

The site lies on the southern bank of the Gawler River, east of Buckland Park Lake and northeast of the Cheetham Salt pans, Figure 2..

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[1] These habitats are a food source, breeding grounds and nurseries for commercial fish and crustaceans. They also have commercial significance to the amateur fishing, marine craft and local tourist industries.

The northern Adelaide metropolitan region has many creeks and rivers that drain into the Gulf St Vincent. The coastline adjacent to the site encompasses Port Gawler, Buckland Park, St. Kilda and Barker Inlet areas. The Gawler River is currently classified as an extensively modified, tide dominated, tidal flat/ creek system. The Gawler River Estuary (located within both the City of Playford and District Council of Mallala) has an approximate catchment size of 1,105 km^2. The highly modified Gawler River has seen 56% of flow diverted for consumptive purposes (Caton *et al.* 2007). As a result of modifications to flows, total volumes, durations and frequencies have been altered from their natural state. Present flow is heavily regulated through dams, weirs and diversions from Gawler River tributaries (Caton *et al.* 2007).

Port Gawler is a significant estuarine habitat for the Gawler River, consisting of extensive tidal flats (shelly silts, clays, and sands) and fringing mangrove forests that are crossed by a multitude of tidal channels. The mangroves at Port Gawler are more than 1km wide, backed by intertidal and supratidal samphires. Shellgrit ridges (stranded beach deposits) occur along a belt within the mangrove forest. To the east of Port Gawler lie extensive shallow saline pans, which are a part of the solar salt-extraction system operated by Cheetham Salt. A narrow samphire saltmarsh community occupies the area between the mangroves and the salt pans.

Buckland Park Lake lies immediately north of the evaporation ponds and east of the site. The lake was formed by damming the mouth of the Gawler River (Baker 2004). Shallow ephemeral freshwater fills this lake, predominantly in winter and draining through the summer months. Several channels flow on from the lake system emptying in nearby lignum swamps forming a long narrow estuary at Port Gawler (Baker 2004).

When Buckland Park Lake overflows, water leaves the Lake via spillways and is channelled through the mangroves and out to sea. Port Gawler and Buckland Park Lake are listed as Wetlands of National Importance - Ref. No. SA015, recognised for their significant estuarine function (ANCA 1996, AMLR 2007). Port Gawler is also listed on the Register of the National Estate. These areas provide habitat for around 65 coastal bird species, many of which are listed as rare or threatened or are listed under treaties (see Sections 1.2.4 & 1.2.5). Buckland Park Lake is one of the most important breeding habitats for a range of waterfowl within the Adelaide region (Morelli and de Jong, 1995, cited by Baker 2004).

Saltwater Evaporation Ponds (Cheetham Salt pans)

Approximately ½ km inland from the coast and adjacent to Buckland Park Lake are extensive shallow salt water evaporation pans, currently under lease and operated by Cheetham Salt.

Constructed levee banks between the salt pans and the sea have mostly prevented the natural flushing process of the marsh-lands, leading to high evaporative concentrations of salts found within the groundwater compared to adjacent seawater salt concentrations (DEH 2007).

The saltwater ponds proliferate with bird life and combined with the Buckland Park Lake provide an important breeding and feeding area for species including migratory species (Cooper, Roy P. 1964 and 1980, Rix, C.E. 1978 and Day, F.A.G. 1994). Cheetham Salt produces salt mostly used by Penrice in the Gawler Inlet for making soda ash.

1.2.4 Marine habitats

Gulf St Vincent is the second largest inverse estuary found within South Australia and is both physically and biologically diverse, comprising cold temperate and transitional cold to warm temperate species (Edyvane 1999a), resulting from a long period of geographical isolation and characteristically low nutrient, or oligotrophic waters.

Gulf St Vincent encompasses a range of habitat types supporting extensive subtidal and tidal wetlands, seagrass meadows and ecologically significant mangrove (*Avicennia marina*) and saltmarsh ecosystems covering approximately 20,000 hectares. The sub-littoral, shallow subtidal zone at Port Gawler supports seagrass meadows of *Zostera mucronata*, *Z. tasmanica* and *Posidonia australis* (Morelli and de Jong, 1995). A wide variety of marine fauna and flora within Gulf St Vincent are found to be endemic to the region.

Surveys undertaken by Mifsud *et al.* 2004, using aerial photography and field surveys described the extent and distribution of coastal and marine flora along the coastline from Outer Harbour to Port Gawler. Detailed vegetation maps showing mangrove, seagrass and samphire communities from the 2004 survey were used to generate an updated coastal and marine vegetation map using 2008 orthorectified multispectral photographs. The map in Figure 6 extends the original boundary further north to fully cover the potential impact area from the Buckland Park site.

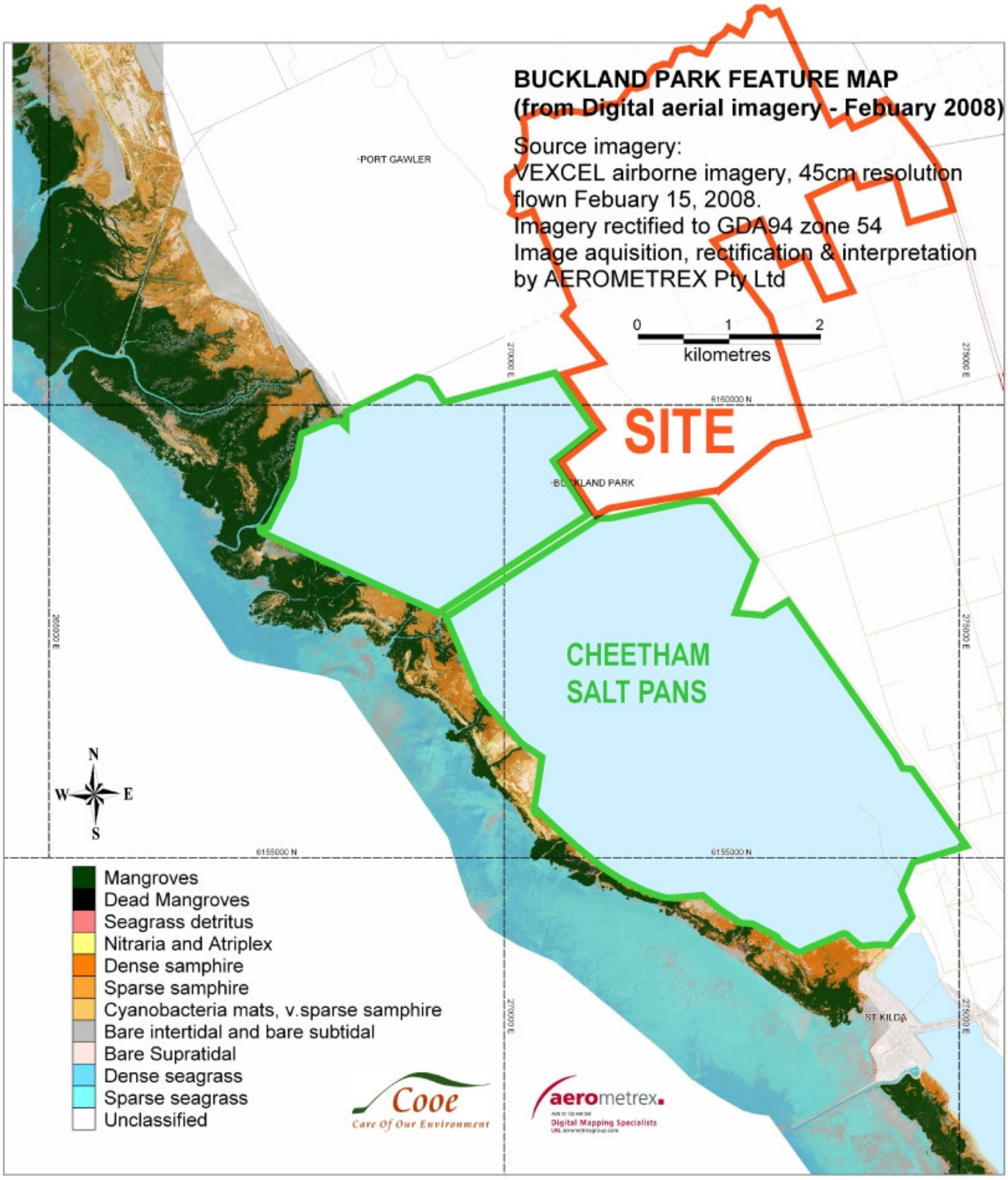


Figure 6: Coastal and Marine Vegetation

Seagrass off the Adelaide metropolitan coast has been severely degraded over the last few decades. A recent government research program "The Adelaide Coastal Waters Study" found that the nitrogen in discharge from wastewater treatment plants, industry and stormwater runoff was the main pollutant that affects the health of seagrass, which in turn triggered the loss of seagrass habitat and species associated with the habitat (Fox *et al* 2007). Turbidity also contributed to poor seagrass health by reducing photosynthesis (Shepherd *et al* 1989).

Mangroves / Saltmarsh Communities

The Port River-Barker Inlet and Gawler River Estuary are the only two estuaries within the Gulf St Vincent region that support mangrove communities (Caton *et al*. 2007), namely the grey mangrove (*Avicennia marina*). Mangroves act as a buffer between land and sea, where they filter discharge from the terrestrial environment, decreasing sediment and nutrient loads entering the marine environment and maintaining the integrity of the coastline (Baker 2004, Hobday *et al*. 2006).

Mangrove communities within the Buckland Park region consist of low woodland forest extending from mean sea level to spring high-tide level (Edyvane 1999b), followed by higher zones of associated vegetation assemblages of samphire/saltmarsh (*Halosarcia-Sarcocornia/Sclerostegia* spp.) and saltbush (*Atriplex* spp.) (Edyvane 1999b).

Mangroves are significant detritus recyclers with estimations suggesting that one square metre of mangrove contributes approximately 600 tonnes/ year of vegetative litter to the marine food web (Baker 2004). They are also important nursery and resource habitats, consisting of feeding and breeding grounds for many economically and ecologically important species including Western King Prawn, King George Whiting and Southern Sea Garfish. Mangroves play an important role in nutrient and carbon cycling (Hobday et al. 2006). A multitude of marine organisms, including marine snails (*gastropods*), bivalves, worms and tubeworms (*polychaetes*), crustaceans, fish and coastal birds are also reliant on mangroves and associated communities for refuge and as a food source (Edyvane 1999b).

Together, extensive mangrove and saltmarsh communities found along the coastline of SA cover an approximate 82,000 hectares; within this, 20,000 hectares are located within the Gulf St Vincent (Edyvane 1999a).

A study by Mifsud *et al*. 2004, using aerial multispectral photography and ground-surveys, showed the distribution of mangroves and associated vegetation showing mangrove dieback within the Gulf St Vincent region as extensive and ongoing.

This study investigated possible reasons for the observed mangrove dieback and found that the removal or deposition of sediment around the pneumatophores appeared to be the most significant factor leading to plant mortality.

Detailed measurements suggested that sediment loss of -20cm or accretion of +30cm would cause mangrove deaths. Prolonged water inundation from pooling around the pneumatophores of approximately +30cm, also result in mangrove deaths. This study also suggests that the loss of mangrove may be connected to loss of associated seagrass beds.

Seagrass Meadows / Algae

Edyvane (1999b) estimated the total coverage of seagrass meadows within Gulf St Vincent to be approximately 2,436km^2, which represents approximately 25% of the entire seagrass area found within South Australia.

Diverse and extensive seagrass communities found within Gulf St Vincent are major drivers of primary production (Edyvane 1999a). They are an essential component of food web structures with functions including nutrient cycling and increasing the stability of the seafloor through the growth of extensive root and rhizome mats, as well as baffling water flow (Fonseca & Fisher 1986, Hobday *et al*.2006).

Seagrass provide an important substrate for a diverse and abundant epiflora and epifaunal species in addition to providing refuge and feeding grounds for an abundant number of both ecological and economically important species (Baker 2004). Seagrasses provide habitat and food source for numerous fish, crustacean and invertebrate species, forming the basis of the state's commercial fisheries economy (Edyvane 1999a) including the Marine Scalefish Fishery and the Western King Prawn Fishery, see Section 1.2.4.

Extensive benthic surveys conducted off the Adelaide Metropolitan Coast and St. Kilda concluded that seagrass, particularly large and intact patches of *Posidonia sp*. are significant in terms of conservation values but that areas comprising of remnant patches of seagrass classed as 'unhealthy', were at great risk of total dieback and protection from further degradation of these areas is vital for the recovery of the seagrass beds in the Gulf St Vincent (Mifsud *et al*. 2004).

The sub-tidal zones of Gulf St Vincent are dominated by seagrass communities of; *Posidonia sp., Amphibolis antarctica, A. Griffithii, Heterozostera tasmanica, Halophila australis, Zostera mucronata* and *Z. Muelleri* (Edyvane 1999a, AMLR 2007).

Seagrass species colonising the muddy tidal flat areas are *Posidonia australis* and *Amphibolis antarctica* (Edyvane 1999b). *P. australis* is the most extensive seagrass throughout the northern regions of the Gulf often found growing in association with *P. sinuosa* and *P. angustifolia,* (Edyvane 1999b).

Seagrasses are known to sequester an estimated 6 grams of carbon per m^2/day (AMLR 2007) making them significant for CO_2 reduction and associated climate change implications.

Macro-algae found within the Gulf St Vincent are dominated by the brown algae *Hormosira banksii*, on hard substrates, and the green alga, *Ulva*, *Enteromorpha* and *Chaetomorpha* found in, near or within mangrove communities, as well as, the smaller red macro-algae *Gelidium.*

Studies by Shepherd *et al*. (1989) found that seagrass meadows are particularly sensitive to anthropogenic disturbances including discharges from urban and industrial wastes, agricultural runoff and coastal development. Studies conducted by Mifsud *et al*. (2004) suggest seagrass communities between the Barker Inlet and Port Gawler are under stress, particularly from high epiphyte loads on seagrass blades resulting from nutrient enrichment.

The Adelaide Coastal Waters Study found that the extensive degradation of seagrass along the Adelaide metropolitan coastline is a significant indicator of poor ecosystem health (Fox *et al* 2007). Contributing factors to ecosystem decline include urban runoff, treated wastewater outfall, and an increase in nutrient and industrial discharges (Edyvane 1999a and Fox *et al* 2007).

Significant nutrient discharge from the Bolivar Waste Water Treatment Plant (WWTP) has been noted to impact the seagrass beds to the west of the site (DEH 2007). Nutrients discharged from the WWTP pose a major threat to water quality within the region. Reports by the ACWS have clearly demonstrated that the primary cause of seagrass decline in Adelaide coastal waters has been from nutrients originating mostly from Bolivar WWTP (1,200 tonnes N/y), Penrice (1,000 tonnes N/y) stormwater (150 tonnes N/y) based on data collected between 2001 and 2003, (Fox *et al* 2007).

Extensive seagrass loss appears to be a response to these high nutrient levels found in the region. This trend towards further decline and eventual loss of seagrass in the near shore areas surrounding Adelaide's metropolitan coastline is expected to continue. Caton *et al*. 2007 report an estimated loss of 6000 ha of seagrass from the metropolitan area.

As noted earlier studies by Mifsud *et al*. 2004 suggest impacts to seagrass beds contributed to the loss of mangrove communities. Studies by the AMLR NRM Board in 2007 also reported increasing seagrass decline along the metropolitan coastline in connection with increasing levels of urbanisation.

Samphire/Saltmarsh Communities

The Port Adelaide Estuary and Barker Inlet inter-tidal and supra-tidal marshes are a discharge zone for Quaternary aquifers across the Adelaide plain (AMLR 2007), comprising shallow saline and hyper-saline groundwater that are susceptible to marine intrusion (Pavelic & Dillion 1993). These marsh-land ecosystems support communities of samphire and saltmarsh connecting terrestrial vegetation and mangrove communities within the tidal zone (AMLR 2007). The salt-tolerant samphire communities form broad bands in the upper inter-tidal and supra-tidal zones bordering associated mangrove forests.

Samphire communities within the St. Kilda to Barker Inlet are dominated by *Sarcocornia* and *Halosarcia* species and it is noted that within vicinity of the Port Gawler Conservation Park (Gawler River Estuary) bead samphire (*Halosarcia flabelliform*) has been classified as nationally vulnerable (under the EPBC Act 1999 and NPW Act 1972) (Caton et al. 2007). Higher bands of the saltmarsh consist of shrub lands including *Maireana* spp. and *Atriplex* spp. mixed with *Sclerostegia* spp. The lower heath areas are dominated by several species of *Halosarcia* (Morelli and de Jong 1995, cited by Baker 2004).

Soils found within saltmarsh/samphire communities are important for the nutrient cycling component of food web processing. Function includes accumulation, consumption and re-mineralisation of organic matter including recycling organic detritus (Baker 2004).

1.2.5 Flora and Fauna

The following sections present information from literature reviews and field work on flora and fauna found in the coastal and marine environment between Gillman and Port Parham. Appendix A presents a comprehensive list of species provided by Peri Coleman. The flora and fauna recorded in this list were observed over a 15 year period and include opportunistic observations (flora and fauna) as well as vouchered surveys (flora).

Benthic Fauna and Invertebrates

The soft sediments found within Gulf St Vincent are complex and diverse. Variations in sediment types, including grain size and chemistry, determine the fauna and flora living within (Edyvane 1999C).

Soft sediments in deep waters (12-25m) are dominated by invertebrate animal groups including bivalve molluscs (scallop and razorfish), ascidians, Holothuroidea (sea cucumbers) and seastar assemblages (Shepherd & Sprigg 1976, Edyvane 1999c).

Mudflats within Gulf St Vincent are known to comprise of gastropods (coneshells and snails including *Bembicium, Salinator* and *Austrocochlea* spp. and bivalves including *Modiolus* spp. and the cockle *Katelysia*.

The muddy substrates of the upper reaches are dominated by razorshell (*Pinna bicolour*) attached to the seabed (Edyvane 1999b). The razorshells provide habitat and support for an abundant assemblage of epizoic species such as small sponges, tube worms, bivalves, bryozoans and ascidians, including the large milk bottle ascidians (*Phallusia obesa*).

Tube worms (*Diopatera* spp.) and beach worms of the family *Onuphidae* are found within the mudflats and are important for nutrient cycling and as a food resource for higher order fauna. Small aggregations of coral species have also been recorded in the upper region of Gulf St Vincent (Shepherd & Sprigg 1970).

Soils found within saltmarsh/mud flats comprise of abundant microalgae, forming a critical link in the marine food web (Baker 2004).

Estuarine environments within Gulf St Vincent have a high abundance of invertebrate species including various worms, bivalves, crabs and crustaceans in addition to the presence of the common mud crab (*Helograpsus haswellianus*).

Other species of importance include the;

• Black striated sea anemone (*Edwardsia vivipara*),

• The barnacle (*Elminius adelaidae*) and,

• The southern blue ringed octopus (*Hapalochlaena* spp.), found abundantly in the shallow regions of upper Gulf St Vincent (Baker 2004).

Bony & Cartilaginous fishes

Studies by Edyvane (1999b) recorded a total of 216 species of fishes within Gulf St Vincent including 26 species of recognised importance, including 7 that are endemic. Approximately 70 species of bony and cartilaginous fish were recorded in the Barker-St. Kilda Inlet (Baker 2004).

Fish known to use both marine and fresh water environments include Congolli *Pseudaphritis urvillii*, which had been recorded around the Gawler River weir and is a noted species of concern (Baker 2004, cited by Hammer 2002), and is recommended to be listed as 'rare' under the *National Parks and Wildlife Act 1972*. Other fish (including larval and juvenile stages of fish species) reliant on saltmarsh/mangrove ecosystems include Gobies, Hardyheads and Mullet (Baker 2004). Table 1 provides a list of species and the habitats in which they occur at various growth stages.

Commercially and/or recreationally important species

Species of recognised commercial and/or recreational importance within the region include; King George Whiting, Tommy Ruff, Garfish, Yellow-eye Mullet, Snook, Australian Salmon, Blue Mackerel, Yellow-fin Whiting, Snapper, Striped Trumpeter, Red "Mullet", species of Flathead and Flounder, species of Weedy Whiting, estuarine species such as Mulloway and Black Bream, small numbers of wide-ranging species such as Yellow-tail Kingfish, Trevally, Jack Mackerel, Bronze Whaler and/or Black Whaler, Gummy Shark, Dog Shark, Elephant Shark and other shark/ ray species, Blue Crab, Mud Cockle, Southern Calamari, Tube Worm, Blood Worm, Beach Worm, Cuttlefish, Rock Crabs, Sand Crabs, Western King Prawn and Mussels (Baker 2004).

Table 1: Growth stage of significant fauna in the upper Gulf St Vincent habitats

Fauna that are significant to fisheries or of ecological importance, source Bryars 2003. Abbreviations: a = adults/recruits; s = spawners; e = eggs; l = larvae; p = post larvae; j = juveniles

Habitat: Species	Seagrass meadow	Unvegetated soft bottom	Tidal flat	Tidal creek	Mangrove forest
Blue Swimmer Crab	a, s, e, j	a, s, e, l, j	a, s, e, l, j	a, j	a, j
Razorfish	a, s, p, j	a, s, p, j	a, s, p, j		

King/Queen Scallop	a, s, p, j	, s, p, j			
Western King Prawn		a, j	p, j	j	j
Southern Calamari	a, s, e		a		
King George Whiting	a, j	a, j	p, j	a, j	p, j
Australian Salmon	a, j	a	a, j	a, j	j
Southern Sea Garfish	a, j, s, l	a, j, l	a, j	a, j	j
Yellowfin Whiting		a, j, p, s	a, j, p	a, j, p	j
Yelloweye Mullet		a, j	a, j,	a, j	a, j
Snook	a, s	a, s			
Snapper	a, j	a, j			
Tommy Ruff	a, j	a, j	a, j	a, j	J
Mud Cockle			a, j, p, s		a, j, p, s
Baitworm			a, j, p, s		a, j, p, s
Red Mullet	a, j	a, j			
Flathead	a, j	a, j	a, j	a, j	
Flounder		a, j	a, j	a, j	
Trevally	a, j	j			
Black Bream				a, j	a, j
Mulloway		a		a, j	
School Whiting		a			
Whaler Shark	a, j	a, j			
Leatherjacket	j				

Marine mammals

Marine mammals commonly found within Gulf St Vincent (Baker 2004) include;

• the Bottlenose Dolphin (*Tursiops truncates*),

• The Common Dolphin (*Delphinus delphis*).

30 known 'resident' dolphins have been reported to use Port River/ Barker Inlet and Outer Harbour for mating and nursing juveniles.

Other marine mammals that have been occasionally reported within upper Gulf St Vincent (Baker 2004) are;

• The Leopard Seal (*Hydrurga leptonyx*),

• The Blue Whale (*Balaenoptera musculus*),

• The short-finned Pilot Whale (*Globicephla macrorhynchus*) and,

• The Killer Whale (*Orcinus orca*).

The upper Gulf St Vincent is a known habitat for the uncommon and endemic Magpie Fiddler Ray (S.A Museum 2001, cited by Baker 2004). The only recorded sightings of the Magpie fiddler Ray have been documented in the upper Gulf St Vincent region.

Coastal, marine and estuarine birds

The St. Kilda, Chapman Creek and Barker Inlet areas are known to be a significant habitat for many migratory and resident bird species for breeding, feeding and sheltering and are noted as having both national and international importance. Common bird species within this region include those cited by Baker 2004 and in the Field Naturalist Society of SA list. The following list is compiled from these sources and field observations and shows birds of conservation significance as, very endangered (VE), endangered (E), vulnerable (V) and protected migratory * species.

Common name	***Taxonomic name***
• Australasian Shoveller	*Anas rhynchotis*
• Australian Pelican	*Pelecanus conspicillatus* (approx. 100)
• Baillon's Crake	*Porzana pusilla*
• Bar-tailed Godwit	*Limosa lapponica* *
• Bar-tailed Godwit	*Limosa lapponica**
• Black Cormorant	*Phalacrocorax carbo*
• Black-tailed Godwit	*Limosa limosa* *
• Blue-bellied Duck	*Oxyura australis*
• Broad-Billed Sandpiper	*Limicola falcinellus**
• Cape Barren Goose	*Cereopsis novaehollandiae (V)*
• Caspian Tern	*Sterna nilotica*
• Common Greenshank	*Tringa nebularia**
• Common Sandpiper	*Actitis hypoleucos*
• Curlew Sandpiper	*Calidris ferruginea* *
• Eastern Curlew	*Numenius madagascariensis**
• Fairy Tern	*Sterna nereis*
• Freckled Duck	*Stictonetta naevosa*
• Golden Plover	*Pluvialis apricaria*
• Great Egret	*Ardea alba*
• Greenshank	*Tringa nebularia**
• Greenshank	*Tringa nebularia**
• Little Egret	*Egretta garzetta*
• Little Pied Cormorant	*Phalacrocorax melanoleucos*

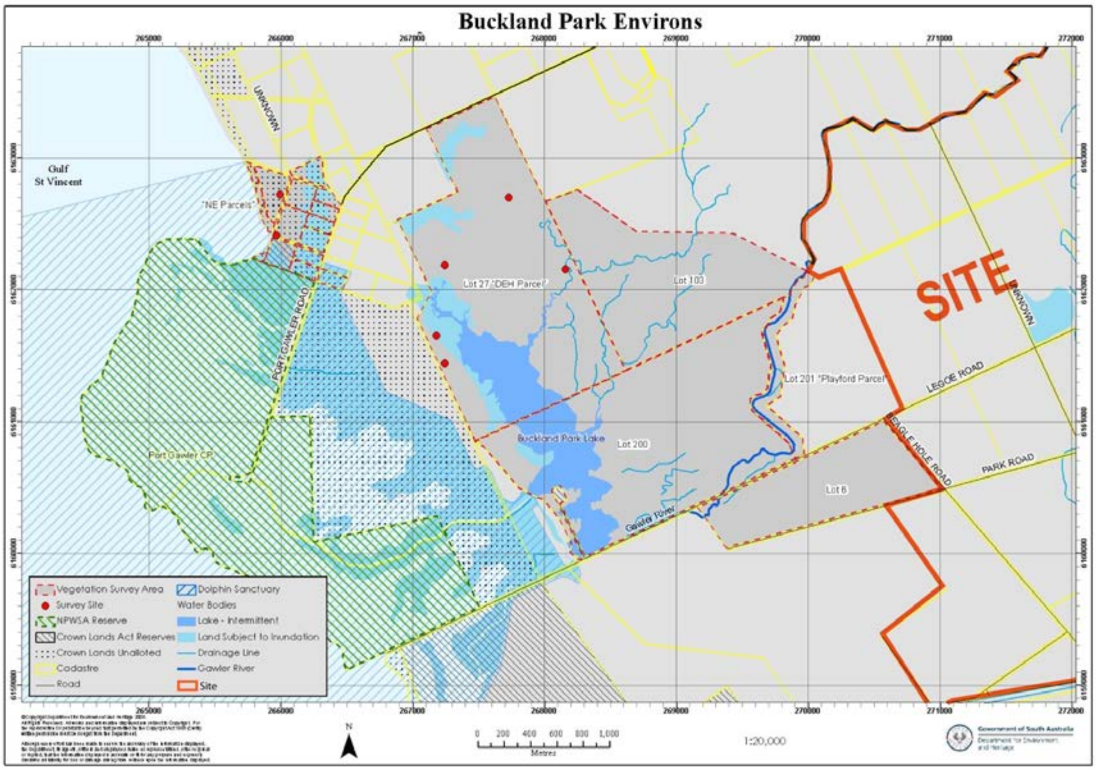
• Little Stint	*Calidris minuta*
• Long-toed Stint	*Calidris subminuta**
• Marsh Sandpiper	*Tringa stagnatilis**
• Musk Duck	*Biziura lobata*
• Orange-bellied parrot	*Neophema chrysogaster* (VE)
• Oystercatchers	*Haematopus* spp.
• Pectoral Sandpiper	*Calidris melanotos* *
• Pied Cormorant	*Phalacrocorax varius* (large colony of approx. 600)
• Plovers	*Pluvialis fluva*
• Red-capped Dotterel	*Charadrius ruficapillus*
• Rock Parrot	*Neophema pefrophila*
• Rufus Night Heron	*Nycticorax caledonicus*
• Silver Gulls	*Larus novaehollandiae* (approx. 300 000)
• Southern emu wren	*Stipiturus malachurus (E)*
• Spotless Crake	*Porzana tabuensis*
• Samphire Thornbill	*Acanthiza iredalei* (V)
• White-bellied Sea Eagle	*Haliaeetus leucogaster**
• Wood Sandpiper	*Tringa glareola**
• Little Bittern	*Ixobrychus minutus*

The region is well documented for its breeding and wading grounds for 57 birds of importance including 16 species in the Buckland Park Lake and 12 at Port Gawler listed under treaties (Baker 2004). Breeding waterfowl include the Australian Shelduck and Chestnut Teal. Additional terrestrial animal communities to be considered are insects, spiders, bush birds, reptiles, and native water rats that are addressed elsewhere in the proposal's environmental assessment.

1.3 Conservation Significance

1.3.1 Protected Areas

The Northern Gulf St Vincent has been proposed as a multiple use marine park under the current development of the State Governments target of 19 new Marine Parks for South Australia by 2010. It is likely that this marine park in the upper Gulf St Vincent would include Port Gawler. Figure 7 shows the relationship of the site to the various parks, reserves and public land holdings in the area.



Map obtained from the Department if Environment and Heritage adapted by Walker Corporation
Management (Aquatic Reserves) Proclamation 2007.

Figure 7: Relationship of the site to reserves, parks and public land

There are two aquatic reserves under the Fisheries Management (Aquatic Reserves) *Proclamation* of 2007, under *The Fisheries Act-1982,* within the region of the site; the St. Kilda-Chapman Creek Aquatic Reserve (870ha) and the Barker Inlet-St. Kilda Aquatic Reserve (2,055ha). The St. Kilda - Chapman Creek Aquatic Reserve includes the coastal waters to the west of the site.

The St Kilda – Chapman Creek Aquatic Reserve was established for the conservation of mangrove and seagrass communities and the protection of nursery areas for major commercial and recreational fish species. It provides a buffer area between commercial fishing activity and the Barker Inlet Aquatic Reserve. Boating and swimming are allowed, as is the taking of blue swimmer crab (*Portunus pelagicus*) by hand, crab rake or hoop net only, but bait digging, fishing and collecting or removing any marine organism (other than blue swimmer crabs) is not permitted. Its samphire-mangrove-mudflat ecosystem is an important, highly productive part of the near shore marine food web that provides shelter and breeding areas for many animal groups, stabilises coastal sediments and protects the coast from storm surge damage.

The Adelaide Dolphin Sanctuary encompasses the Barker Inlet within its zoning and development plans are currently in preparation (AMLR 2007).

1.3.2 Species of conservation significance

Species of conservation significance reported on the coastal ecosystems near the site include:

Critically Endangered (EPBC Act 1999).

• Orange-bellied parrot	*Neophema chrysogaster*

Endangered (EPBC Act 1999).

• Southern emu wren	*Stipiturus malachurus**

Vulnerable (EPBC Act 1999).

• Cape Barren Goose	*Cereopsis novaehollandiae*
• Samphire Thornbill	*Acanthiza iredalei*

Migratory species (EPBC Act 1999) and under the Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA) and the Convention on the Conservation of Migratory Species of Wild Animals - (Bonn Convention)

• Bar-tailed Godwit	*Limosa lapponica*
• Black-tailed Godwit	*Limosa limosa*
• Broad-Billed Sandpiper	*Limicola falcinellus*
• Common Greenshank	*Tringa nebularia*
• Curlew Sandpiper	*Calidris ferruginea*
• Eastern Curlew	*Numenius madagascariensis*
• Greenshank	*Tringa nebularia*
• Long-toed Stint	*Calidris subminuta*
• Marsh Sandpiper	*Tringa stagnatilis*
• Pectoral Sandpiper	*Calidris melanotos*
• White-bellied Sea Eagle	*Haliaeetus leucogaster*
• Wood Sandpiper	*Tringa glareola*

In addition the Coastal sawhedge, *Gahnia trifida* provides significant shelter and food source for the southern emu wren and the golden haired sedge-skipper butterfly, *Hesperilla chrysotricha*.

Marine fauna of conservation significance

Numerous Weedy Seadragons *Phyllopterix taeniolatus* were recorded along the stretch of coast from the Parham area southwards to Outer Harbour, during surveys from 1965 to 1971, generally in waters 5m – 15m depth, in Posidonia and Amphibolis seagrass (S. Shepherd, SARDI, pers. comm. to Dragon Search program, 2001).

The Weedy Seadragon was listed as data deficient in the IUCN Red List 2003, and the species is considered vulnerable to population impacts due to its strong site association. It is now protected, along with all other members of the Syngnathidae family, under the Fisheries Act 1982 (citations in Baker 2004).

Species noted as 'vulnerable' due to their strong site association within the upper Gulf St Vincent are;

• The Syngnathidae Family (Pipefish),

• The Clinidae Family (Weedfish and Snake-bleeny) and

• The Apogonidae Family (Cardinal fishes).

Fish from these Family taxa are known to give birth to live young; making their dispersal limited thereby increasing their vulnerability. The deep-bodied Pipefish (*Kaupus costatus*) can be found in the shallow, low energy areas in the upper Gulf St Vincent (Baker 2004).

Additional species identified for conservation significance within this region are;

• Congolli (*Pseudaphritis urvillii*), Common Galaxias or Jollytail (*Galaxias maculatus*), Mountain Galaxias (*Galaxias olidus*), and Flathead Gudgeon (*Philypnodon grandiceps*),

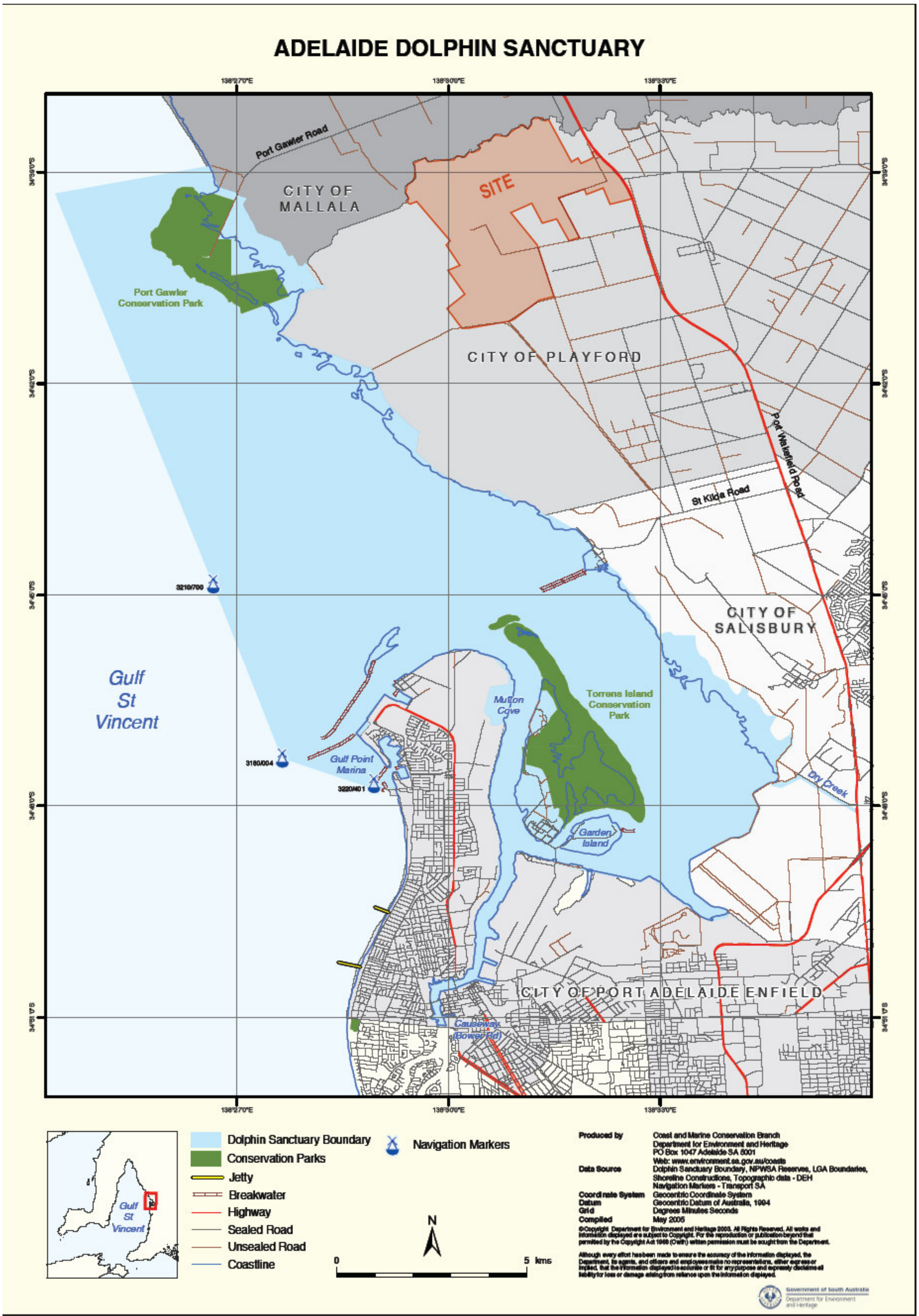
• Magpie Fiddler Ray (*Trygonorrhina melaleuca*) and,

• Invertebrate species including the brown or black striated sea anemone (*Edwardsia vivipara)*, and barnacles (*Elminius adelaidae* and *E. erubescens*).

1.3.3 The Adelaide Dolphin Sanctuary

The Adelaide Dolphin Sanctuary (ADS) is 118 km^2 and located along the eastern shore of Gulf St Vincent,. It is recognised that the Adelaide Dolphin Sanctuary zoning incorporates the Port River and Barker Inlet including the Port Gawler Conservation Park, encompassing the coastline adjacent to the site, Figure 8. *The Adelaide Dolphin Sanctuary Act 2005* states that the key habitat features such as the Port Adelaide River estuary and the Barker Inlet are maintained, protected and restored. *The Adelaide Dolphin Sanctuary Act 2005* also states that water quality within the region must be maintained for the health and wellbeing of the dolphin community.

Further recommendations within the ADS *Act* state that threats of serious or irreversible environmental harm that are absent of scientific certainty will not be justified. Issues of litter and possibilities of entanglement through rubbish are also included within the *Act.*



Map obtained from the Department of Environment and Heritage Cost & Marine ***2007.***

Figure 8: Adelaide Dolphin Sanctuary

1.4 The Site Within its Regional Context

The Cheetham salt pans on the western boundary of the Site are a highly altered coastal ecosystem. The salt pans separate the Site from the remnant samphire and mangrove vegetation by more than 2 kilometres. The Site is between 2.4 and 4 kilometres from the mean seawater level.

Apart from people the main interaction between the Site and the coastal habitats is through surface water runoff and modifications to the natural groundwater regimes. Both surface runoff and groundwater have been highly modified by the Cheetham salt pans and have exerted significant pressure on the natural coastal ecosystem as will be demonstrated in Section 2.

Further changes to the regional hydrology or water quality will increase the pressure on coastal vegetation. Walbridge and Gilbert Consulting Engineers (2008) report that stormwater from the Site currently drains to the Thompson Outfall Channel at the south eastern corner of the Site. The Gawler River is a perched waterway at its boundary to the Site and the banks of the river are higher than the surrounding ground. The Site generally drains from the north west to the north east away from the Gawler River.

The stormwater management philosophy for large flood events will be to detain the peak flows to match the existing predevelopment peak flows from the Site. Minor flows from the Site will be treated to meet South Australian EPA Environmental Protection Policy Water Quality (2003) requirements prior to discharge into the Thompson Outfall Channel.

Walbridge and Gilbert Consulting Engineers calculate that the net overall increase in runoff for the entire catchment is expected to represent 3% to 5% of the overall volume.

2. Investigation of the coastal plain

This Section presents the results of two field surveys conducted in February 2008 to evaluate the status of the coastal ecosystem near the site. The main focus for the survey was the health of the mangrove forests and samphire saltmarsh communities and the levee banks for the Cheetham Salt pans.

2.1.1 Methods

The health of the coastal ecosystem was assessed using vegetation transects, exploratory walks and photographs. The transect records and photographs, were used to estimate percentage ground cover. Species names were noted to the lowest known taxonomic level in the field and confirmed in the office using photographs and vegetation keys. Semi-quantitative methods were used to assess plant health and environmental stressors found within the mangrove or samphire communities.

The following data was recorded in the field:

- Vegetation communities and associations;
- Fauna observed in the mangroves, samphires, creeks and ponds;
- Exotic flora and fauna;
- Visual assessment of the Gawler River estuarine environment;
- General health of mangroves and samphires, including abnormalities or dieback;
- Sediment/soil types; and
- Detailed vegetation transects.

The site selection was based on; accessibility, proximity to the site and/ or likelihood of receiving impact from the proposal. Five sites were near the samphire/ mangrove margins were selected approximately 500m apart (Figure 9).

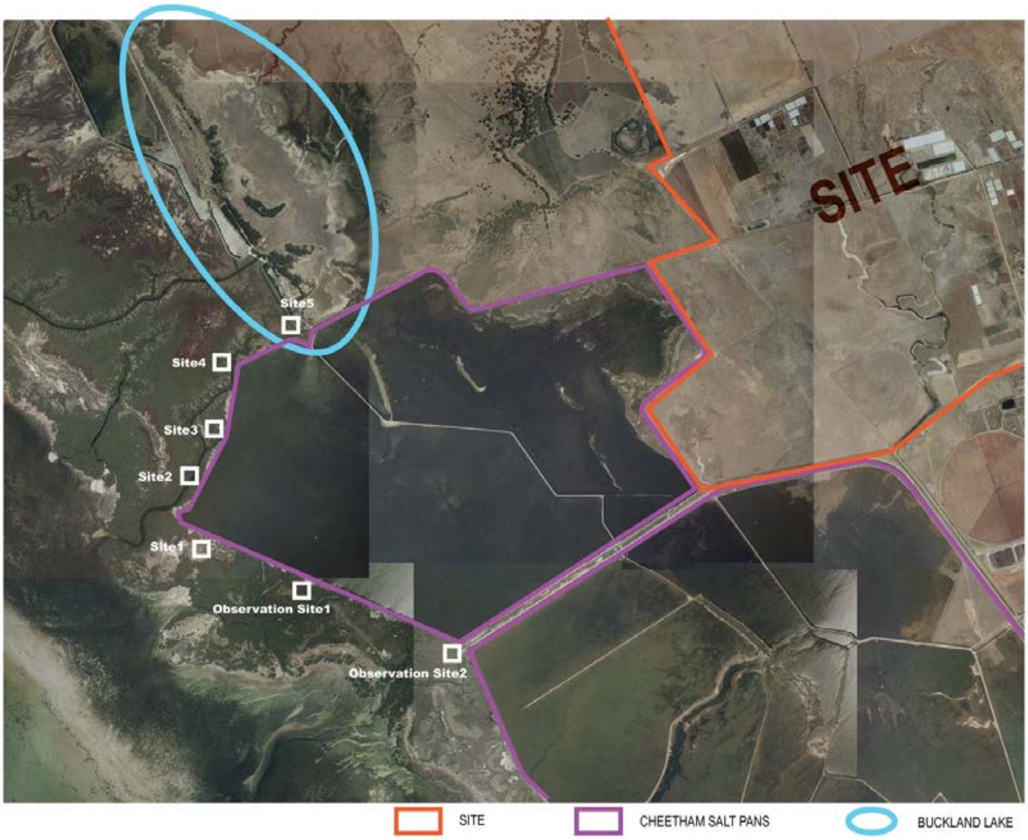


Figure 9: Coastal vegetation survey points

On 25 February 2008 two transects were surveyed at each site; one in mangroves and the other in samphires. Each transect was 25m long. Samphire transects were taken at a 90 degree angle to the levee banks to capture diversity, percent cover and fauna associations from above the high tide line to below the high tide line. Mangrove transects were placed along the front edge of mangrove stands directly behind the samphire transects.

The information recorded at each transect included GPS location, weather conditions, soil type, general elevation above high tide, fauna and flora, and associations between species. Each transect was photographed.

General observations of the health coastal ecosystems and stressors (such as feral animals, garbage, acid soils etc.) were made between transects. Appendix B provides details of all field records.

2.1.2 General Field Observations

• Freshwater creek flows have been modified by the presence of Cheetham Salt pans' levee banks. Flows into the marine environment have been cut off by a pumping system operated by Cheetham Salt.

• Yellow-orange staining was observed on sediments dredged to construct levee banks surrounding the northern end of the evaporation ponds next to the Thompson Outflow channel, which may be the result of pyrite oxidation (Figure).

• The levee banks are between 1m and 3m high.

• Mangroves are constricted by the levee banks, combined with the build up sediment on the seaward side, which is contributing to loss of mangrove.

• Samphire habitats being trampled by deer and polluted by general rubbish.

• Tidal creeks adjacent to the levee banks had variable appearance from clear to yellow stained water to black water sometimes associated with algal blooms (Figure 11 and 12).

• Poor water quality was observed in some creeks adjacent to levee banks showing algal blooms that are indicative of excess nutrients.

• Native terrestrial species observed include a Brown Snake (*Pseudonaja textilis*) and Sleepy Lizards (*Tiliqua rugosa*, see Figure 13) found in samphire communities.

• Abundant unidentified insect and arachnid populations in both mangrove and samphire communities.

• Coastal and mangrove vegetation was generally in good to excellent condition with small pockets of mangroves and samphire showing stress and dieback. These degraded pockets were often associated with stagnant pools of water, algal blooms, soft dark grey sediments and places where feral deer had trampled vegetation.

• Coastal vegetation communities consisted of samphire/saltmarsh and mangrove communities. The vegetation observed:

Common name	***Taxonomic name***
Chenopod	*Sarcocornia* spp.
Bead samphire	*Halosarcia flabelliformis*
Black seeded samphire	*Halosarcia pergranulata* spp. *Pergranulata*
Shrubby glasswort	*Sclerostegia arbuscula*
Nitre bush	*Nitraria billardierei*
Common sea-heath	*Frankenia pauciflora*
Coast saltbush	*Atriplex cinerea*
Coast bonefruit	*Threlkeldia diffusa*
Coast daisy bush	*Olearia axillaris*
Coastal lignum	*Muehlenbeckia gunnii*
Round-leaf pigface	*Disphyma crassifolium*
Knobby club-rush	*Isolepis nodosa*
Grey mangrove	*Avicennia marina*
Salt blue-bush	*Maireana oppositfolia*
African boxthorn	*Lycium ferocissimum* a pest weed species on the levee banks.

Figure 10: Yellow stained soils adjacent to the Cheetham salt pans

Note algal blooms and associated mangrove dieback indicative of poor water quality.

Figure 11: Stagnant water and sediment covering pneumatophores

Figure 12: Creeks adjacent to the levee banks

Figure 13: Sleepy lizard

- Bird life was abundant and diverse throughout the mangrove forest, samphire communities and Buckland Lake. Birds observed during the site visit comprised of:

Common Name	***Taxonomic Name***
Australian magpies	*Gymnorhina tibicen*
Cape Barren Goose	*Cereopsis novaehollandiae*
Pied Cormorant	*Phalacrocorax varius*
Australian Pelican	*Pelecanus conspicillatus*
White faced heron	*Egretta novaehollandiae*
Silver gull (seagulls)	*Larus novaehollandiae*
Black Swans	*Cygnus atratus.*

• Observations of the estuarine environment from the pier (GPS South 34.4115, East 138.2735) adjacent to the evaporation pond showed; abundant schools of juvenile fish including southern garfish (*Hyporhamphus melanochir*) and yellow eye mullet (*Aldrichetta forsteri*). Mangroves around the pier were in excellent condition (Figures 14 and 15).

• Samphire/saltmarsh vegetation growing along the tops of the levee banks appeared to be burnt or dying in response to wind-driven salty foam collecting on samphire species.

• Numerous marine species important to ecosystem function and commercial industry were also observed including the yellowfin whiting (*Sillago schomburgkii*), yellow eye mullet (*Aldrichetta forsteri*), southern garfish (*Hyporhamphus melanochir*) and largemouth goby (*Redigobius macrostoma*).

Photo of an intertidal creek linking Gawler River to the Flood plain note the mangroves appear to be in excellent condition.

Figure 14: Mangrove forest communities along the Gawler River estuary

Figure 15: Healthy pneumatophores of Grey Mangrove in the Gawler River Estuary

2.1.3 Saltmarsh/ Samphire Transects.

Samphire **Site 1** consisted of 3 chenopod species, only the *Sarcocornia* spp extended into the intertidal zones. The two *Halosarcia* spp were only found on the Cheetham Salt levee bank. Figure 16 shows samphire communities forming intermittent bands with dead mangroves. Muddy and anoxic sediments found at this site are typical of tidal flats in this region.

The levee banks consisted of heavy brown to red clay and beyond the levee bank very fine grey to black marine sediment. The mud crab (*H. haswellianus*) was generally found in association with the Halosarcia samphire. This site was in good health although the coastal retreat is cut off by the Cheetham Salt levee banks and the samphire species were spreading over old mangrove ground.

Samphire at **Site 2** was restricted to the Cheetham Salt levee bank shown inFigures 16 and 17, beyond this area was a complex drainage system consisting of dead mangroves and soft black marine sediment. Small creeks in this area are intertidal and connected to the freshwater drainage systems from the Gawler River. Minimal flushing of the creek system was evident by algal growth in creek. Trampling by deer at this site is causing further loss of vegetation. Fox prints and scat were found throughout this transect.

Figure 16: Site 1, samphire dead mangroves and mud

Figure 17: Site 2, open samphire community

Samphire **Site 3** was characterised by a steep gradient from the top of the levee bank to a small intertidal/ freshwater drainage creek shown in Figure 18. Most samphire species were restricted to the levee bank, with the exception of *Sarcocornia* spp that extended out to the mangroves. An algal bloom was observed in one of the small drainage creeks along with old tyres, plastic bags and general rubbish.

Site 4 consisted of samphire and coastal saltbush above the high tide line and extensive community of *Sarcocornia* spp in areas where water periodically pools (Figure 19). The constructed levee banks have cut off the coastal retreat of mangroves and leave very limited growing area for the samphires.

Deer tracks were found throughout this site and in places have created permanent walking tracks. Two drainage creeks were found at this site, one directly at the base of the levee bank and the second creek separated the *Sarcocornia* spp and the mangroves. The transect at the toe of the levee bank followed the high water mark, the *Sarcocornia* spp grew on the seaward side below the high water mark.

Figure 18: Site 3, Samphire intersected by a creek with an algal bloom

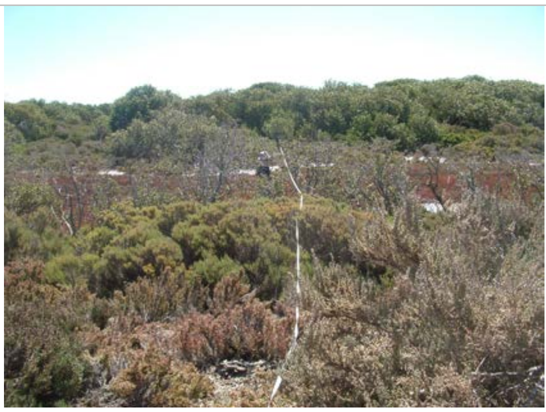


Figure 19: Site 4, Samphire and coastal saltbush

Samphire/saltmarsh complex at **Site 5** adjacent to the Gawler River was in very good condition (Figure 20). Sediments varied from fine grain mud close to the river through to coarser grained sand away from the river.

The good condition of this site was attributed to more growing space between the high tide and the Cheetham Salt levee bank. As seen in Figure 20, the large area of available land has promoted greater species diversity. Deer tracks were found along the edge of the creek and extended out to the mangroves approximately 400m away. General rubbish was found intermittently scattered on the site, mostly around the drainage channel from the Gawler River.

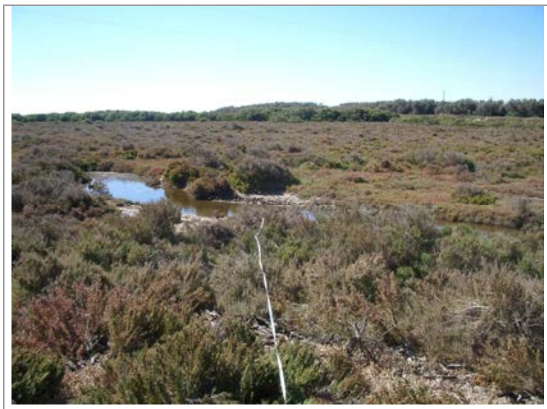


Figure 20: Site 5, Samphires on the mouth of the Gawler River

2.1.4 Mangrove Transects 25/02/08.

Mangrove health for each site was evaluated using measures of plant height, pneumatophores clearance above sediment and trunk widths for each transect, Table 2.

Table 2: Indicators of Mangrove Health

Mangrove	Site 1	Site 2	Site 3	Site 4	Site 5
Average Height (m)	2.5	1.6	0.75	4.16	4.2
Average Trunk width (cm)	23.75	9.15	6.28	30.6	30
Average Pneumatophores (cm)	20.6	6.63	5.92	13.3	15

The five mangrove transect were categorised into two groups; large healthy robust trees at sites 1, 4 and 5, (Figure 21) and small trees suffering stress due to sediment build up and water inundation at sites 2 and 3 (Figure 22).

Sites 1, 4 and 5 had the healthiest pneumatophores with clearances above sediment averaging between 13.3cm and 20.6cm. These sites also had greater average heights and trunk widths.

Sites 2 and 3 are located in an area with intermittent pooling of water and pneumatophore clearance is only 6.6cm and 5.9cm, indicating that sites 2 and 3 are at a greater risk of dieback associated with sedimentation (Figure 22 shows dead and stunted mangroves). Both sites 2 and 3 are located in an area where small drainage channels cut through the area between the Cheetham Salt levee banks and mangrove stands. These areas trap seawater and freshwater from the Gawler River during flood events, probably contributing to the degradation of mangrove stands in this area.

Figure 21: Site 1, Healthy mangroves

Figure 22: Dead or dying mangroves and water pooling

2.1.5 Summary of Mangrove and Saltmarsh/ Samphire Survey

The field surveys undertaken for the purpose of this study do not encompass seasonal variations and associated fauna and flora assemblage changes between seasons. However, the field surveys have confirmed the literature review that the coastal ecosystem to the west of the site supports abundant flora and fauna. In general the mangrove forest and samphire habitats are in good to very good health. At the same time the survey noted the significant anthropogenic impact on these habitats and signs of the gradual loss of mangroves and samphire were evident.

The most significant impact is the physical barrier created by the Cheetham Salt levee banks that are blocking the retreat of mangroves and samphire as sediment and detritus is deposited in successive storms builds up. Sedimentation around the pneumatophores increases mangrove mortality (Mifsud *et al* 2004). Any rise in sea level will further restrict the available land for mangrove and samphire.

Other environmental stressors on these habitats include trampling by deer predation by foxes and weed such as the African boxthorn observed growing on the levee banks. Rubbish (discarded tyres, plastic bags and oil drums) and the more widely fluctuating flows of the Gawler and Thompson Rivers are also having an impact on the health of the mangroves and samphire habitats.

2.1.6 Conclusion

The remnant coastal plain is within reserves or unallocated Crown Land. It is understood the Department of Environment and Heritage has responsibility for the management of that land.

Our survey of the coastal plain west of the Site found ecologically significant vegetation and habitat, but has suffered degradation from feral animals and general rubbish. The impacts of Cheetham's salt pans, with changes to land form and hydrology were also evident.

The site, while adjacent to the coastal plain does not directly form part of its ecological systems. The proposal has therefore the potential to indirectly impact on the coastal environment. These potential impacts are discussed in Section 3

3. Marine and Coastal Environment Risk Assessment and Management

This section is divided into two parts; the first describes the existing stressors to the coastal and marine ecosystems, the second part identifies potential risks that may arise from the Buckland Park proposal and presents a risk assessment with recommendations of appropriate control measures to reduce the level of risk on these ecosystems.

3.1 Existing Stressors to the Marine and Coastal Ecosystems

3.1.1 Coastal retreat

The loss of extensive areas of seagrass along the Adelaide metropolitan coast has caused the mobilisation of exposed sediment. Resuspended sediment moves northwards and is deposited on sand banks (such as Section Bank) off Outer Harbor and the northern beaches (Mifsud *et al* 2004, Fox *et al* 2007). The build-up of sediment and detritus around the mangrove pneumatophores appears to be causing the loss of mangroves on the shore front; the mangroves retreat further inland if suitable land is available (Mifsud *et al*, 2004). However, in Buckland Park the Cheetham Salt levee banks west of the site, prevent the retreat of mangroves.

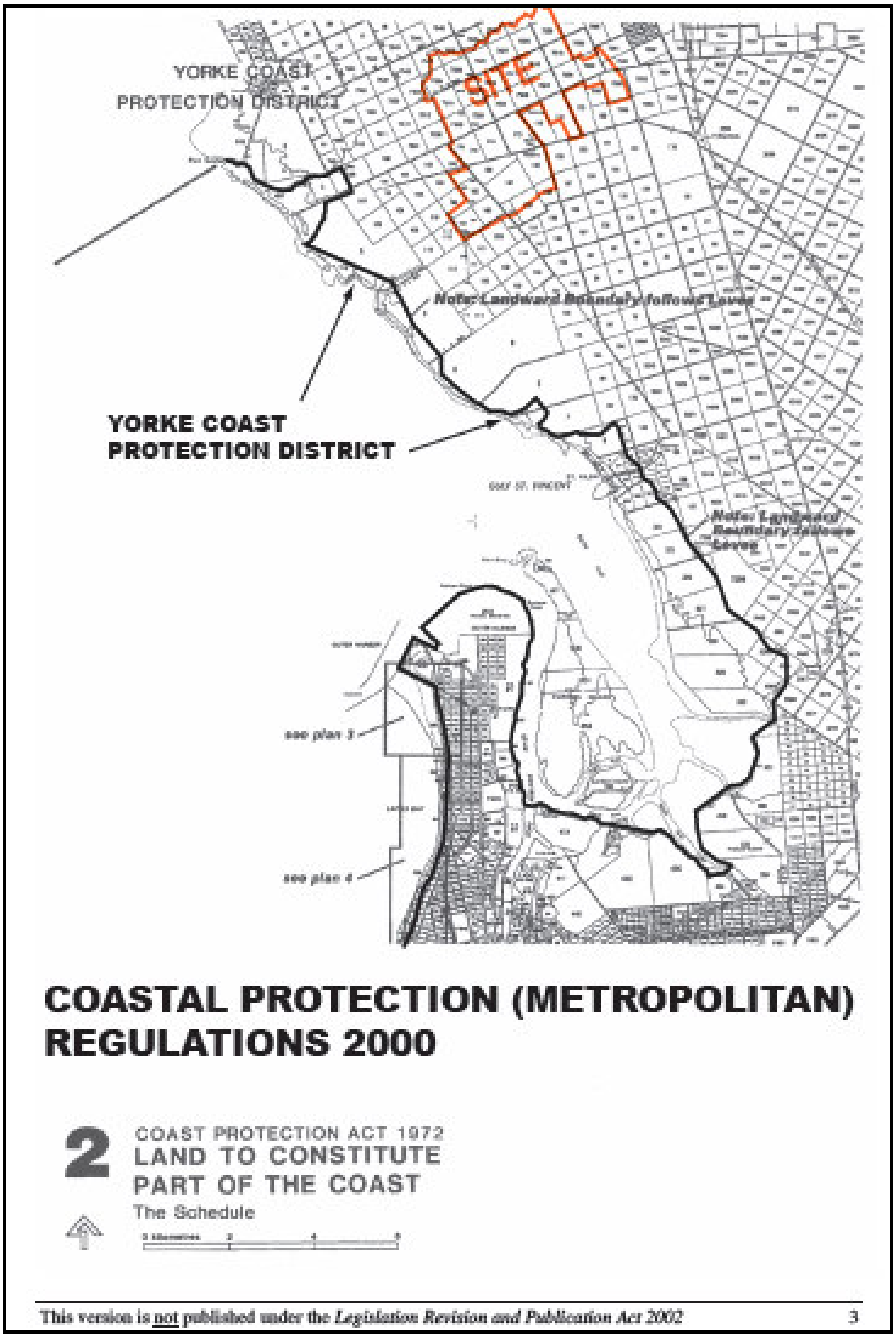
Sea level rise, attributed to climate change, will increase the pressure on seagrass, mangroves and samphire communities to advance further inland, or retreat (Harvey 2002). This will become more pronounced along coastlines that are characterised as low gradient, such as the upper Gulf St Vincent. This topic is dealt in more detail elsewhere in proposal's environmental assessment.

The retreat of coastal vegetation as sea level rises is prevented by the Cheetham salt pans, which create a barrier at the eastern edge of the coastal plain. Accordingly the proposal will not influence the outcomes of coastal retreat in this area.

3.1.2 Sea level rise

Sea level rise are predicted to effect developments near the coast. The site is at a higher elevation than the Yorke Coast Protection District and does not constitute land that is "part of the coast" under the schedule Coast Protection Act of 1972 as shown inFigure 23. Sea level rise will affect coastal land adjacent to the site through:

- Increased intensity and frequency of storm surges and coastal flooding;
- Increased salinity of rivers and coastal aquifers;
- Increased coastal erosion;
- Loss of mangroves and samphire flats;
- Increased sedimentation and impact on marine ecosystems.



Map supplied by Walkers Corporation adapted from Coast protection Act 1972.

Figure 23: Site location with respect to the Yorke Coast Protection District

The Intergovernmental Panel on Climate Change (IPCC) assessments in 2004 predict global sea level rise will range between 0.09m and 0.88m, averaging 0.48m by the year 2100. During 1991 the South Australian Coast Protection Board predicted sea level rise for SA to be within the range of 0.33m - 1.10m, averaging 0.65m by 2100, advising that any new coastal development should be capable of being reasonably protected by a 1m sea level rise by 2100 (Harvey 2002).

The Coast Protection Board recommended in 1991 recommend that flood protected designs should incorporate extreme storm water events (Caton et. al 2007) and tidal surges, in addition to wave effects. It is noted that more research into climate change predictions within this region are required including coastal vulnerability assessments for management purposes.

As stated earlier in this report, general trends of elevated sea level are expected to cause mangroves and associated saltmarsh communities to retreat further inland to adapt to sea level rise resulting in changes to ecological zoning of both supra-tidal and inter-tidal communities including displacement of seagrass meadows (Harvey 2002, Caton *et. al* 2007).

Further implications include the possibility of localised flooding in low gradient coastlines, raised groundwater levels, in addition to modifications of estuarine environments (Harvey 2002). Sea surface temperatures by 2070 are predicted to be 1-2 $^{\circ}$C warmer, with the greatest warming to occur in SE Australia and the Tasman Sea due to a strengthening of the East Australian Current (Hobday *et al*. 2006).

Accurate predictions for sea level rise, including thermal expansion and glacial melt, are constantly changing due to variations in opinions, data and predictive models. Currently there are no State or National management plans to advise coastal developments on accurate measures of sea level rise within South Australia. Research is currently underway by the Coast Protection Board to make recommendations that will withstand 100 - 200 year planning for coastal development purposes with special regard to developments in low lying areas of between 1m and 5m.

Implications of climate change likely to affect the Site include protection from the predicted more frequent storm surges and more frequent flooding events. Hydrological studies for this EIS provide more specific information regarding water intrusion events from fresh water flooding and marine intrusion. The levee banks currently in place at the Cheetham Salt operations may provide protection from incoming tidal surges within the area, see hydrological report for more information <enter cross reference to W&G Consulting Engineers>).

3.1.3 Stormwater Discharges

Coastal urbanisation is known to modify flows from rivers entering the marine environment (DEH, 2007). Stormwater and wastewater entering the sea can be high in sediments, nutrients and pollutants, including pesticides, detergents and other organic compounds. Urban developments are also known to change flow rates to more intermittent, higher velocity regimes, which cause erosion and increase sediment input into the sea (DEH, 2007).

Turbidity and sedimentation have been identified as important contributors to seagrass loss (EPA 1988). Studies undertaken by Shepherd *et al.* 1989 identified that the primary cause for seagrass decline within the Gulf St Vincent region was through anthropogenic disturbances that increases turbidity and nutrients resulting in the loss of light availability for photosynthetic process and reduced ability to fix carbon.

Increased nutrients have also been associated with increased epiphyte load on seagrass blades reducing light availability and reducing the resilience to wave action. The extensive loss of seagrass off Adelaide's metropolitan coast has been attributed to many years of near-continuous inputs of nutrient rich, turbid, and coloured water and wastewater (Fox *et al* 2007).

As seagrass meadows are known to sequester carbon, a decline in the ability of seagrass communities to fix carbon may have further implications for climate change strategies and objectives set out recently by both the State and Commonwealth Governments.

Additionally, increase in sedimentation within the water column coats the seagrass leaf blade and inhibits light penetration to the leaf surface (Shepherd et al. 1989). As a flow on effect from a decline in seagrass health, degraded seagrass beds cause loss of sediment stability, further increasing turbidity within the water column. Extreme cases of sedimentation are likely to result in complete burial and eventual dieback of seagrass beds (Harvey 2002) and mangroves (Mifsud *et al* 2004).

The proposal will result in an urban population in a new location and has the potential to contribute to polluted stormwater discharge through the Gawler River and Thompson Channel Outfall.

3.1.4 Coastal Acid Sulphate Soils

Sediments containing iron sulphides and organic matter have the potential to generate acid on exposure to air. Coastal Acid Sulphate Soils (CASS) are generally found within mangrove, estuaries and lakes and associated low energy areas such as the tidal flats found within northern Gulf St Vincent (DEH 2007). On exposure to air CASS oxidise and release acid, sulphates, granules of iron, aluminium and heavy metals. These pollutants may contaminate streams, pools and the receiving sea waters.

A separate study testing soils and subsoils by Golders & Associates for acid sulphate soils found potentially acid generating soils in the southern portion of the property but are not likely to be intercepted by proposed land uses described in the proposal's Masterplan .<include reference by Golders & Associates>.

3.2 Environmental Risk Assessment and Risk Management for the Marine and Coastal Ecosystems

The approach to risk management used in this study is based on the Australian Standard 4360:2004 risk management framework, which consists of:

- The identification of activities that may impact on the surrounding environment;
- Implementing control measures to reduce the level of risk; and
- Monitoring the effectiveness of the control measures.

In this study we have added contingency plans for unpredictable failures of any control measures recommended and implemented.

3.2.1 Activities that may impact on the surrounding environment

A number of risks associated with various stages of the proposal have been considered including construction activities during the initial subdivision and subsequent activities, such as the construction of dwellings and ongoing occupation. This risk assessment recognises that the proposal will take place in a staged manner over a 25 year period.

A risk register for the marine and coastal environments used for this assessment is presented in Table 3. The level of risk if any they present to the coast and marine environment are evaluated in Section 3.3. This register is divided into three columns listing the aspects of the environment that may be affected; the specific components of that aspect; and the identified risk that may harm the marine or coastal ecosystem. Note that the risks listed are registered for evaluation purposes and are not necessarily a real or significant risk to the coastal marine ecosystem.

Table 3: Marine and Coastal Environments Risk Register

Aspect	Component	Potential risk to the marine or coastal environment
Air quality	Odour and gaseous (volatile) emissions	1. Petroleum hydrocarbon spills during construction may generate offensive odours that may affect fauna. 2. Marine sediment and CASS disturbed by construction activities may generate offensive odours that may affect fauna.

	Dust (particulate) emissions	3. Traffic and earth moving activities may generate dust that could cover vegetation and reduce biological production. 4. Wind and vehicular activities may generate dust from exposed surfaces and reduce biological production.
Noise	Noise	5. Construction machinery may generate nuisance noise and disrupt breeding patterns of coastal fauna. 6. Traffic and urban noise may generate nuisance noise that may disrupt breeding patters of sensitive coastal species.
Surface water	Surface water protection	7. Stormwater runoff from the development may contaminate the Gawler River estuary and the sea.
	Flow	8. Altered discharge regimes may result in prolonged dry periods or extended inundation that may affect vegetation and animals' dependent of the ecosystem. 9. Altered salinity regimes, either increased freshwater or increased saline water may alter the composition of coastal vegetation. 10. Increased risk of storm surge caused by a combination of increased tide levels and the backup of runoff water from urban water shedding, which may result in the loss of coastal vegetation.
Land - Soil	Soils management	11. Vehicular access may cause soil compaction. 12. Excavation of CASS may release acid and metals that will contaminate soil and affect plants and animals. 13. Land use conversion from rural to urban may reduce or improve the opportunity for marine/ coastal plants and animals.
Groundwater	Groundwater Protection	14. Pollutants from urban occupation and acid leachate from disturbed soil may contaminate groundwater.
Flora & Fauna	Flora	15. Acid leachate may harm acid intolerant terrestrial plants. 16. Turbidity may reduce production of marine flora. 17. Nutrients may cause eutrophication. 18. The introduction of exotic species will degrade the vegetative cover and reduce the availability of some animal food sources and refuge.
	Fauna	19. Acid and metal leachate may be toxic to marine animals. 20. The introduction of exotic species will compete with other animals for limited resources.
Heritage	Heritage	21. Human activities on the coastal plains may harm significant flora and fauna on the coastal fringe.
Social	Recreational	22. Coastal and marine focused recreational activities. 23. Recreational fishing may result in overfishing of the mangrove habitat.
	Waste generation	24. Rubbish will adversely affect plant and animal life.
	Commercial	25. Reduction of fisheries

Risk is a function of impact (consequences) and likelihood (probability) of a harmful event occurring. The level of risk can be reduced by implementing control measures and a management program.

The level of risk posed to the marine environment from the proposal was determined qualitatively based on literature and data available at the time of undertaking this study; including the project description, field survey, site observations, professional experience and judgement.

To evaluate the potential impacts of activities or events such as stormwater discharge, traffic, recreational activities and the generation of waste on the coastal and marine environment, the duration of the harmful event, the severity of the impact, the extent of the impact and the resilience of the ecosystem to the stressor were considered. In this study the level of impact was evaluated using the matrix outlined in Table 4.

Table 4: Impact assessment matrix

Consequence \Level	1	2	3	4
Duration of impact stress	**Immediate** Few days.	**Short-term** 1 season.	**Medium-term** 1-2 years.	**Long-term** > 2 years.
Severity of impact	**Negligible** Not detectable.	**Minor** Temporary impact on few species.	**Moderate** Effect significant proportion of population of one or more	**Severe** Threatening the survival of one or more species.

			significant species.	Destruction of habitat.
Scale of impact	**Local** Within 100m.	**Embayment** A few kilometres.	**Regional** Tens of kilometres.	**Global** Loss of an endemic species.
Ecosystem resilience	**Good** Small or temporary loss in productivity.	**Moderate** Will recover within 1 season.	**Poor** Will not recover locally or take a few decades.	**Devastating** Irretrievable loss.

The likelihood of harming the marine environment is very dependent on the control measures implemented and enforced both during and after construction. In this assessment, three levels of likelihood will be used to calculate the level of risk:

- **Low**, the event could occur, but is not expected (1% probability or less),
- **Medium** the event may occur but not always (between 1 and 20% probability), and
- **High** the event is expected to occur frequently (probability of 50% or more).

This level of risk calculation consists of adding the impact scores (consequences) from Table 5 and multiplying by the likelihood of the event occurring where low is given the value of 1, medium the value 2 and high the value 3.

Using this formula the lowest risk score is 4 and the highest risk is 48. Note these are qualitative values and care should be taken in extrapolating beyond the limits of this study. For comparative purposes risk scores between 4 and 12 will be considered as an acceptable level of risk, scores from 13 to 24 are low level risk, scores from 25 to 36 are medium level of risk and 37 to 48 are a high level of risk.

Table 5: Risk Matrix

4	5	6	7	8	9	10	11	12	13	14	15	16
8	10	12	14	16	18	20	22	24	26	28	30	32
12	15	18	21	24	27	30	33	36	39	42	45	48

Clear boxes = some level of risk, Green = low level risk, Yellow = medium level of risk and Tan = high level of risk.

The control measures recommended in the following sections are intended to reduce the risk to an acceptable level. This does not mean that they have no impact on the environment, for example the impact of increased recreational fishing on fish populations will never be zero because more fishers means more fish removed. This type of assessment does not adequately factor in the community's social values and issues that are addressed elsewhere in the environmental assessment.

3.2.2 Assumptions:

- It is assumed that the stormwater management philosophy is implemented as reported by the Proponent to ensure that runoff from the Site will meet the SA-EPA Schedule 2 water quality criteria for aquatic ecosystems (EPA 2003) and that groundwater levels and quality will not change from existing conditions. (Wallbridge and Gilbert)
- It is assumed that flows to the Gawler Estuary and the coastal plains will not be altered by the proposal.
- It is assumed that construction activities will not disturb acid sulphate soils commonly found on the wetlands and intertidal areas in the Gulf St Vincent, accordingly it is assumed that the proposal is not expected to directly cause the release of acid and metal bearing leachate into the coastal and marine environment.

These assumptions were based on information provided by the proponent and discussed elsewhere in the environmental assessment.

3.3 Detailed Risk Assessment

This Section evaluates the potential environmental impacts that may arise from the Buckland Park proposal, sets management objectives and proposes a control measure to achieve those objectives. Each risk event identified in Table 5 is systematically evaluated assuming that the control measures proposed have been implemented. That is the size of impact and likelihood of a specific event occurring are based on the control measures being in place and used to calculate the residual risk after control measures have been implemented.

3.3.1 Air quality

Risk 1: Petroleum hydrocarbon spills may generate offensive odours that may affect fauna. **Risk 2:** Marine sediment and CASS disturbed by construction activities of generate offensive odours that may affect fauna.

Potential impacts: Petroleum hydrocarbon spills or the disturbance of CASS or marine muds may generate offensive odours that may physically affect marine fauna or alter their behaviour or may be a public nuisance. The Site is over 2 kilometres from the coastal ecosystems, it is envisaged that if an accidental petroleum spill occurs there will be considerable opportunity to control the spill before it reaches the coastal vegetation. The proponent does not intend to disrupt acid sulphate soils and has generated maps of where this soil is likely to occur on the Site.

Management Objective: To prevent petroleum spills and the excavation of CASS and marine muds.

Control Measure: The proponent will ensure that all contractors working on the proposal have implemented Standard Operating Procedures (SOP) for all vehicles and equipment on site. The proponent or their designated responsible person will check the SOP and verify that they are properly implemented. The responsible person will have the authority to reject operating procedures that do not meet the management objective and / or stop unacceptable activities on site. If these control measures are satisfactorily implemented the level of risk will be maintained at an acceptable level.

Duration: [1] The odour emitted by hydrocarbons, decomposing organic matter and sulphides will last from a few days from any single emission event.

Severity: [2] Odours gases will have a temporary effect on a few animal species and a nuisance factor to humans. A loss of small sensitive animals may occur in the immediate vicinity of the source.

Scale: local [1] These odours gases are expected to remain within a 100m of the site.

Resilience: [1] The sense of smell will recover within a few hours of an exposure, the local effect of gases on fauna will not last more than a few days.

Likelihood of risk event: **Low** to **medium.** There is a very low likelihood of hydrocarbon spills or excavation of CASS or anoxic marine mud to occur with the proposed control measures during development but a medium likelihood of a spill to occur or illegal excavation of CASS post construction, with less supervision.

Residual Risk: 10, insignificant to low level of risk remaining

Performance Indicator: No odours from petroleum or oil and no odours from excavated marine mud or CASS.

Monitoring: The proponent will undertake routine site inspections to check for any signs of hydrocarbon spills or any excavation outside of the designated areas.

Contingency: If offensive odours are detected during construction the source will be identified and appropriate action taken. This may consist of covering excavation with clay, neutralising or removing the odour generating material to a designated landfill. Any petroleum or oil spill will be immediately removed using the appropriate oil spill response equipment and recycled or disposed in an environmentally safe manner.

New control measures will be implemented to prevent the event from reoccurring; these may include reviewing the oil management plan or soil survey results (for classifying CASS or organic marine muds) and modify the work program to avoid excavation of potentially putrid soils.

Risk 3: Traffic and earth moving activities may generate dust that could cover vegetation and reduce biological production. **Risk 4:** Wind generate dust from exposed surfaces and reduce biological production.

Potential impacts: Airborne dust may cover plants and inhibit photosynthesis, which will lead to reduced biological productivity or loss of vegetation. Fauna will be directly affected from nuisance value of fine dust and indirectly affected from the loss of habitat and food. Airborne dust may become a nuisance to people working or living nearby. Most of the dust will fall out before reaching the coastal vegetation over 2 kilometres from the Site.

Management Objective: To prevent excessive dust generation.

Control Measure: Activities that have the potential to generate dust will be restricted to periods of low wind and the surface kept moist to prevent dust from leaving the site. Exposed surfaces that may generate dust will be sprayed with water or a dust suppressant until they are sealed and revegetated.

Duration: [4] over the construction period (25 years).

Severity: [2] temporary impact on some plants and animals particularly insects.

Scale: [1] local within few 100m of the Site.

Resilience: [2] vegetation will recover within one season.

Likelihood of risk event: **Low** likelihood of dust generation after control measures because of the unpredictable nature of winds and the rate of soil drying are medium but distance from site reduce the likelihood of impact on the coastal ecosystem.

Residual Risk: 7, low level of risk remaining

Performance Indicator: No build-up of dust on coastal vegetation.

Monitoring: The proponent will undertake routine site inspections to check for any signs of airborne dust, install and monitor dust deposition gauges to demonstrate the effectiveness of dust suppression.

Contingency: If dust generation should exceed the management objective the activity will be stopped until remedied; exposed surfaces will be immediately sprayed with water or dust suppressant and sealed or vegetated as soon as practicable.

3.3.2 Noise

Risk 5: Construction machinery may generate nuisance noise and disrupt breeding patterns of coastal fauna. **Risk 6:** Traffic and urban noise may generate nuisance noise that may disrupt breeding patters of sensitive coastal species.

Potential impacts: construction noise particularly during the breeding season may result in birds that use the coastal wetlands to abandon their nests. The impact of noise on other animals is not clearly documented but anecdotal evidence suggests that noise limits the opportunities for predation by some animals such a snakes. It is not anticipated that noise levels reaching the coastal habitats will be higher then background levels.

Management Objective: To prevent excessive noise generation.

Control Measure: Since blasting is not proposed the main sources of noise will be construction equipment and vehicles. All construction equipment and vehicles will meet the relevant Australian noise standards.

Duration: [4] Up to 25 years during the construction phase

Severity: [2] temporary impact on some animals particularly birds.

Scale: [1] local within few 100m of the construction zone.

Resilience: [1] most animals will recover with small loss in production, although a few birds may miss a breeding season.

Likelihood of risk event: **low** likelihood of significant noise reaching the coastal habitats from the Site.

Residual Risk: 8, low level of risk remaining

Performance Indicator: No disruption to breeding season.

Monitoring: The proponent's designated person will check for nuisance noise and follow-up on complaints attributable to noise from the Site during construction.

Contingency: If loud noise attributable to construction activities is detected the source will be identified and shut down until it can be repaired or an alternative is found. All potential noise sources that are related to construction activities will be inspected to ensure that the nose baffling control measures are in place and operating to specifications.

3.3.3 Surface water

Risk 7: Stormwater runoff from the development may contaminate the Gawler River estuary and the sea.

Pollutants associated with urban projects include nutrients, oil/grease, detergents, particulate and soluble metals, organic chemicals, suspended particulates, turbidity, salinity and increased acidity or alkalinity. These pollutants will affect coastal and marine vegetation and animal life (see impacts under flora and fauna below).

Potential impacts: Loss of seagrass beds, mangroves and associated ecosystems.

Management Objective: To prevent release of water that does not meet the EPA-SA water quality criteria (marine).

Control Measure: All effluent from the site will be piped to SA Water treatment facilities at Bolívar. Stormwater will be intercepted and treated or diverted for reuse.

Duration: [4] Several hundred years starting from stage 1 and over the life of the proposal.

Severity: [3] Loss of seagrass, mangroves and associated ecosystems.

Scale: [2] Local within the Gawler estuary and embayment.

Resilience: [3] Seagrass will take decades to recover and possibly a hundred years if there is no active seagrass replanting. Mangroves are also slow to regenerate but take less time, around one or two decades to recover. The problem with mangrove recovery in this area is that there is very limited suitable land available to re-establish especially if other species establish first.

Likelihood of risk event: **low** likelihood of the release of nutrients and sediment from the Site because all sewage effluent will be piped to the SA Water treatment facilities and stormwater runoff from the proposal will be intercepted and treated to meet the EPA-SA *Water Quality (Marine) Criteria* (EPA, 2003) prior to discharge.

Water temperature was not considered to be an issue because ambient water temperature from runoff would be similar to the surrounding surface water from the catchment area.

Residual Risk: 12, low level of risk remaining

Performance Indicator: All runoff and stormwater leaving the development will meet the SA EPA *Water Quality (Marine) Criteria* see Table 6.

Table 6: SA EPA Water Quality (Marine) Criteria

Pollutant	Schedule 2 water quality criteria EPA - SA (Marine)
Antimony Total (mg/L)	0.5
Arsenic Total (mg/L)	0.05
BOD (5 day @ 20oC)	10
Boron Total (mg/L)	0.3
Cadmium Total (mg/L)	0.002
Chlorine Total (mg/L)	0.0075
Chromium VI (mg/L)	0.0044
Colour (Colour Unit)	15
Copper Total (mg/L)	0.01
Lead Total (mg/L)	0.005
Mercury Total (mg/L)	0.0001
Nickel Total (mg/L)	0.015
Nitrogen - Ammonia (mg/L)	0.2
Nitrogen - Oxidised (mg/L)	0.2
Nitrogen - Total (mg/L)	5
Phosphorus – Dissolved (mg/L)	0.1
Phosphorus - Total (mg/L)	0.5
Selenium Total (mg/L)	0.07
Silver Total (mg/L)	0.001
Thallium Total (mg/L)	0.02
Total Organic Carbon (mg/L)	10
Total Suspended Solids (mg/L)	10
Turbidity (NTU)	10
Zinc Total (mg/L)	0.05

Adapted from EPA (2003)

Monitoring: The proponent will implement a water quality monitoring program to verify that all surface water leaving the property (through the Thompson Channel Outlet and groundwater) meets the SA EPA *Water Quality (Marine) Criteria*. In the longer term, as the proponent's role in the proposal ends, this monitoring program will be handed over to Playford City Council, as ultimate owner of the open space and stormwater systems.

Permanent turbidity, salinity, pH and water temperature monitoring stations will be established prior to the outlet of artificial lakes or water holding facilities to provide an early warning system of the eminent release of potentially poor quality water, and on the Thompson Channel Outlet and on strategic groundwater monitoring bores to demonstrate that the water is in compliance with the criteria.

Automatic water samplers triggered by a flow event will be used to sample water for testing nutrients, suspended solids, metals, organic chemicals (including synthetic pollutants such as pesticides and fungicides.), hydrocarbons (petroleum products) detergents and other suspected pollutants to ensure they meet the SA EPA water quality criteria.

Contingency: The release of polluted water that would have an immediate effect is not considered likely. However, if contaminated water is accidentally released a detailed review of the water quality control system will be initiated by the proponent or the Playford City Council and new control measures will be implemented to address the unforseen event from reoccurring.

Risk 8: Altered discharge regimes may result in prolonged dry periods or extended inundation. **Risk 9:** Altered salinity regimes, either increased freshwater or increased saline water. **Risk 10:** Increased risk of storm surge caused by a combination of increased tide levels and the backup of runoff water from urban water shedding.

Potential impacts: Prolonged dry periods caused by the reduction of water flow from either the interception or redirection of flow will result in the loss of coastal vegetation and dependent animals. Changes in salinity regimes will alter the composition of coastal vegetation, and may lead to the loss of mangroves. Increased storm surge may increase the damage to samphire flats. Hydrological models by the Proponent's engineers have shown that there will be no change to the natural groundwater level or salinity, storm water discharge will be primarily through the Thompson Channel Outlet and is expected to increase the catchment stormwater discharge by between 3% and 5%, (Section 1.4).

Management Objective: To ensure that the proposal does not significantly alter surface water flow and does not cause the loss of coastal vegetation.

Control Measure: release clean surface water in sufficient quantities and in a timely manner that will maintain the coastal vegetation healthy. Details of storm water management are found elsewhere in the environmental assessment <cross reference to storm water management plan>.

Duration: [2] one season

Severity: [2] temporary loss of biological production

Scale: [2] a few kilometres between the site and the sea.

Resilience: [1] small temporary loss in production

Likelihood of risk event: **medium**, whilst every effort will be made to maintain normal flows it will be difficult to manage in perpetuity. Risk 10 will have no significant impact on coastal vegetation.

Residual Risk: 14, acceptable level of risk remaining

Performance Indicator: No loss of coastal vegetation or associated fauna

Monitoring: No monitoring is proposed by the Proponent.

Contingency: Should flows not be sufficient or released in a timely manner the proponent will re-engineer the water diversion systems to restore natural flows into the coastal plain and if necessary revegetate the samphire to their previous species diversity and abundance.

3.3.4 Land & Soil

Risk 11: Vehicular access may cause soil compaction and damage to the ecosystem.

Potential impacts: Vehicular access to the samphire flats will cause soil compaction and damage vegetation and associated fauna.

Management Objective: prevent vehicular access onto coastal vegetation.

Control Measure: Vehicles associated with the proposal and its construction will not be permitted to drive onto the samphire flats. It is unlikely that vehicles will enter the coastal floodplains, which are off site and separated by Cheetham's salt pans, and private property. To reach Buckland Lake and the nearby coastal vegetation, vehicles would have to travel north along Port Wakefield Drive, across the Gawler River, and east along Port Gawler Road, and potentially through fenced and private property. No parts of the coastal plain are on any logical construction route.

Duration: [3] compacted soil may take more than 2 seasons to recover

Severity: [2] loss of biological production for a few seasons

Scale: [2} tracks can extend a few kilometres on the samphire flat

Resilience: [3] vegetation will not recover for a few seasons

Likelihood of risk event: **Low**, good signage and lack of access roads coupled with adequate policing will prevent vehicular access, however, over the life of the proposal it is foreseeable that some future residents will ignore signs, overcome physical barriers and defy the law.

Residual Risk: 10, low level of risk remaining

Performance Indicator: No vehicle damage to coastal soil or vegetation.

Monitoring: The Department of Environment and Heritage is responsible for reserves or unallocated Crown Land.

Contingency: The DEH assisted by the Police, will apprehend and prosecute offenders. In the unexpected event that the offenders are employed or contracted by the Proponent, the Proponent will repair any damage done by vehicles to vegetation by revegetating the tracks with the same species.

Risk 12: Excavation of Acid Sulphate Soils may release acid and metals that will contaminate soil and affect plants and animals.

Potential impacts: Acid leachate from exposed (Coastal) Acid Sulphate Soils (CASS) will reduce water quality, damage estuarine environments, decrease wetland biodiversity, and reduce fisheries production (R.W. Fitzpatrick *et al*, 2008). Potential Acid Sulphate Soils (PASS) have been identified on the site. Most of the high risk PASS is around the drainage lines, the proposed detention basins, and proposed residential areas in the southern area of the site. Other proposed residential areas are in areas identified as having a medium risk of PASS, while the remainder of the site is at low risk (Golder "Draft Preliminary ASS Investigations" Nov 2008)

Management Objective: No contamination of soil or loss of vegetation from acid leachate.

Control Measure: PASS soils have been accurately mapped on the Site (Golder 2008). All engineering control measures recommended by Golder for exposing PASS will be adhered to by the Proponent and will be a condition of any land division or construction approval issued by government.

Duration: [4] CASS may release acid for several years

Severity: [2] Leachate from exposed CASS may result in the loss of some coastal plants and fauna that depend on them downstream of the Site but very limited in extent to around the Thompson Outfall Channel.

Scale: [1] local within a 100m of Thompson Outfall

Resilience: [3] Vegetation will not recover for a few seasons until the soil pH rises.

Likelihood of risk event: **Medium**, All excavation for foundations and detention ponds will strictly adhere to Golder's recommendations, which will be implemented by the proponent during any earthworks associated with land division.

Residual Risk: 20, low level of risk remaining

Performance Indicator: Soil pH to remain within 1 unit of background levels or not fall below pH4.5. The vegetation around Thompson Outfall Channel should remain healthy.

Monitoring: DEH is responsible for managing vegetation on the Coastal Plains in this region.

Contingency: Should acid leachate be detected and it is attributed to construction of the proposal, the exposed soil will either be removed to an appropriate landfill or treated *in situ* using neutralising material such as lime and covering the exposed soil with 1 to 2 m of clean topsoil. The proponent will replace dead or poor vegetation within one season of remediating the soil.

Risk 13: Land use conversion from rural to urban may reduce or improve the opportunity for marine / coastal plants and animals.

Potential impacts: Some plants and animals will benefit from the proposal through improved resource opportunities such as insects and some reptiles others will be adversely affected from the proximity to the proposal <reference to Flora Fauna section>. The downstream impacts or benefits on marine flora and fauna may include the increase of nutrients, the potential loss of food resources and predators of marine species.

Management Objective: To protect and maintain the ecosystem.

Control Measure: Develop educational literature to explain the coastal ecosystem and function and how new residents can help to maintain the balance and minimise disturbance of animals particularly during the breeding season.

Duration: [4] New residential areas will remain for decades.

Severity: [3] Loss of some species that are sensitive to human occupation

Scale: [2] Few kilometres around the development

Resilience: [3] species that are not tolerant of human habitation will not return.

Likelihood of risk event: **Medium**, it will be difficult to protect the ecosystem from a nearby urban population particularly from the introduction of weeds and feral animals.

Residual Risk: 24, low level of risk remaining

Performance Indicator: Species diversity and abundance will remain within the existing range.

Monitoring. DEH is responsible for managing vegetation on the Coastal Plains in this region.

Contingency: If the ecosystem is affected by activities at the Site, the proponent will identify the cause(s) and take action and were possible to restore the ecosystem. If this is not possible the proponent will fund local sustainability projects to offset the lost environmental benefit of the native flora and fauna.

3.3.5 Groundwater

Risk 14: Pollutants from urban occupation and acid leachate from disturbed acid sulphate soil may contaminate groundwater, which will pollute the marine environment with nutrients, synthetic compounds and heavy metals.

Potential impacts: Nutrients, heavy metals, organic chemicals, detergents and hydrocarbons that may be transported via groundwater to the coastal and marine habitats may result in loss of plants and animals or loss of productivity (see impacts on flora and fauna).

Metals mobilised by acid leachate may accumulate in animals and move through the food chain. High nutrient loads will lead to eutrophication, algal blooms and loss of seagrass.

Management Objective: To ensure that groundwater is not polluted.

Control Measure: See Risk 12.

Duration: [3] groundwater contamination will last several years

Severity: [3] Some plant species may be lost

Scale: [1] groundwater plume may spread several hundred meters from the source.

Resilience: [3] groundwater quality will not recover for a few years

Likelihood of risk event: **Medium**, while surface water will be intercepted and treated, there is still a likelihood that groundwater may be contaminated by fertilizers and other urban pollutants. There is also a risk of metals leaching from PASS into the ground and surface water.

Residual Risk: 20, low level of risk remaining

Performance Indicator: groundwater quality does not change over time.

Monitoring: Groundwater observation bores have been installed in strategic locations to monitor groundwater level and quality. Testing will include nutrients, pH, conductivity, metals, oils, organic and domestic chemicals.

Contingency: if groundwater is contaminated the source will be identified and removed or treated. The groundwater may require treatment such as applying lime to neutralise acid or removing oil. < Cross reference to SKM's report>

3.3.6 Flora & Fauna

Risk 15: Acid leachate may harm acid intolerant terrestrial plants.

Potential impacts: Australian coastal plants can tolerate relatively low soil pH but acid leachate may drive soil pH below 4.5 resulting in extensive loss of vegetation. The proponent will not be excavating within 2 kilometres of the coastal vegetation.

Management Objective: Prevent the acid generation

Control Measure: see Risk 12

Duration: [4] soils will remain acid if untreated for many years.

Severity: [1] loss of vegetation can be extensive on acid soils.

Scale: [1] localised to within 100m of the exposed soil.

Resilience: [3] plants are not tolerant to low soil pH

Likelihood of risk event: **Low** The proponent will not excavate acid sulphate soils off site and any disturbance of acid sulphate soil on Site will be minimised and managed.

Residual Risk: 9, acceptable level of risk remaining

Performance Indicator: No plants lost to acid leachate

Monitoring: Coastal vegetation is monitored by DEH.

Contingency: Should plants be damaged by acid leachate from the site the proponent will remediate the site and revegetate with local species (see risk 12).

Risk 16: Turbidity may reduce production of marine flora.

Potential impacts: turbid water reaching the Gulf of St Vincent will reduce available light for photosynthesis by seagrass and therefore reduce productivity. Precipitates from lime treatment of PASS may increase the level of turbidity in run off water.

Management Objective: Turbidity in runoff water from the site will not exceed the EPA-SA *Water Quality (Marine) Criteria*.

Control Measure: Settling ponds and silt traps will be constructed prior to the commencement of works on the site as required to reduce water turbidity. Water will not be released until it is in compliance with EPA-SA *Water Quality (Marine) Criteria*.

Duration: [2] turbidity from stormwater discharge may be visible for a few days.

Severity: [1] the amount of turbidity and volume of water generated over the development site is expected to be small compared to the available catchment area.

Scale: [2] the turbidity plume would spread over a few kilometres.

Resilience: [1] small loss in seagrass productivity

Likelihood of risk event: **Low**, wetlands are effective filters and used successfully by the Salisbury Council.

Residual Risk: 6, acceptable level of risk remaining

Performance Indicator: turbidity in surface water remains below Schedule 2 water quality criteria EPA - SA (marine) NTU = 10.

Monitoring: see risk 7 for surface water quality monitoring

Contingency: Should the EPA-SA *Water Quality (Marine) Criteria* be exceeded the contingency plan described for Risk 7 will be initiated and the impact on seagrass beds will be determined by the monitoring program outlined in Risk 17.

Risk 17: Nutrients may cause eutrophication.

Potential impacts: Nutrients may cause eutrophication in shallow pools that may result in the loss of fauna; nutrients at sea will increase the level of fouling organisms, increase the risk of algal blooms (red tide) and the loss of seagrass.

Management Objective: Nutrients in water leaving the proposal will not exceed the EPA-SA water quality criteria (marine).

Control Measure: Educational literature will be provided by the proponent to inform new residents on the proper use of fertilisers and how to properly dispose of organic matter. The proposed artificial lakes and wetlands will reduce the amount of nutrients washing off properties and buildings, and a maintenance program will be implemented to ensure that nutrients do not build-up in the lakes.

Duration: [4] the effect of nutrients on seagrass particularly Posidonia spp. may last indefinitely as happened off the Adelaide metropolitan beaches.

Severity: [3] Posidonia and Amphibolis species will be severely affected as will other seagrass species.

Scale: [2] within a few kilometres to tens of kilometres off the coast.

Resilience: [3] Posidonia is not likely to recover for many decades once lost.

Likelihood of risk event: **Low**, nutrients will be mopped up by the proposed wetland system, however, it is still likely that nutrients in groundwater will build-up over the years and gradually seep into the sea.

Residual Risk: 12, acceptable level of risk remaining

Performance Indicator: Nutrients in surface water remain below Schedule 2 EPA *Water Quality (Marine) Criteria* - see Table 6

Monitoring: The proponent during operations will monitor surface and groundwater as described in Risk 7 and Risk 14.

Contingency: See Risk 7 and 14 for managing nutrient levels if they exceed the EPA-SA criteria.

Risk 18: The introduction of exotic species will degrade the vegetative cover and reduce the availability of some animal food sources and refuge

Potential impacts: Exotic plants may become weeds on the samphire plains, replacing native species and degrading habitat resources for some animals.

Management Objective: No exotic plants (weeds) to invade the samphire flats.

Control Measure: Select appropriate species for public gardens and open species and contribute to public education regarding suitable vegetation to plant around home gardens. Conduct an annual weed control campaign to stop exotic plants from spreading into the samphire plains.

Duration: [4] exotic species (weeds) will remain for many years unless removed.

Severity: [3] loss of some species from smothering or competition for resources.

Scale: [2] Weeds will spread a few kilometres around the residential development.

Resilience: [3] native species will not recover unless the weeds are removed.

Likelihood of risk event: **Low-Medium**, It is likely weeds will escape the Site; however, with the annual weed eradication program the risk of these establishing on the samphire plains is low to medium. Weeds are more likely to invade samphire than mangrove forest.

Residual Risk: 24, low level of risk remaining

Performance Indicator: No new weeds found in the coastal ecosystems.

Monitoring: The proponent will operate a register of weed sighting during the construction phase to help target weed species and undertake a biannual flora survey to demonstrate the effectiveness of the weed control measures.

Contingency: If exotic species (weeds) establish on the samphire plains they will be removed by the proponent for up to one year after handover. Weed control measures include physical removal, biological control and spot spraying with "safe" herbicides.

Risk19: Acid and metal leachate may be toxic to marine animals.

Potential impacts: Acid and metals in runoff water may be toxic to some sensitive species; for example fish are very sensitive to copper or changes of 1 pH unit from background. Other metals may accumulate in certain species such as cadmium in bivalves and even magnify up the food chain such as mercury in sharks or dolphins.

Management Objective: All runoff and stormwater leaving the site will meet the EPA *Water Quality (Marine) Criteria* see Table 6

Control Measure: Same as Risk 7, 12 and 14.

Duration: [4] An acid pulse may sterilise small ponds and soil near the source. Metals will stay in seawater for a few months before they settle on the seabed and a few years before they become biologically unavailable in sediment. Bottom dwellers are still exposed to metals for a few years until the contaminated sediment is covered by "clean" sediment.

Severity: [3] Some animals will die if exposed to rapid pH changes or increase in heavy metals.

Scale: [2] Large dilution effects combined with precipitation of many metals by seawater will limit the distribution of metals from a few hundred meters to kilometres of the site.

Resilience: [3] Once metals are in the system sensitive species will take several seasons to recover. Some animals (particularly invertebrates) are known to develop a resistance to heavy metals over decades of exposure.

Likelihood of risk event: **Medium**, It is likely that acid sulphate soils will be disturbed during construction. Management and monitoring will be in place during construction.

Residual Risk: 24, acceptable level of risk remaining

Performance Indicator: No accumulation of metals in animals or animal deaths through water quality issues. Water released off the Site will meet the EPA-SA *Water Quality (Marine) Criteria*.

Monitoring: As for Risk 7, 12 and 14.

Contingency: Should metals be released to the marine environment there is little that can be done to remediate the situation; however, these will eventually precipitate or fall out of suspension. Fish, crustaceans and bivalves will be monitored if high cadmium or mercury levels are detected in runoff water (this not likely to occur in an urban proposal).

Risk 20: The introduction of exotic species will compete with other animals for limited resources.

Potential impacts: Pets including horses, dogs, cats, rabbits and other exotic animals will compete with or kill native animals, disrupt breeding patterns and destroy vegetation.

Management Objective: Prevent domestic animals accessing the coastal ecosystem.

Control Measure: The proponent will develop an education program through welcome packs and Design Guidelines to illustrate the damage that domesticated animals can cause to native flora and fauna.

Duration: [4] Domesticated animals and exotic species will remain a problem for hundreds years while the proposal is occupied by people.

Severity: [4] Feral animals such as deer are already exerting pressure on the coastal habitats the introduction of more grazing and predatory pressure will severely affect the coastal flora and fauna.

Scale: [2] Domesticated animals will roam and hunt over a few kilometres around the residential areas.

Resilience: [3] Some animal species will not recover; for example migratory birds may not return to the area.

Likelihood of risk event: **Medium**, despite barriers and educational campaigns people inadvertently let pets roam unattended, some pets will escape and some people will ignore educational material and regulations. There is significant evidence of deer, feral cats and foxes already damaging the coastal ecosystems

Residual Risk: 26, medium level of risk remaining

Performance Indicator: No loss of native fauna or destruction of breeding grounds by domestic or feral animals. Note the existing feral animals on the coastal plains are the responsibility of state government and will not become the responsibility of the proponent unless they encroach the site.

Monitoring: The proponent will operate a register to report sightings of exotic species in coastal habitats; these reports will be followed by spot surveys to target feral animals. The DEH monitors the Coastal Habitats.

Contingency: If feral animal numbers increase the proponent will undertake a trapping campaign or as a last resort an eradication program to remove the feral animals from the area.

Risk 21: Human activities on the coastal plains may harm significant flora and fauna.

Potential impacts: Human activities on the coastal plains may uncover and harm rare flora or fauna that were not previously recorded in the area or known to science. Ongoing pressure from small incidents caused by nearby human habitation could also harm significant species.

Management Objective: No rare or endangered flora or fauna are to be harmed or removed from their site.

Control Measure: The proposal does not include any clearing or excavation beyond the site boundaries. All land clearing and excavation activities during construction are to be carefully mapped, inspected and approved by the responsible authorities to ensure that the activities are not encroaching on coastal habitats. It is assumed that the DEH and Playford City Council will continue to enforce biodiversity regulations. The DEH and Playford Council, assisted by the Police will monitor and control trespassing.

Duration: [4] the risk of harming rare or endangered species will be ever present with human habitation near sensitive habitats.

Severity: [4] the damage to a species of heritage significance (rare or endangered) could be irreversible.

Scale: [2] the influence of human activity may extend a few kilometres from the proposed development.

Resilience: [3] the harm or loss of species may be irreversible or take decades to recover.

Likelihood of risk event: **Medium.** Several significant plants and animals were found in the area (see Section 1). Over decades or centuries of human habitation 2 to 5 kilometres from the coast the likelihood of the loss of significant species is considered to be medium.

Residual Risk: 26, medium level of risk remaining

Performance Indicator: No loss of species of heritage or cultural significance.

Monitoring: The DEH currently manages the coastal habitats. The proponent can assist by undertaking a biannual flora and fauna survey of the marine and coastal ecosystems with an emphasis on significant species. New residents will be provided with educational material.

Contingency: If despite the control measures implemented to protect native flora and fauna, the population of a significant species diminish, a detailed scientific investigation will be undertaken by the proponent or DEH and new control measures by implemented to resolve the issue.

Risk 22: Coastal and marine focused recreational activities. **Risk 23:** Recreational fishing may result in over fishing of the mangrove habitat.

Potential Impacts: General access to the coast may degrade the sensitive samphire habitat. The effect of physical disturbance from trampling and collecting throughout sensitive intertidal mudflats has been known to have a negative impact on both the faunal and floral communities' existing within these environments (Rossi *et al*. 2007).

The site is within 5 kilometres of the coast. The boat ramp facilities at St. Kilda and to a lesser extent Port Gawler are expected to experience an increase in boating activities off the northern Adelaide coastal waters. Although this is not easy to quantify it is likely to reduce fish, crustacean and shellfish population from increased fishing pressures. Anchors have been observed to damage seagrass meadows and razorshell beds (Mifsud and Wiltshire, 2005).

Damage to intertidal zone from boat propellers particularly on an outgoing tide, and an increase in pollution levels traditionally associated with recreational boating and fishing, such as fuel spills, plastic bags, drink bottles and cans, and organic waste. Other activities such as crabbing, bait collecting or playing in the mudflats will also harm the habitat and harm native flora and fauna.

Management Objective: To ensure increased boating and recreational fishing activities do not impact on the marine environment. To ensure that crabbing, bait collecting and other recreational activities in the samphire or mangrove habitats do not damage these areas.

Control Measure: Operational management of the boat ramps is out of the control of the proponent and is the responsibility of the St. Kilda and Port Gawler boat ramp operators. The Department of Primary Industries and Resources SA currently distributes educational material to advise boat users how to behave responsibly to protect the marine and coastal environment. Bag limits and fishing seasons reduce the overall impact and provide protection to populations of target species.

Public amenities such as the boat ramps within the area may need to be assessed for potential increase in capacity and if necessary the proponent will contribute towards improving these facilities.

Duration: [4] the impact is long term, although there may be seasonal fluctuations.

Severity: [3] some loss of species and seagrass habitat depending on appropriate management of activities.

Scale: [3] the impacts from boating and fishing activities can extend tens of kilometres along the northern Adelaide coastal waters.

Resilience: [3] Poor recovery of fish and crustacean stocks due to the existing pressures from the Adelaide Metropolitan area.

Likelihood: **Low**. It is feasible that increased pressure from fishing and boating activities will affect marine flora and fauna; this impact is largely beyond the control of the proponent. However, bag limits and fishing seasons provide some protection to populations of target species.

Residual Risk: 13, medium level of risk remaining

Performance Indicator: No increased impacts on the marine and coastal environment attributable to the new development.

Monitoring: Fisheries in the northern Adelaide Coastal waters are currently monitored by PIRSA.

Contingency: PIRSA is responsible for fisheries in South Australia.

Risk 24: Rubbish will adversely affect plant and animal life.

Potential impacts: Rubbish consisting of construction and domestic waste may accumulate on the samphire flats, in the mangrove forest and eventually out to sea increasing the level of stress on these habitats and adversely affecting plant and animal life.

Conversely, rubbish dumping currently occurring is facilitated by the remoteness of the area. The introduction of an urban community, will increase surveillance, discouraging dumping, and will also bring services to the area, such as Council clean ups and maintenance programmes.

Management Objective: Prevent human waste and rubbish from the site accumulating on the coastal environment.

Control Measure: Provide waste disposal facilities during the construction phase and rubbish collection service post development.

Duration: [4] rubbish from the site particularly plastics and other non-biodegradable material will remain for hundreds of years.

Severity: [3] many animals may be lost or injured from entanglement or trying to digest rubbish.

Scale: [2] careless disposal of waste and rubbish from the Site may spread a few kilometres.

Resilience: [3] some animals will eventually adapt (learn to avoid) human waste and rubbish but this may take several decades.

Likelihood of risk event: **Low.** People are becoming better educated and government action to reduce the level of waste and rubbish such as banning plastic shopping bags are expected to reduce the level of rubbish.

Residual Risk: 12, medium level of risk remaining

Performance Indicator: No additional waste or rubbish to be found on coastal habitats near the site.

Monitoring: During construction regular site inspections will ensure that all waste and rubbish is collected and properly recycled or disposed. This will be addressed in the Construction Management Plan. During operations the build-up of waste and rubbish will tracked during the biannual coastal flora and flora surveys.

Contingency: Should rubbish accumulate on the coastal habitats during construction the proponent will clean up the rubbish and review the Construction Management Plan to prevent further occurrences. During operations the Playford City Council will implement normal urban rubbish management policies. The DEH will continue to manage unallocated crown land within the adjoining coastal plain.

Risk 25: Reduction of commercial fisheries.

Potential impacts: The lucrative Prawn Fishery established within Gulf St Vincent is reliant on the Port River, Barker Inlet and Gawler River estuaries as an important resource for prawn larval recruitment and as a nursery habitat (AMLR 2007). The Marine Scale Fishery also relies on these estuarine ecosystems as many targeted fish and crustacean species spend a part of their life-cycle within these estuarine environments (AMLR 2007).

Management Objective: Protect the crab, prawn and fish nurseries associated with the Gawler River and the mangrove forest.

Control Measure: Intercept and treat stormwater and divert wastewater to avoid harming important fish and prawn nurseries and linked habitats. Prevent as far as practical physical harm or public access to the intertidal or estuarine areas.

Duration: [4] Human occupation near the coast will place pressure on the coastal and marine habitats.

Severity: [2] If the Gawler River and associated coastal nursery habitats are harmed the portion of fisheries will be reduced.

Scale: [2] the extent of the nursery habitat for commercial fisheries that may be affected will be restricted to the Gawler River estuary and surrounds.

Resilience: [3] some animals will adapt or find new habitats to shelter and feed in but it would take several seasons for this to occur.

Likelihood of risk event: **Low.** The control measures implemented to protect the coastal ecosystems, including managing water quality, and the inaccessibility of the mangrove forest and coastal plains near the Site will ensure that harmful events or activities are infrequent.

Residual Risk: 11, acceptable level of risk remaining

Performance Indicator: No degradation of coastal habitats.

Monitoring: Groundwater and discharge water quality will be monitored to demonstrate that no potentially harmful pollutants are entering the Thompson Outlet Channel, the Gawler River estuary or the sea from the Site.

Contingency: Should the commercial fisheries be harmed as a result of the loss of the nursery grounds due to the proposal; the proponent, PIRSA and DEH will compensate for the loss of income and remediate the damaged habitats.

3.3.7 Risk Rating

The overall risk rating for the development is presented in Table 7. The level of risk has been quantified by assigning scores for the assessed impact using Table 4 and a score of 1 (low) to 3 (high) for the likelihood assessment. The risk score has been determined by summing the impact scores and multiplying by the likelihood score, see Section 3.2.1.

Table 7: Qualitative Risk Calculation Matrix

RISK	Duration	Severity	Scale	Resilience	Likelihood	Level of Risk
1. Odour from hydrocarbon spill	1	2	1	1	2	**10**
2. Odour from marine sediment and CASS	1	2	1	1	2	**10**
3. Dust from vehicles.	4	2	1	2	2	**7**
4. Dust from exposed surfaces	4	2	1	2	2	**7**
5. Noise from construction machinery	4	2	1	1	1	**8**
6. Noise from traffic and urbanisation.	4	2	1	1	1	**8**
7. Stormwater runoff from development	4	3	2	3	1	**12**
8. Altered flow regimes.	2	2	2	1	2	**14 (x)**
9. Altered salinity regimes.	2	2	2	1	2	**14 (x)**
10. Storm surge	2	2	2	1	2	**14 (x)**
11. Soil compaction by traffic.	3	2	2	3	1	**10**
12. soil contamination from leachate	4	2	1	3	2	**20 (x)**
13. Land use conversion	4	3	2	3	2	**24 (x)**
14. Groundwater pollution.	3	3	1	3	2	**20 (x)**
15. Acid leachate on flora.	4	3	1	3	1	**9**
16. Turbidity on seagrass	2	1	2	1	1	**6**
17. Eutrophication.	4	3	2	3	1	**12**
18. Weeds	4	3	2	3	2	**24 (x)**
19. Acid leachate on fauna.	4	3	2	3	2	**24 (x)**
20. Feral animals.	4	4	2	3	2	**26 (xx)**
21. Reduction of significant species.	4	4	2	3	2	**26 (xx)**
22. Boating impact on seagrass beds.	4	3	3	3	3	**13 (x)**
23. Recreational fishing.	4	3	3	3	3	**13 (x)**
24. Impacts from rubbish	4	3	2	3	1	**12**
25. Reduction of commercial fisheries	4	2	2	3	1	**11**

* Level of risk where a score less than 12 indicates no significant risk, higher scores require further attention and are grouped as low level of risk (x), medium level of risk (xx) and high level of risk (xxx), note no high risk scores were found.

The highest risk to the coastal and marine environment come from activities/events 20 (introduction of feral animals and weeds) and 21 (ongoing human pressure on significant flora and fauna). These activities/events remain a medium level of risk because they relate to human behaviour and expectations.

4. Conclusion

The Buckland Park proposal is located between 2.4 to 4 kilometres from the Gulf St. Vincent shoreline. The Cheetham salt pans are between the southern boundaries of the Site and the natural coastal ecosystems, while Buckland Park Lake and the Port Gawler Conservation Park are to the north and east of the Site, they are separated by the Gawler River.

The coastal and marine ecosystems range between good quality samphire and mangroves around the Gawler River estuary to poor quality east of the Cheetham salt pans. All sites surveyed showed some degradation from feral animal grazing, weeds and general rubbish, however, much of the Conservation Park land appears to be in good condition.

Offshore from the Site are the Adelaide Dolphin Sanctuary, St. Kilda-Chapman Creek Aquatic Reserve and the Barker Inlet-St. Kilda Aquatic Reserve. These coastal habitats provide for many animals from nurseries to commercially significant fish and crustaceans, to shelters for migratory bird species.

The area is well regarded by birders for its many species including some rare species such as the orange bellied parrot, southern emu wren, the Cape Barren goose and the samphire thornbill. Twelve migratory birds found in the coastal wetlands are listed on the CAMBA, JAMBA and the Bonn Convention.

Marine species identified for conservation significance or vulnerable include the Syngnathidae Family (Pipefish), *t*he Clinidae Family (Weedfish and Snake-bleeny) and the Apogonidae Family (Cardinal fishes) the Congolli, Common Galaxias or Jollytail, Mountain Galaxias, Flathead Gudgeon, Magpie Fiddler Ray and invertebrate species including the brown or black striated sea anemone and barnacles.

The most significant interaction between the proposal and coastal habitats will be through groundwater and surface runoff. Both water quality and natural flows will be maintained by the proposed water management plan (provided elsewhere in this proposal). The proponent intends to manage groundwater levels and water quality such that not detectable changes from the existing regimes will occur.

Surface water from the Site will be intercepted and treated such that on release from the Site it will meet the South Australian Environmental Protect Authority *Water Quality Criteria (EPA, 2003)*. Surface water runoff will be controlled so that minimal changes from natural flows will occur. Modelling has shown that an increase in flow from the Western Virginia catchment which discharges into the Thompson Outfall Channel will have a net overall increase in runoff for the entire catchment of about 3% to 5% of the overall volume. This increase in runoff from the proposal is due to the combined effect of not practically being able to capture the highest of the peak flows on an annual basis.

A qualitative environmental risk assessment found that the highest risks to the coastal and marine habitats are from feral animals and the reduction of natural vegetation though increased illegal trespass. Other environmental risks that can be managed include weeds and rubbish. Population pressures will also generate impacts on the coastal habitats, people's behaviour is managed through education and legislation enforced by the DEH, the Police and the Playford City Council.

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Glossary

Bioregions	Marine bioregions are biogeographic regions containing distinctly recognisable patterns of biodiversity. These are on the scale of 100s of square kilometres and are as diverse as the regional marine conditions they are found in, in the study area the bioregions have flora and fauna adapted to the cold, exposed waters of the lower south-east which are distinct from those of the warmer, sheltered waters of upper St Vincent Gulf.
Biounits	Biounits were delineated on the basis of major coastal physiographic features and the representation and distribution of major marine habitats and are on the scale of 10s of square kilometres. The seaward boundary of the gulfs biounits was defined using the 30 m bathymetric contour, on the basis that major habitat changes are known to occur in deeper waters, beyond the photic zone. Similarly, the seaward boundary of the oceanic biounits was defined using the 50 m depth contour, on the basis that the photic zone is known to occur deeper in the clearer oceanic waters of South Australia. Thirty five biounits have been identified along the inshore coastal waters of South Australia. These include 30 coastal biounits and 5 offshore biounits, which comprise offshore islands and waters without adjacent mainland coasts (i.e. Nuyts, Flinders, Investigator, Gambier, and Sprigg).
Oligotrophic waters	Having low mineral content, an oligotrophic ecosystem offers little to sustain life. The term is commonly utilized to describe bodies of water or soils with very low nutrient levels.
Benthic	Pertaining to the seabed ecosystem. The benthic zone is the ecological region on the sea bed or lake bottom it includes the sediment surface and the organic sub-surface layers. Organisms living in this zone are called benthos. They generally live in close relationship with the substrate bottom; many such organisms are permanently attached to the bottom.
Taxa	Plural of taxon or taxonomic unit, is a name designated to a group of organism in biological nomenclature.
Pneumatophore	A specialized root that grows upward out of the water or mud to reach air and obtain oxygen for the root system of mangroves.
Anthropogenic	Made by people or resulting from human activities.
Eutrophication	An increase of nutrients in the ecosystem that results in excessive plant growth and decay, which often results in a reduction of water quality, oxygen and aquatic animals.

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Appendix A: Comprehensive List of Coastal and Marine Fauna and Flora in the Buckland Park Area

This appendix was adapted from detailed work by Peri Coleman of Delta Environmental. The flora and fauna recorded in this list were observed over a 15 year period and include opportunistic observations (flora and fauna) as well as some vouchered surveys (flora). Some taxonomic changes have occurred during this period. Please refer to the Census of SA Flora for the most recent specific epithets".

Key to habitats

Tidal flats	Salina - marine salinity
Mangroves	Salina - low hypersaline
Mid and low saltmarsh	Salina - mid hypersaline
Higher saltmarsh	Salina - highly hypersaline
Freshwater tidal swamps (saltmarsh backswamps)	Salina - near to post saturation NaCl
Buckland Park Lake and surround	Saltbush country
Chenier ridges & dunes	Mallee
Seawall and other embankments	Sabkhas
Tidal creeks	Stormwater treatment wetlands

Macroalgae & periphyton

Bryopsis plumosa									x	x								
Caulerpa sp	x																	
Centroceras sp (red)									x	x								
Ceramium sp (red)									x	x								
Chaetomorpha billardierii	x								x	x								x
Chara sp					x						x							x
Chondrei sp									x	x								
Cladophora sp	x								x	x								
Codium duthiae									x	x								
Codium sp									x	x								
Enteromorpha intestinalis	x	x							x	x								
Enteromorpha linza									x	x								
Enteromorpha prolifera	x	x							x	x								
Enteromorpha spp	x								x	x								x
Gelidium sp	x								x	x								
Hypnea sp (red)	x								x	x								
Polyphysa peniculus	x								x	x	x							
Polysiphonia spp									x	x								
Ulva lactuca	x								x	x								

Plankton and benthic mat

Acanthes sp										x	x							
Achnanthes brevipes										x	x							
Achnanthes exigua										x								
Achnanthes javanica	x									x								
Actinocylus subtilis	x									x								
Actionoptychus splendens	x									x								
Alexandrium minutum	x	x							x	x	x							
Alexandrium spp	x	x							x	x	x							
Amphora angusta										x								
Amphora bigibba										x								
Amphora coffeaeformis										x	x							
Amphora holsatica										x	x	x						
Amphora ocellata										x								
Amphora proteus										x								
Amphora ventricosa										x	x	x						
Anabaena circinalis									x	x							x	x
Ankistodemus sp	x	x	x						x	x								x
Bacillaria paradoxa	x									x								
Beggiatoa spp	x	x																
Biddulphia pulchella										x								
Biddulphia toumeyi										x								
Camplyodiscus incertus										x								
Caloneis sp										x								
Chaetoceros sp	x	x	x						x	x								x
Chlamydomonas sp		x	x						x	x								x
Chlamydomonas sp	x	x	x						x	x	x							x
Chromatium spp											x	x						
Chroococcus turgidous										x	x	x						
Cocconeis distans										x								
Cocconeis pediculis										x	x							

Cocconeis placentula										x	x	x						
Cocconeis pellucida										x								
Cocconeis pseudomarginata										x								
Cooconeis stauroneiformis										x	x							
Cocconeis scutellum										x	x	x						
Coscinodiscus devius										x								
Coscinodiscus nitidis										x								
Cyclotella meneghiniana										x								
Cymbellonitzschia diluvium										x								
Desulphovibrio spp		x								x	x	x						
Dimerogramma minor										x								
Diploneis abnormis										x								
Diploneis chesonensis										x								
Diploneis ovalis										x								
Dunaliella salina										x	x	x	x					
Dunaliella viridis	x	x	x						x	x	x	x						x
Entomoneis (Amphiprora) sp	x									x								
Eunotia sp										x	x							
Gleocapsa sp										x	x							
Gomphonema parvulum										x								
Gomphonema sp										x	x							
Gonium sp										x	x							
Grammatophora oceanica										x	x							
Gymnodinium sanguineum	x	x	x						x	x								
Gymnodinium spp	x	x	x						x	x								
Gyrosigma balticum										x	x							
Gyrosigma scalproides										x								
Halobacter sp													x					
Hantschia sp										x								
Heterosigma sp	x	x							x	x								

Licmophora Thomas sp3										x								
Limophora flabellata										x								
Lyngbya sp	x								x	x								x
Mastogloia baldjikiana										x	x							
Mastogloia erythraea											x							
Mastogloia exigua										x								
Mastogloia exilis										x								
Mastogloia pumila										x	x							
Melosira granulata										x								
Melosira nummuloides										x								
Microcoleus sp											x	x						
nannoplankton		x							x	x	x	x						
Navicula avenacea										x								
Navicula lyra										x								
Navicula granulata										x								
Navicula ramosissima										x	x	x						
Navicula salinarum										x								
Navicula spp	x	x	x						x	x	x	x						x
Nitzschia apiculata										x								
Nitzschia constricta										x								
Nitzschia dissipata										x								
Nitzschia fluminesnis										x								
Nitzschia granulata										x								
Nitzschia hungarica										x	x							
Nitzschia hummii										x		x						
Nitzscgia longissima var reversa										x	x							
Nitzschia marina										x	x							
Nitzschia obtusa var scalpelliformis										x	x							

Nitzscia punctata										x								
Nitzschia rostellata										x	x	x						
Nitzschia sigma										x	x							
Nitzschia sp	x	x	x						x	x								x
Nitzschia stundlii										x								
Nitzschia tryblionella										x								
Nitzschia vidovichii										x								
Odentella levis										x								
Opephora martyi										x								
Oscillatoria miniata	x								x	x	x						x	
Peridinium sp	x	x	x						x	x								x
Pinnularia sp												x						
Plagiogramma staurophorum										x								
Plagiotropis lepidoptera										x								
Pleurosigma rigidum										x								
Pleurosigma spp	x	x	x						x	x								
Prorocentrum spp	x	x	x						x	x								
protozoans	x	x	x		x	x			x	x								
Rhoicoshenia sp										x								
Rhopalodia gibberula										x	x							
Rhopalodia musculus										x	x							
Schizothrix sp												x						
Spirulina sp										x	x							
Stephanoptera sp											x	x					x	
Surirella fastuosa										x								
Synechococcus sp											x	x						x
Synedra fasciculata	x	x							x	x	x							
Synedra laevigata var hyalina										x								
Synedra crystalina										x	x							
Tabularia fasciculata										x	x							

Thalassiosira sp	x	x	x						x	x								x
Trachneis sp										x								
Triceratium dubium										x								
Triceratium favus										x								
Vaucheria sp	x																	x

Aquatic angiosperms

Ceratophyllum sp (horsetail)					x	x												x
Halophila ovalis	x								x	x								
Heterozostera sp	x	x																
Lepilaena spp	x				x					x	x						x	x
Myriophyllum sp					x	x												x
Potamegeton crispus						x												x
Ruppia megacarpa	x				x													x
Ruppia polycarpa	x				x													x
Ruppia tubersoa	x									x	x						x	
Zostera sp	x	x							x	x								

Intertidal, supratidal and extratidal vegetation

Trees																		
Allocasuarina verticilliata							x											
Avicennia marina		x	x															
Callitris gracilis (preissii)							x											
Eucalyptus socialis																x		

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Melaleuca halmaturorum					×	×		×										×
Melaleuca lanceolata							×											×
Shrubs																		
Acacia cupularis						×	×	×										
Acacia ligulata						×	×											
Acacia longifolia var sophorae							×											×
Acacia paradoxa							×											
Acacia pycnantha							×											
Adriana klotchzii							×	×										
Alyxia buxifolia							×											
Asclepias rotundifolia*							×	×										
Atriplex cinerea (Coast saltbush)							×	×										×
Atriplex paludosa ssp cordata (Marsh saltbush)				×			×	×							×			×
Atriplex (Lagoon saltbush)				×			×	×										
Dissocarpus biflorus							×	×							×			
Dodonea viscosa							×											×
Enchylaena tomentosa var tomentosa							×	×							×			×
Exocarpus aphyllus							×											
Frankenia pauciflora			×	×			×	×										×
Geijera linearifolia							×	×										
Halosarcia flabelliformis			×														×	
Halosarcia halocnemoides				×				×									×	×
Halosarcia indica			×	×				×									×	
Halosarcia pergranulata				×			×	×									×	×
Halosarcia pruinosa				×			×											
Halosarcia syncarpa				×			×	×										
Lawrencia squamata					×		×								×			
Lycium ferocissimum*							×	×										
Maireana brevifolia						×	×	×							×			×
Maireana erioclada																	×	

Maireana oppositifolia				×			×	×									×	×
Myoporum insulare							×	×										×
Nicotiana glauca*						×	×											
Nitraria billardierei				×		×	×	×							×		×	×
Olearia axillaris							×	×										
Olearia muelleri							×											
Pittosporum phylliraeoides							×											
Rhagodia candolleana ssp candolleana							×	×							×			×
Sarcocornia blackiana			×			×											×	
Sarcocornia quinqueflora			×		×	×	×											
Sclerolaena diacantha				×				×										
Sclerostegia arbuscula			×	×														
Sclerostegia tenuis				×														
Senecio lautus				×		×	×											×
Suaeda australis			×	×	×			×										×
Threlkeldia diffusa							×	×										
Grasses																		
Avena barbata*							×	×							×			×
Bromus diandrus*							×	×							×			×
Bromus rubens*							×	×							×			×
Chloris truncata (Windmill grass)								×							×			
Danthonia caespitosa (Wallaby grass)							×								×			
Danthonia clelandi							×	×										
Distychlis distichophylla (Emu grass)				×			×	×										
Enneapogon nigricans (Bottle washers)															×			
Enteropogon ramosus (Twirly umbrella grass)															×			
Hordeum marinum*				×				×										×
Lagurus ovatus*							×								×			×
Lolium rigidum*							×	×										×
Molineriella minuta								×										

Parapholis incurva*				×														
Puccinellia strictum (Austral saltmarsh grass)			×	×														
Rostraria cristata*				×			×											
Schismus barbatus*				×			×											
Setaria (Paspadilium) constricta (Pigeon grass)															×			
Sphenopus divaricatus*				×														
Sporobolis virginicus (Saltwater couch)								×										×
Stipa (Austrostipa) drummondii (Cottony speargrass)							×								×			
Stipa (Austrostipa) elegantissima							×	×							×			
Stipa (Austrostipa) eremophila															×			
Stipa (Austrostipa) nitida							×	×							×			
Vulpia myorus*				×			×											
Vines and Twiners																		
Clematis microphylla							×											
Comesperma volubile (Love creeper)							×											
Muehlenbeckia cunninghamii (leafless)					×	×												×
Muehlenbeckia gunnii (climbs on shrubs, has leaves)						×	×	×										
Vicia sativa*								×										×
Sedges, Rushes and associated vegetation																		
Bolboschoenus caldwellii					×													×
Cotula coronopifolia					×	×												×
Dianella brevicaulis						×	×	×										
Dianella revoluta					×		×	×										×
Gahnia filum				×	×		×											×
Isolepis nodosa							×											×
Juncus acutus*					×	×												×
Juncus kraussii						×												
Juncus bufonius				×	×													×
Lomandra collina (now divided up - look up local one)					×	×	×											
Phragmites australis					×													×

Triglochin mucronatum				x														
Triglochin striatum (Streaked arrow grass)				x	x													
Mat plants																		
Atriplex semibaccata				x			x	x										x
Carpobrotus rossii				x			x	x										x
Disphyma crassifolium				x			x	x							x			x
Galenia spp.*							x	x										
Hibbertia virgata							x											
Mesembryanthemum crystallinum*				x			x	x										x
Samolus repens			x															
Tetragonia decumbens						x		x										
Tetragonia implexicoma						x	x	x										
Wilsonia humilis			x	x				x										
Herbaceous species																		
Angianthus preissianus				x														
Angianthus tomentosus							x											
Apium annuum				x														
Asphodelus fistulosus*							x	x										
Brachycome lineariloba							x											
Brassica tournefortii*				x			x	x										x
Bupleurum semicompositum*							x											
Calostemma purpureum															x			
Centaurea melitensis*							x											
Chondrilla juncea*							x											
Crassula sieberiana				x			x											
Cynara cardunculus*				x			x	x										
Euphorbia terracina*							x	x										x
Foeniculum vulgare*								x										x
Gnaphalium indutum							x	x										
Gynandris setifolia*				x			x	x										x

Hymenolobus procumbens*				x														
Hyperchoeris glabra*								x										
Limonium sp*				x			x	x										
Lotus australis							x	x										
Marrubium vulgare*						x	x	x										x
Medicago minima*				x														
Medicago polymorpha*							x	x										x
Melilotus indica*							x											
Mesembryanthemum nodiflorum*				x			x	x										x
Oncosiphon suffruticosum*				x			x	x										x
Oxalis pes-caprae*								x										x
Pelargonium australe							x	x										
Pogonolepis muelleriana				x														
Reichardia tingitana*							x											x
Senecio glossanthus				x			x											
Silene nocyurna*							x											
Sonchus oleraceus*				x			x	x										x
Spergularia diandra*				x			x											
Spergularia marina*				x				x										
Trifolium tomentosum*				x														
Vittadinia gracilis							x	x							x			
Mosses and lichens				x		x	x	x										

Aquatic invertebrates (marine and brackish-fresh)

Gastropods																		
Austrocochlea (Monodonta) constrictor (gastropod)	x	x							x	x								
Batillaria estuarina (gastropod - mud creeper)	x									x								
Bembicium melanostoma (gastropod - mangrove conniwink)		x							x	x	x	x						

Bembicium nanum (gastropod - striped mouth conniwink)		×							×	×								
Cominella spp (gastropods - whelks)		×																
Coxiella (gastropod - awl shaped salt lake snails)										×								
Eubittium (gastropod - awl shaped salt lake snails)										×								
Hydrococcus (gastropod - round snail)										×								
Lepsiella vinosa (gastropod - whelk)		×																
Nerita atramentosa (gastropod - black periwinkle)		×																
Pancarnassa pauperata (gastropod - poor dogwhelk)		×							×	×								
Salinator fragilis (gastropod- estuary sand snail)	×	×	×															
Salinator solida (gastropod)	×	×	×	×														
Bivalves																		
Crassostrea gigas* (bivalve - pacific oyster)									×	×								
Flavomala biradiata (bivalve - sunset shell)	×								×	×								
Irus crebrelamellatus (bivalve - boring venerid)	×								×	×								
Katelysia scalarina (bivalve - stepped venerid or cockle)	×								×	×								
Lanternula recta (bivalve - rectangular lantern shell)	×								×	×								
Modiolus inconstans (bivalve - mussel)	×								×	×								
Ostrea angasi (bivalve - oyster)									×	×								
Pinna bicolor (bivalve - razor shell)	×								×	×								
Semele exigua (bivalve - cockle)	×								×	×								
Venerupis anomola (bivalve - bean cockle)										×								
Xenostrobus pulex (bivalve- estuarine mud mussel)	×								×	×								
Crustaceans																		
Acartia clausi (crustacean copepod - calanoid)									×	×	×	×						
Amphitoe flindersii (crustacean - amphipod)										×								
Artemia franciscana* (crustacean - brine shrimp)												×	×	×			×	
Austrochiltonia (crustacean - seaflea)										×								
Australocypris (crustacean - ostracod)										×	×							

Carcinus maenus* (crustacean - euro shore crab)	x	x	x						x	x								
Cladoceran crustacea (crustacean - daphnia)					x	x												x
Corophiidae (crustacean amphipods)									x	x								
Crabyzos longicaudatus (crustacean - green sea centipede)		x							x	x								
Crangon sp (crustacean - snapping prawn)									x	x								
Cymodoce longicaudata (crustacean isopod)									x	x								
Cytheromatid ostracods																		x
Diacypris dictyote (crustacean ostracod - seed shrimp)									x	x	x	x						
Elminius modestus (crustacean - estuarine barnacle)		x							x	x								
Eriocheir spinosus (crustacean - crab)		x																
Exosphaeroma bicolor (crustacean isopod)									x	x	x							
Haloniscus searlii (crustacean - salt lake slater)											x	x						
Helograpsus (Helice) haswellianus (crustacean - little mud crab)		x	x															
Iais pubescens (crustacean - lives on Cymodoce)										x								
Leander intermedius (crustacean - shrimp)	x	x							x	x								
Leander litoreus		x																
Macrophthalmus latifrons (crustacean - crab)		x																
Mesochra parva (crustacean copepod - harpacticoida)									x	x	x	x						
Microcyclops (crustacean - copepod)											x	x						
Neospaeroma laticauda (crustacean isopod - wide tailed sea pillbug)		x							x	x								
Palaemon serenus (crustacean - prawn)		x							x	x	x							
Paracalliope sp (crustacean amphipod)									x	x								
Parartemia zietziana (crustacean - native brine shrimp)											x	x	x				x	
Parhyalella sp (crustacean gammarid amphipod)											x						x	
Peneus latisculatus (western king prawn)		x							x	x								
Phylyra laevis (crustacean - pebble crab)		x							x	x								
Pilumnus fissifrons (crustacean - tasselled crab)									x	x								
Portunus pelagicus (crustacean - blue swimmer crab)	x	x							x	x								
Reticypris herbsti (crustacean ostracod)									x	x	x	x						
Rotifers (unidentified)		x			x	x			x	x								x

Synischia sp (crustacean isopod)									x	x	x						x	
Zuzara venosa (crustacean isopod)									x	x								
Insects																		
Cladotanytarsus sp (chironomid)	x								x	x	x	x	x				x	x
Corixa (false boatmen)					x	x												x
Ephydrdrella (brine fly)			x						x	x	x	x	x				x	
Lestidae sp (dragonfly larvae)						x												x
Notonectidae (water boatmen)					x	x												x
Symphitoneuria wheeleri (caddis fly)						x												x
Tanytarsus barbitarsus (chironomid)									x	x	x	x	x					
Worms																		
assorted nematode worms	x	x							x	x	x	x						
Austronereis sp. (polychaete - baitworm)	x		x															
Neanthes vaalii (polychaete worm)	x	x							x	x								
Sabella spallenzani* (polychaete - euro fanworm)									x	x								
Assorted																		
Anthopleura aureoradiata (estuarine anemone)		x							x	x								
Bryozoans (unidentified sea-mosses)	x	x							x	x								
Cassiopea sp (jellyfish)									x	x								
Ciona intestinalis* (sea squirt)									x	x								
Crichophorus nutrix (anemone)		x							x	x								
Hydracarina (water mites)					x	x												x
Ophiuroidea (brittle star)		x							x	x								
Patirella exigua (biscuit star)									x	x								
Asterina sp. (cushion star)									x	x								
Zoobotryon verticillatus (bryozoan)									x	x								
Edwardsia vivipara (burrowing anemone)									x	x								

Fish

Gambusia affinis* (mosquito fish)					×													×
Acanthopagrus butcheri (black bream)	×	×							×	×								
Aldrichetta forsteri (mullet)		×							×	×								
Arenogobius bifrenatus (bridled goby)		×							×	×								
Argyrosomus hololepidotus (mulloway)	×	×																
Arripis trutta (Australian salmon)	×	×																
Atherinosoma microstoma (hardyhead)									×	×	×	×					×	
Chaetodon armatus (old wife)									×	×								
Christiceps australis (crested weedfish)									×	×								
Chrysophrys auratus (Snapper)	×	×																
Galaxias kayi (minnow)																		×
Gallogobius mucosus (sculptured goby)									×	×								
Gobius lateralis (long fin goby)		×																
Gymnopistes marmoratus (SA cobbler)									×	×								
Hyporamphus melanochir (garfish)	×	×							×	×								
Kaupus costatus (pipefish)	×	×																
Liza argentea (jumping mullet)	×	×																
Melambaphes zebra (zebra fish, pajama fish)									×	×								
Mughil cephalus (sea mullet)									×	×								
Myxus elongatus (sand mullet)									×	×								
Pelotes sexlineatus (trumpeter/striped perch)		×							×	×								
Platycephalus bassesnsi (southern sand flathead)	×								×	×								
Platycephalus fuscus (flathead)									×	×								
Platycephalus laevigatus (rock flathead)									×	×								
Pseudaphritis bursinus (congoli)					×													×
Pseudogobius olorum (blue spot goby)					×					×								×

Rhombosolea tapirina (greenback flounder)		x							x	x								
Scorpaena ergastulorum (red rock cod or gurnard)									x	x								
Sillaginodes punctatus (spotted whiting)	x	x	x						x	x								
Sillago bassensis (silver whiting)		x							x	x								
Sillago schomburgkii (yellow fin whiting)	x	x																
Stigmatopora argus (spotted pipefish)									x	x								
Stigmatopora nigra (pipefish)	x	x							x	x								
Toadfish (assorted)									x	x								
Trygonorhina guanerius (southern fiddler ray)									x	x								

Terrestrial invertebrates

Apis mellifera* (honeybees)						x	x	x										
Beetles		x	x	x	x	x	x	x							x	x	x	x
Camponotus spp (black ants)				x			x	x										x
Centipedes				x	x	x	x	x									x	x
Delias spp. (Jezebels)				x	x		x									x		
Gasteracantha mirax (Christmas spiders)			x	x				x										
Hesperidae (skipper butterflies)				x	x		x	x							x			x
Iridomyrmex spp (Meat ants)				x			x	x									x	x
Lycenidae (blue butterflies)				x	x		x	x							x	x		x
Ochlerotatus camptorhynchus (winter mozzie)				x	x	x												x
Ochlerotatus vigilax (saltmarsh mosquito)				x	x	x												x
Oligochaetes (earthworms)				x		x	x											x
Phonognatha sp. (Leaf rolling spider)		x	x	x				x										
Saldid bugs			x	x	x	x												x
Scorpions							x	x										
Trioza sp. (Myoporum psylla)							x	x										x
Utetheisa pulchelloides (day flying heliotrope moth)			x	x	x	x	x	x										x

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Terrestrial vertebrates

Reptiles																		
Amphibolus barbatus (bearded dragon)							x	x										
Amphibolus pictus (painted dragon)							x	x										
Heteronotia binoei (Bynoe's geckoe)				x			x	x										
Phyllodactylus sp (geckoe)				x			x											
Pseudonaja textilis (eastern brown snake)				x			x	x									x	
small skinks (at least 7 species)				x		x	x	x									x	x
Tiliqua spp (Blue tongues, 2 species - western and eastern)				x			x	x										
Trachydosaurus rugosus (Sleepy lizard)				x		x	x	x									x	x
Unechis flagellum (whip snake)							x											
Varanus various (monitor or goanna)						x	x											
Acanthophis antacticus (Death adder)							x											
various little dragon lizards							x											
Amphibians																		
Limnodynastes dumerlii (bonk frog, banjo frog, pobblebonk)						x												x
Limnodynastes tasmaniensis (Spotted grass frog, marsh frog)						x												x
Neobatrachus pictus (spotted burrowing frog)				x	x	x	x											x
Mammals																		
Dama dama* (fallow deer)	x	x	x	x	x	x	x	x										
Lepus capensis* (hare)						x	x	x										
Mus musculus* (house mouse)		x	x	x	x	x	x	x									x	x
Oryctolagus cuniculus* (rabbit)					x	x	x	x										x
Rattus rattus*		x	x	x	x	x	x	x									x	x
Vulpes vulpes* (fox)		x	x	x	x	x	x	x									x	x
Chalinlobus morio (chocolate wattled bat)		x	x	x	x	x	x	x									x	x
Chalinolobus gouldii (Gould's wattled bat)		x	x	x	x	x	x	x										x
Hydromys chrysogaster (water rat)		x	x					x	x									x
Macropus fuliginosus (grey kangaroo)				x		x	x	x										

Macropus robustus (common wallaroo)		x	x	x	x	x	x	x										x
Nyctophilus geoffroyi (little long eared bat)		x	x	x	x	x	x	x									x	x
Rattus fuscipes (bush rat)				x	x	x	x											x
Tachyglossus aculeatus (echidna)						x		x										
Vespadelus regulus (prev Eptesicus sp, little bat)						x	x	x									x	x

Appendix B: Field Survey

Samphire Species Key

Species.	Description.
Species 1 = *Halosarcia spp 1.*	0.1m to 0.5m tall, generally found one to two metres above the high tide line.
Species 2 = *Halosarcia spp 2.*	0.5m to 1.2m tall, are very salt tolerant as they can be found growing between two metres above the high tide line and at the base of mangrove stands. This plant was almost always associated with H. haswellianus burrows (crab species).
Species 3 = *Sarcocornia spp 1.*	0.1m to 0.2m tall, this generally small ground cover samphire can be found in high abundances in the mudflat zone between the high tide mark and the mangrove stands (generally surrounding intertidal muddy creeks).
Species 4 = *Disphyma crassifolium.*	0.1m to 0.2m tall, commonly called round-leaf pigface is a ground cover that is commonly found in salty coastal soil above the high tide mark.
Species 5 = *Nitraria billardierei.*	0.5m to 1.5m tall, this species is a woody, low spreading shrub is very tolerant to salt effected soils and can be found only a few metres above the high tide mark.
Species 6 = unidentified woody shrub.	Is an algae and was found sporadically in some of the drainage creeks associated with stagnant freshwater from the Gawler River (yet to be identified)
Species 7 = *Sarcocornia spp 2.*	0.1m to 0.2m tall, similar to Species 3 is found in the mudflat/ marsh zone, this samphire is tolerant of extremely saline conditions and was only found in one site in small abundances growing next to a saline intertidal creek.

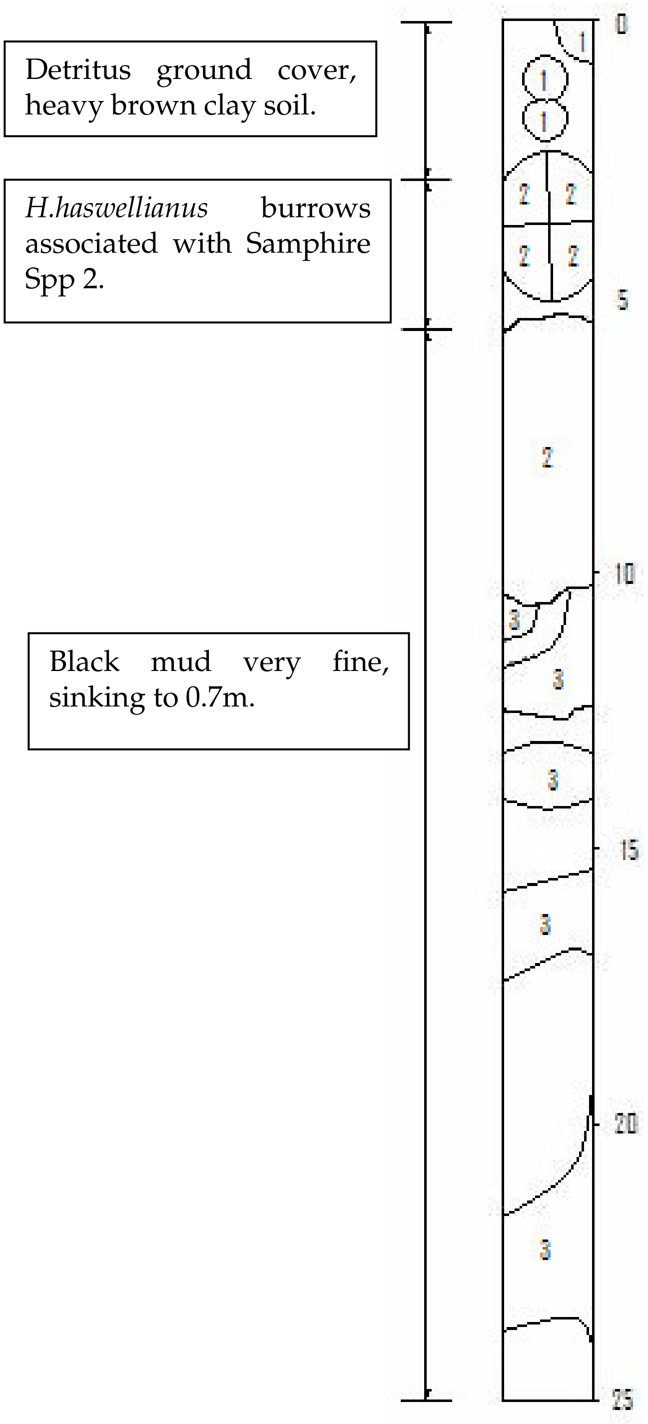
Mangrove Identification Key

Species 1 = Dead individuals

Species 2 = Alive individuals

Pne = Pneumatophores clearance above sediment (mangrove roots).

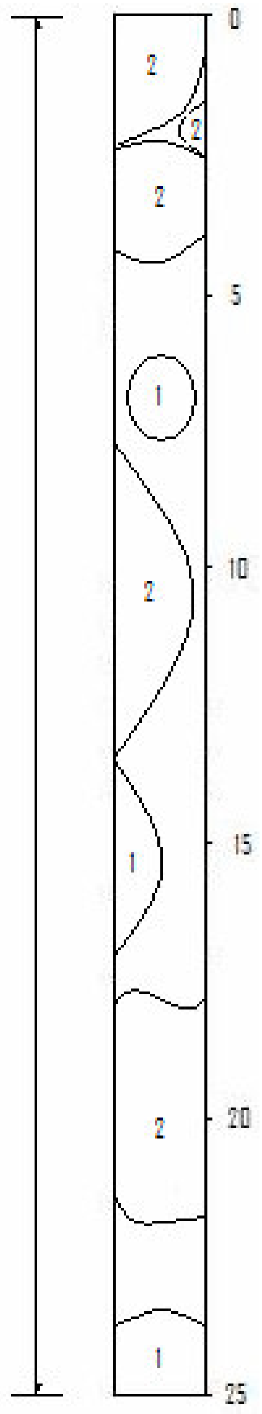
Samphire Site 1, (34,42,20S, 138,27,40E)



Site 1; consisted of firm heavy brown clay that has partly been eroded from the nearby levee bank to the 9.5m transect mark. From the 9.5m mark to the 25m mark the soil consisted of dark grey to black mud associated with small drainage channels between *Sarcocornia spp 1*. Plants in this area were generally healthy, although they appeared to be restricted between the high tide line and the levee bank to the evaporation ponds.

Mangrove Site 1. (34,42,20S, 138,27,40E)

Sediment was all black mud which continued to a depth of 0.7m.



3m tall, pne 2cm, trunk 40cm

2m tall, pne 15cm, trunk 15cm

3m tall, pne 50cm, trunk 40cm

1.5m tall, pne nil, trunk 10cm

4m tall, pne 50cm, trunk 20cm

Only just alive, 2m tall, pne 5cm, trunk 20cm.

2.5m tall, pne 40cm, trunk 30cm

2m tall, pne nil, trunk 15cm

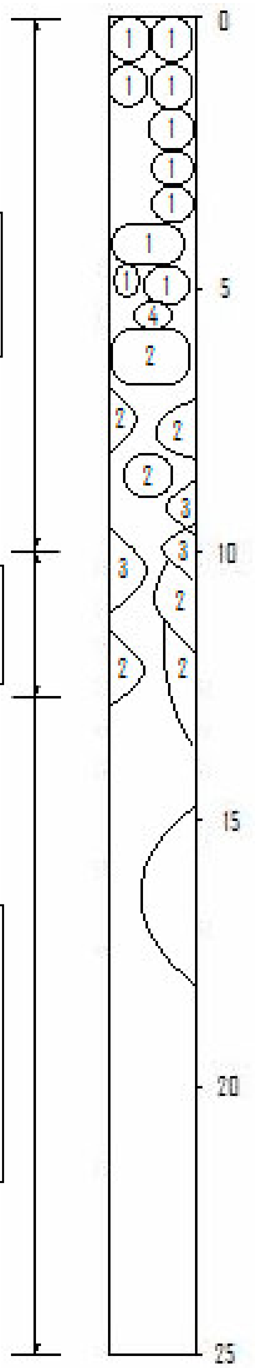
Pneumatophores at Site 1 were concentrated around the base of the mangrove trunk; root diameter around trunks was between 1m and 1.5m and seemed to correlate with height. Leaves in this area were either falling off or yellow, which is not unusual but indicates prolonged periods of hypersalinity. No crab burrows were found in this area as the mud was unstable and not suitable to promote structural diversity. Mangrove habitat was only 5m fromthe levee bank.

Samphire Site 2, (34,41,07S, 138,27,46E)

Heavy orange to brown clay, with detritus forming a thick organic layer

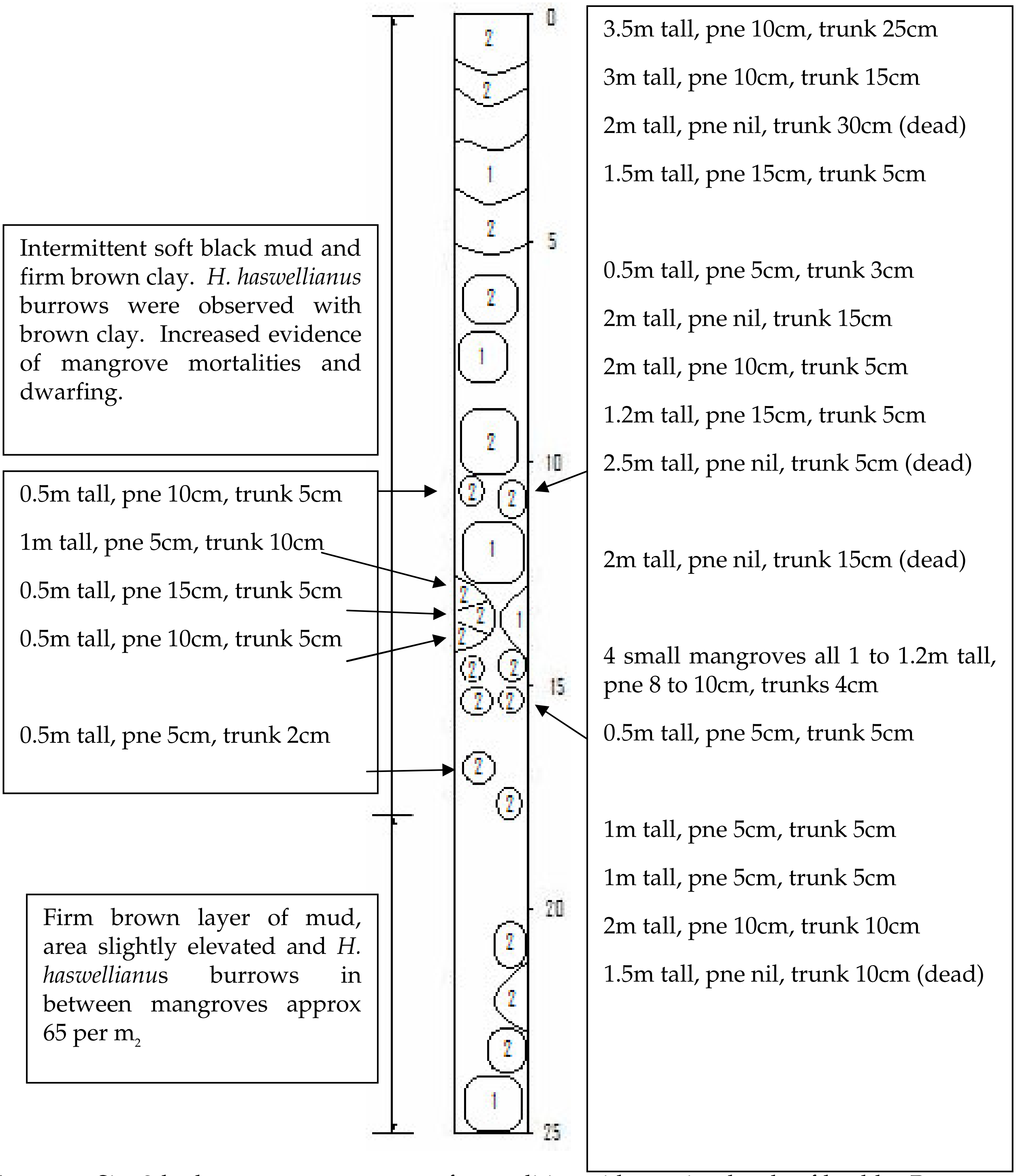
H. *Haswellianus* burrow, soil heavy brown clay

The area consisted of black to grey mud and soft to 0.2m. Small creeks, runoff from levee banks and the Gawler River drained through this area. Small grazing gastropods were observed.



Samphire in this site was restricted to narrow band from the face of the levee bank, the mudflat and marsh area. From 12.5m to 25m mark was a complex system of soft mud drainage channels. Channels are influenced by the intertidal nature of the site, pools were formed by freshwater runoff and seawater ingress. Trampling of samphire is an issue in this area as deer and fox tracks and scats were found throughout this site, along with walking tracks that have been carved out between the levee bank and the high tide mark. Grazing gastropod *S. Solidus* was noted in the mudflat area.

Managroves Site 2, (34,41,07S, 138,27,46E)

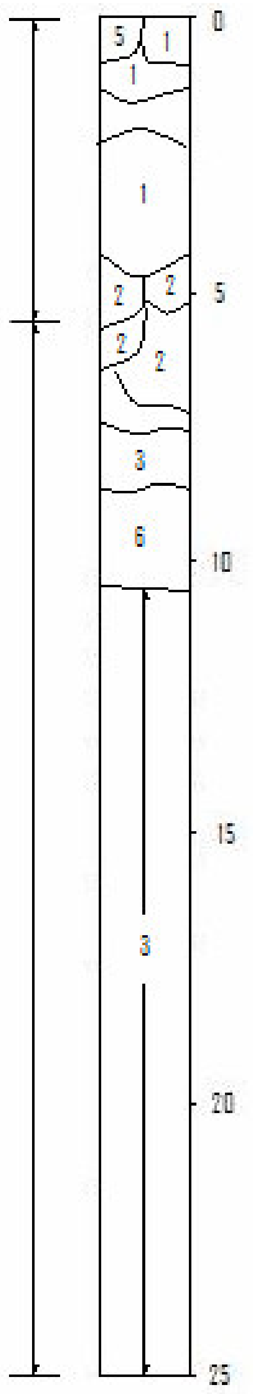


Mangrove Site 2 had a greater percentage of mortalities with varying levels of health. Poor health and mortalities were generally linked to inundation and smothering of pneumatophores by sediment. Dwarfing was also occurring with some thicker trunked plants having yellow or little to no foliage. This area seems to be a pooling area for water runoff from the levee banks (35m away) and the Gawler River. Small pools and creeks contained *H. haswellianus*, *S. solidus* and small fish species most likely a *gobbididae* (*lateralis*).

Samphire Site 3, (34,40,57S, 138,27,51E)

Heavy red/ brown clay, firm under foot. Spp 6 represents an algal bloom in a small drainage creek. Areas with out vegetation have marine detritus covering the ground.

Black extremely soft mud, Spp 3 dominating this area with almost 100% cover. This area is described as a low lying drainage area from the Gawler River, small intertidal/ freshwater drainage creeks dominated by algal species. Small fish were present in creek system and crab species *M. latrifrons* was recorded in this area.



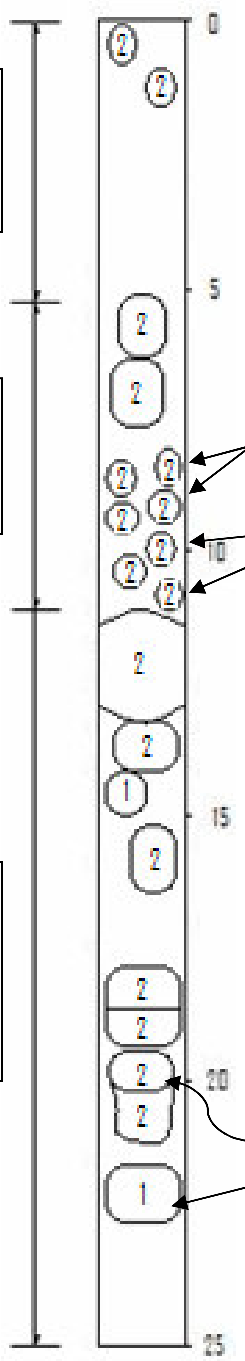
Samphire Site 3 featured a levee bank at 1.5m above the flood plain near the start of the transect then dropping to the high tide level at 7m transect mark. The tidal flat extends out for 35m to the mangrove stand, small intertidal/ drainage creeks are found throughout the tidal flat at this Site. Most samphire species are restricted to the Cheetham Salt levee bank, which cuts off as further coastal retreat.

Mangrove Site 3, (34,40,57S, 138,27,51E)

Intertidal creeks and soft black mud. Grazing gastropods and small fish species were observed at he end of the transect.

Crust layer formed on sediment in the mangroves, this was associated with a band crab burrows.

Small mangroves generally at the base of larger trees, area slightly elevated above high tide line hence small mangroves are not distributing with tidal movement.



0.5m tall, pne 10cm, trunk 2cm

0.5m tall, pne 10cm, trunk 2cm

1m tall, pne 5cm, trunk 5cm

1m tall pne 5cm, trunk 10cm

4 small mangroves all 0.5m tall, pne 10cm, trunks 5cm

2 small mangroves 0.5 tall, pne 5cm, trunks 4cm.

1.5m tall, pne 10cm, trunk 10cm

1m tall, pne 10cm, trunk 5cm

2m tall, pne nil, trunk 20cm (dead)

40cm tall, pne 5cm, trunk 2cm

1.5m tall, pne 5cm, trunk 5cm

1.0m tall, pne 5cm, trunk 5cm

0.5m tall, pne 5cm, trunk 20cm

12 small mangroves approx 0.5m tall, pne 3cm, trunk 1cm

2m tall, pne nil, trunk 50cm (dead)

Mangroves in this area are interceted by a band of intertidal/ drainage creeks similar to Site 2. Mangrove health in this area is intermediate consisting of a complete row of dead individuals, the cause is not evident, although areas of mortalities are associated with intertidal creeks/ drainage areas (stunted trees also noted in this area). Rubbish was found in this area, which may have been depositied be recent flooding events. Mangroves are approx 40m from Cheetham Salt levee bank.

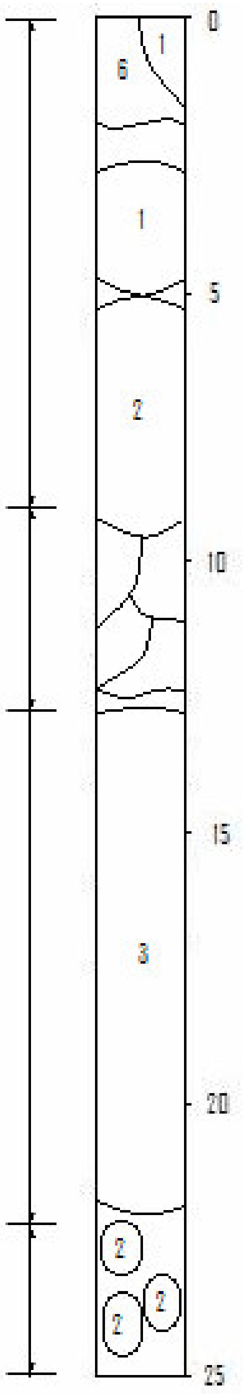
Samphire Site 4, (34,40,44S 138,27,54E)

Heavy brown clay associated with levee bank. Deer have trampled this site. *H. haswellianus* burrows found only in association with samphire Spp 2.

Small drainage creek at the base of levee bank associated with 90% mortality rate in mangroves, large amounts of rubbish found in this area.

Low lying area that is raised slightly above pools of water. Healthy samphire in firm black mud.

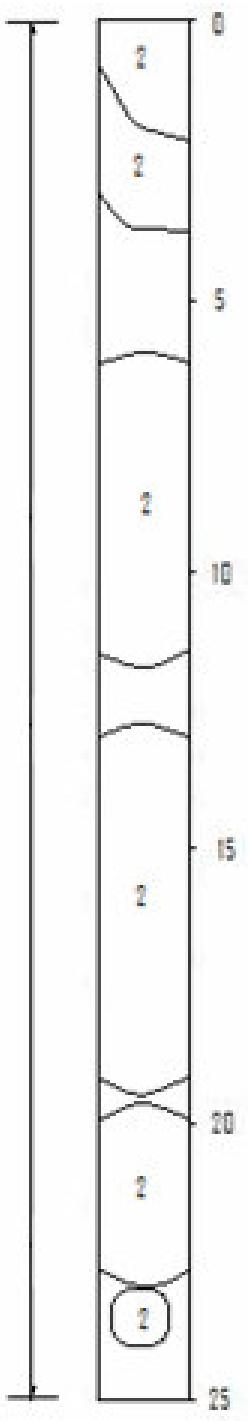
Spp 2 established in an area that is elevated above Spp 3 zone. Spp 2 in this area is found directly at the base of mangrove stands, with *H. haswellianus* burrows.



Samphire Site 3 is restricted between the Cheetham Salt levee bank and a large intertidal creek approximately 10m beyond the end of the transect line. This has caused a drainage channel to form in the middle of the samphire. Mangroves previously occupied this area but most are now dead. This area seems to receive periodical events of high water flow and sedimentation. The Samphire stand has deer tracks throughout; trampling seems to be damaging vegetation in this area.

Mangrove Site 4, (34,40,44S 138,27,54E)

Mangroves in this area are elevated above the drainage creeks in the samphire zone. The Gawler Creek, the main drainage channel in the area that contains saline water even at low tide, lies directly behind this site. Crab burrows were much more abundant at this site than any other as the sediment consisted of heavy brown clay complementing structural diversity.



4.5m tall, pne 20cm, trunk 42cm

4.5m tall, pne 20cm, trunk 45cm

4.5m tall, pne 15cm, trunk 30cm

4.75m tal, pne 15cm, trunk 25cm

4.75m tall, pne 5cm, trunk 35cm

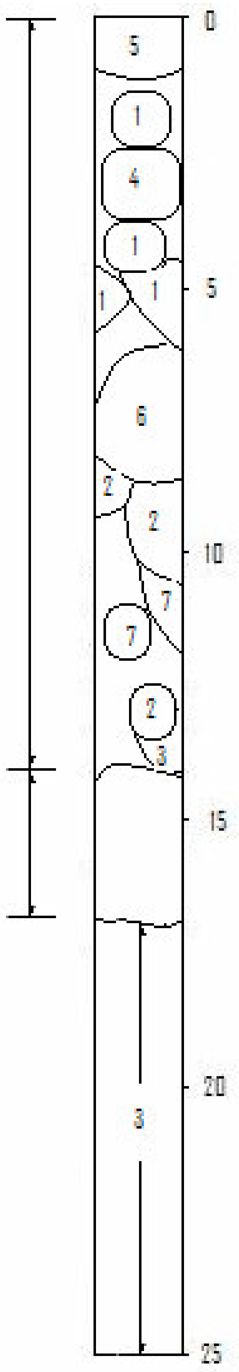
2m tall, pne 5cm, trunk 7cm

Mangrove health in this area is generally good with large trees having been established for many years. At this Site the area of pneumatophores around the base of individual trees is higher then other sites (diameter 4m to 5m). The mangrove stand is 27m from the Cheetham Salt levee bank.

Samphire Site 5 (Gawler River Mouth), (34,40,39S 138,28,08E)

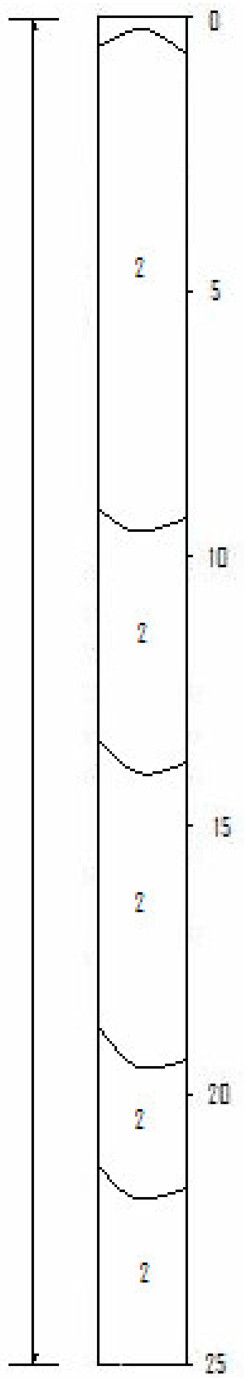
This area had a steeper slope from the levee bank, as is evident through the mix of species recorded. This area was heavily impacted by rubbish; deer trampling and salt spray from the neighbouring evaporation ponds. Concentrated foam/ salt from the evaportation ponds covered and damaged samphires.

Intertidal creek, sediment in creek was generally hard under foot. Small fish were present in large numbers, as well as grazing gastropods



Site 5 incorporated an intertidal creek that is also the main drainage creek during floods. Samphire in this area was generally in good health with the exception of yellow stained sediments next to the creek bed. Deer activity in the site was the observed in this survey, with defined tracks that extend out to the mangroves approximately 400m away. *H. haswellianus* burrows were evident on the levee bank side of the creek system and small fish were observed in the creek. General rubbish was also recorded in this area.

Mangroves Site 5 (Gawler River Mouth), (34,67,66S 138,46,70E)



4m tall, pne 20cm (very dense and wide spread, trunk 40cm

4m tall, pne 15cm very dense and wide spread, trunk 30cm

5m tall, pne 15cm very dense and wide spread, 30cm trunk

4m tall, pne 10cm very dense and wide spread, trunk 30cm

4m tall, pne 15cm very dense and wide spread, trunk 20cm.

The mangroves closest to the Gawler River were in very good health. *H. haswellianus* burrow were abundant with 80 to 90 per m^2, as was *S.solidus*. Also samphire species 2 was found at the base of mangrove stands. Sediment consisted of brown heavy clay and was firm under foot.

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Environmental Noise Impact Assessment
Buckland Park Proposal
Walker Corporation / DayCorp

3 November 2008
Reference 31495-001
Revision 3

Connell Wagner

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0	2 Feb 2008	Initial Draft	YKL	YKL	NCM	NCM
1	28 April 2008	Revision 1 (Master Plan, version 2)	YKL	YKL	NCM	NCM
2	23 September 2008	Revision 2 (Master Plan, version 6)	YKL	YKL	NCM	NCM
3	3 November 2008	Final	YKL	YKL	NCM	NCM

Contents

1. General

1.1 Introduction

Walker Corporation Pty Ltd and Daycorp Pty Ltd propose an urban project on a 1308 hectare site at Buckland Park, between Virginia and Port Gawler (refer to Figure 1). The proposal will transform the site into a new urban area consisting of dwellings, town centre, commercial, community and recreation facilities.

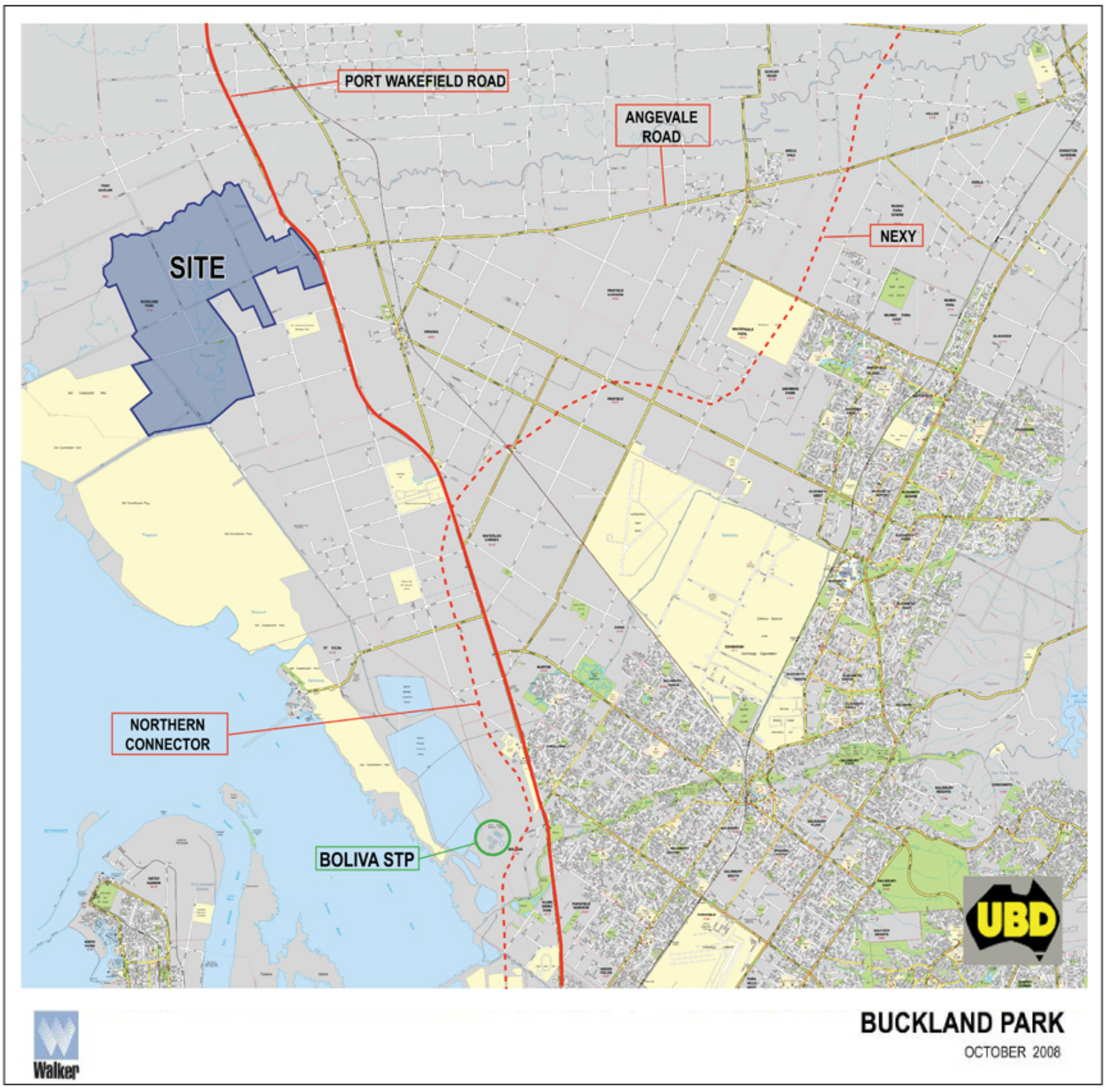


Figure 1: Location of the proposal

This report was prepared to satisfy the requirements of the Development Act 1993 and addresses environmental noise issues noted in the *Guidelines for Preparation of an Environmental Impact Statement on the Proposed Buckland Park Country Township Development* (dated August 2008) issued by the Development Assessment Commission (DAC), South Australia.

This report presents the findings of environmental noise studies of the existing environment and the potential impacts of the development.

1.2 Proposed development

The proposal involves the construction of 12,000 dwellings, a town centre, schools, shopping and commercial facilities, community facilities, sports and recreation facilities staged over a period of 25 years. Figure 2 shows the proposal's Masterplan.

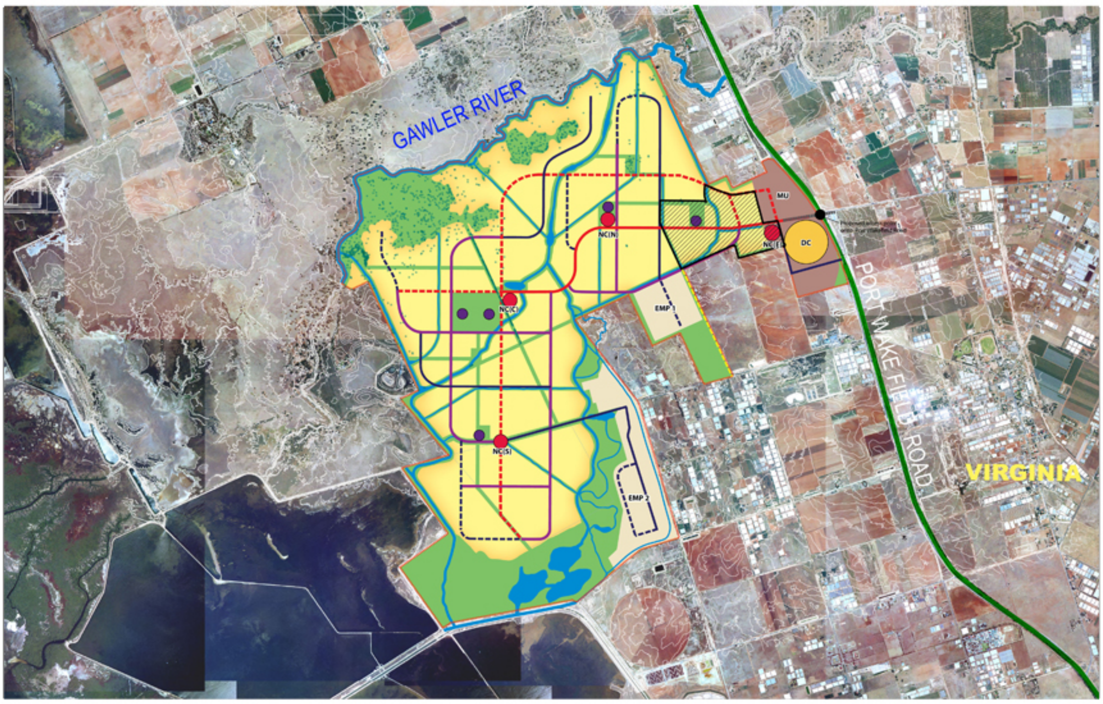


Figure 2: Proposed development (Master plan layout)

2. Existing environment

2.1 Environmental noise measurements

A continuous environmental noise survey was carried out around the site to determine the existing ambient background noise levels. Three *Larson Davis LXT* sound level meters were installed onsite (as shown in Figure 4) to monitor the environmental noise levels continuously in a 15 minute interval and over a minimum of 5-day period. The sound level meters were field calibrated with *Larson Davis LD CA 200* pistonphone prior to the monitoring. The microphones of the sound level meters were fitted with approved windshields at all times over the measurement period.

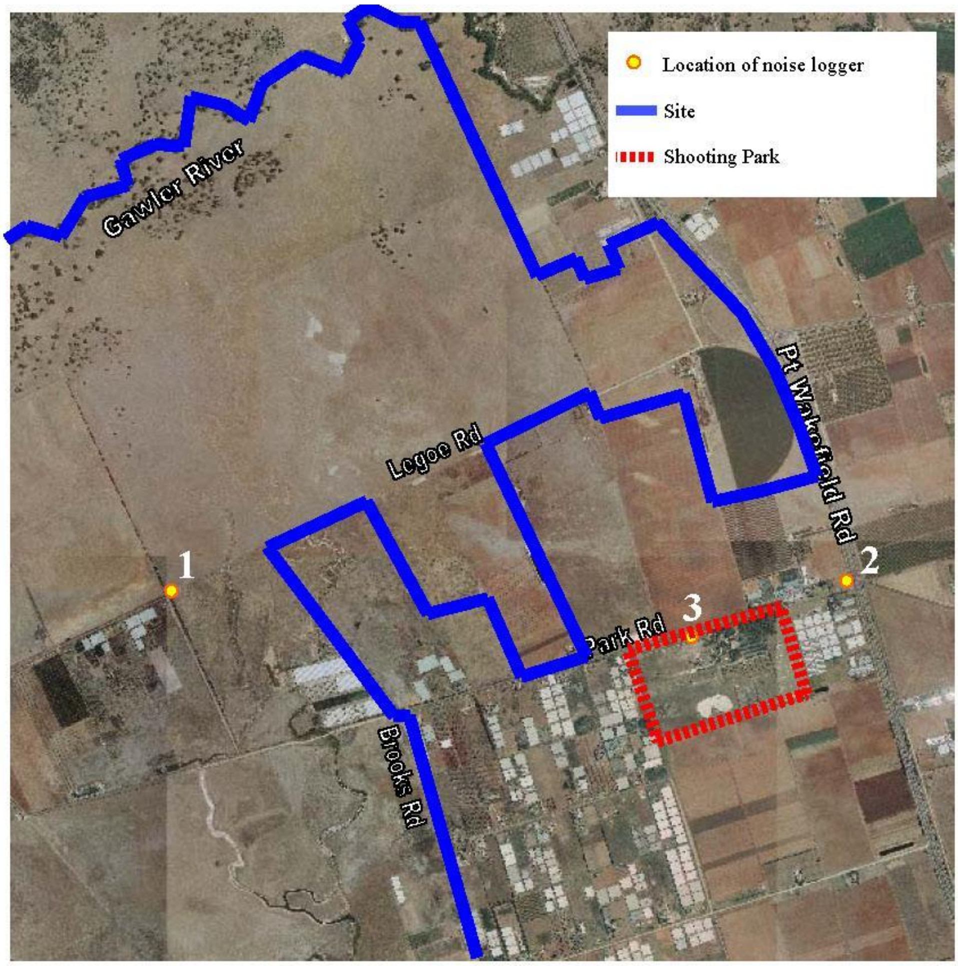


Figure 3: Continuous noise monitoring location

Table 1 summarises the average noise levels recorded over the monitoring period. The detail noise logging results are attached in Appendix B.

Table 1: Summary of background noise survey results

Monitoring details		Day (7am – 10pm)				Night (10pm – 7am)				Note
Site no (Refer to Figure 3)	Monitoring period	L_{eq}	L_{max}	L_{A10}	L_{A90}	L_{eq}	L_{max}	L_{10}	L_{90}	
		dB(A)				dB(A)				
1	11-16 December 2007	48	65	49	40	35	49	37	29	*1*
2	11-19 December 2007	64	79	67	53	60	79	63	40	*2*
3	18-22 January 2008	56	79	54	43	45	63	44	34	*3*

Note 1: Ambient noise level at site 1 is low, and generally due to nature, wind (rustling of leaves), insects, birds chirping, distant traffic, surrounding agricultural and horticulture activities, and occasionally light-aircraft flying over.

Note 2: Noise level measured at site 2 is mainly due to traffic along Port Wakefield Road.

Note 3: Noise at site 3 is primarily resulting from traffic along Park Road, State Shooting Park activities and surrounding agricultural and horticulture activities.

2.2 Attended noise survey at Shooting Park

In addition to unattended noise monitoring, an attended noise survey was also conducted on Saturday (19 January 2008) during outdoor Clay Target shooting activities at the SA Shooting Park.

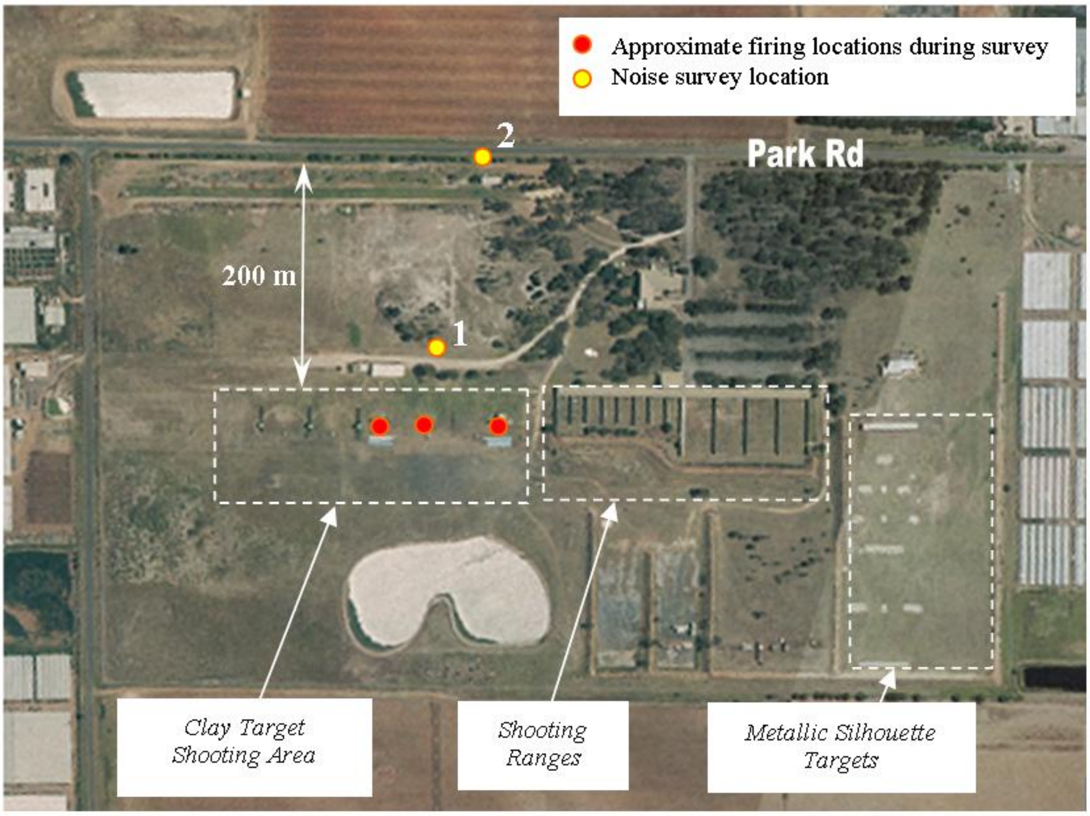


Figure 4: Noise survey at Shooting Park

The results of the attended noise measurements are summarised in Table 2. Survey show that gun firing noise emitted from State Shooting Park at the boundary of the site next to Park Road was around 101-106 dB (L_{peak}), and is less than noise resulting from heavy vehicle travelling along Park Road.

Table 2: Results of gun firing noise survey at Shooting Park

Location (Refer to Figure 4)	**Description**	**L_{peak} (dB)**
1	Gun firing noise from outdoor Clay Target Shooting area	108-120
2	Intermittent local traffic (heavy vehicle) along Park Rd	106-111
	Gun firing noise emitted from outdoor Clay Target Shooting area with no adjacent vehicle movement.	101-106

3. Regulations

Several criteria are used for assessment of the proposal, depending on the type of disturbance (noise/vibration) impacting on the potential noise-sensitive premises (i.e. dwellings and residential premises). The criteria for the acoustic assessment of the proposed development are outlined below.

3.1 Road Traffic Noise Guidelines

The Department for Transport, Energy and Infrastructure (DTEI) Road Traffic Noise Guidelines are applicable for assessment of road traffic noise where traffic noise could possibly affect nearby noise-sensitive premises as a result of the construction of new roads, roadworks (e.g. re-alignment, road widening) or change in the function of roads [2]. We note that in the proposal's Masterplan, the nearest proposed residential area (i.e. noise-sensitive premises) to the Port Wakefield Road is approximately 330m from the road. The DTEI Road Traffic Noise Guidelines is used as a guide to determine if noise resulting from the increase of traffic along Port Wakefield Road resulting from the proposal would be deemed as excessive at noise sensitive locations (e.g. dwellings, nursing homes, education institutions, etc), and the degree of noise control required.

The Road Traffic Noise Guidelines specify the following limits (in accordance with the flowchart in the Guidelines):

- For areas presently exposed to road traffic noise of less than day time 53dB(A) $L_{Aeq,15hr}$ and night time 48dB(A) $L_{Aeq,9hr}$, the external target criteria will be: day time 55dB(A) $L_{Aeq,15hr}$ and Night time 50dB(A) $L_{Aeq,9hr}$.
- For areas presently exposed to road traffic noise of greater than day time 53dB(A) $L_{Aeq,15hr}$ and night time 48dB(A) $L_{Aeq,9hr}$, the external target criteria will be the lower of:
  - the existing noise level plus 2dB(A).
  - a day time 65dB(A) $L_{Aeq,15hr}$ and night time 60dB(A) $L_{Aeq,9hr}$.

Based on the results of our Port Wakefield Road traffic noise monitoring, existing noise levels at the proposed residential area closest to the Port Wakefield Road is calculated to be less than day time 53dB(A) $L_{Aeq,15hr}$ and night time 48dB(A) $L_{Aeq,9hr}$. The appropriate criteria for assessment of the impact of traffic noise on the proposed residential location are therefore:

- Day-time (7:00 a.m. to 10:00 p.m.) $L_{Aeq,15hr}$ not more than 55dB(A)
- Night-time (10:00 p.m. to 7:00 a.m.) $L_{Aeq,9hr}$ not more than 50dB(A)

3.2 SA Environment Protection (Noise) Policy

3.2.1 Continuous noise emitted from Commercial or Industrial activities

The South Australia EPA Environmental (Noise) Policy (EEP) 2007 [1] sets guidelines for external noise at the most noise sensitive premises (from commercial and industrial activities) depending on time of day, land use and zoning. Figure 3 shows the existing zones in the site's locality.

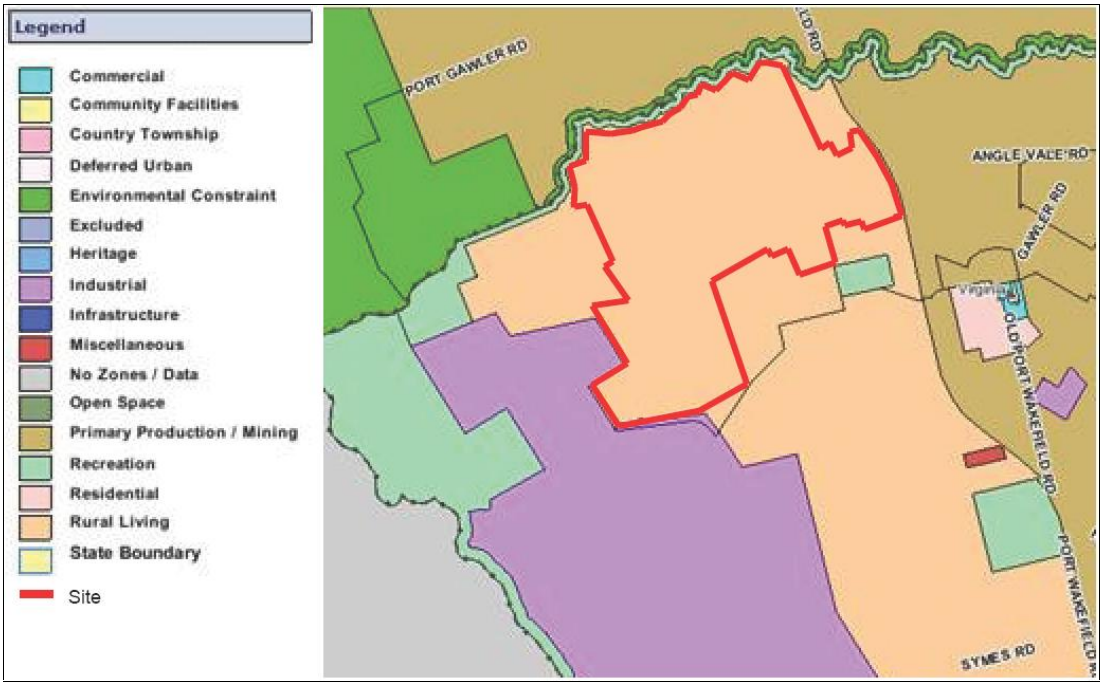


Figure 5: Existing land use zones identified in the Playford City Development Plan [9]

The site is zoned "Horticulture West". Should the major development application be approved, a rezoning will be sought to permit urban activities.

The EEP [1] specifies the following noise levels for different land use and zoning:

Table 3: Indicative noise factor by EEP

Land Use Category	Indicative Noise Factor (dB(A))	
	Day	Night
Rural / Rural Living	47	40
Residential	52	45
Light Industry	57	50
Commercial	62	55

In addition, a 5dB(A) penalty applies (to a maximum penalty of 10dB(A)) if the noise exhibits tones, modulation or contains an impulsive component.

For planning purposes, assessment criteria for the proposed mixed use and employment areas should be based on the indicative noise factor less 5dB(A).

3.2.2 Fixed domestic machine noise

The operation of a fixed domestic machine has an adverse impact on surrounding amenity if noise measurements taken in relation to the noise source and noise-affected premises when the machine is operated exceeds the following levels:

- 52dB(A) during day-time (between 7:00 a.m. to 10:00 p.m.); or
- 45dB(A) during night-time (between 10:00 p.m. to 7:00 a.m.).

3.2.3 Noise from Construction activities

The South Australia EPA Environmental (Noise) Policy 2007 [1] sets guidelines for noise from construction activities, and it states the following:

Under "Part 6 — Special noise control provisions" of "Division 1 — Construction noise"
23 — Construction activity

(1) The following provisions apply to construction activity resulting in noise with an adverse impact on amenity:

  (a) subject to paragraph (b), the activity—

    (i) must not occur on a Sunday or other public holiday; and

    (ii) must not occur on any other day except between 7.00 a.m. and 7.00 p.m.;

  (b) a particular operation may occur on a Sunday or other public holiday between 9.00 a.m. and 7.00 p.m., or may commence before 7.00 a.m. on any other day—

    (i) to avoid an unreasonable interruption of vehicle or pedestrian traffic movement; or

    (ii) if other grounds exist that the Authority or another administering agency determines to be sufficient;

  (c) all reasonable and practicable measures must be taken to minimise noise resulting from the activity and to minimise its impact, including (without limitation)—

    (i) commencing any particularly noisy part of the activity (such as masonry sawing or jack hammering) after 9.00 a.m.; and

    (ii) locating noisy equipment (such as masonry saws or cement mixers) or processes so that their impact on neighbouring premises is minimised (whether by maximising the distance to the premises, using structures or elevations to create barriers or otherwise); and

    (iii) shutting or throttling equipment down whenever it is not in actual use; and

    (iv) ensuring that noise reduction devices such as mufflers are fitted and operating effectively; and

    (v) ensuring that equipment is not operated if maintenance or repairs would eliminate or significantly reduce a characteristic of noise resulting from its operation that is audible at noise-affected premises; and

    (vi) operating equipment and handling materials so as to minimise impact noise; and

    (vii) using off-site or other alternative processes that eliminate or lessen resulting noise.

(2) The responsible person for construction activity must ensure that if the construction activity results in noise with an adverse impact on amenity, the construction activity does not occur or commence except as permitted by subclause (1)(a) and (b).

Mandatory Provision: Category B offence.

(3) For the purposes of this clause, construction activity results in noise with an adverse impact on amenity if measurements taken in relation to the noise source and noise-affected premises show—

(a) that the source noise level (continuous) exceeds 45 dB(A); or

(b) that the source noise level (maximum) exceeds 60 dB(A).

3.3 City of Playford Development Plan's criteria

Relevant environmental noise performance criteria for new development are documented in the City of Playford Development Plan:

Principle of development control for non-residential development in residential zones states that:

No. 70 (b) - Non-residential development such as business, commercial or industrial activities in living areas should provide adequate protection for residents from air and noise pollution, traffic disturbance and other harmful effects on health or amenity.

Principle of development control for centre and shops states that:

No. 142 - the location and design of centres and shopping development should ensure that all sources of noise, including refrigeration and air conditioning equipment, garbage collection and car parking, do not cause excessive or disturbing noise at neighbouring properties.

Principle of development control for Agricultural Industries (small-scale), Wineries, Mineral Water Extraction and Processing Plants and Home Based Industries states that:

No. 476 - Agricultural industries, home based industries, mineral water extraction and processing plants and wineries should not:

(d) generate significant additional traffic noise or other nuisance which would detract from residents' or other land holders' enjoyment of the locality.

(e) generate noise of greater than 40 decibels during the hours of 10 pm to 7am and 47decibels between 7 am to 10 pm respectively as measured at the nearest neighbouring dwelling or boundary of a vacant allotment;

3.4 South Australian EPA Guidelines for Music Noise

The South Australian EPA provides guidelines on noise assessment for venues where music may be played [7]. Based on the guidelines, the criteria for assessment of music noise are as follows:

- Music noise ($L_{OCT10,\ 15min}$) measured over a 15-minute period from an entertainment venue should be less than 8dB above the background noise level ($L_{OCT90,\ 15min}$) in any octave band of the sound spectrum, and
- Music noise ($L_{A10,\ 15min}$) measured over a 15-minute period from an entertainment venue should be less than 5dB(A) above the overall A-weighted background noise level ($L_{OCT90,\ 15min}$).

3.5 Shooting Ranges

South Australian Environment Protection Act 1993 [8] states the following:
Schedule 1 Prescribed Activities of Environmental Significance
Under "Section 8 – Other" of "Part A – Activities":

(6) Shooting Ranges

the conduct of facilities for shooting competitions, practice or instruction (being shooting involving the propulsion of projectiles by means of explosion), but excluding indoor facilities or facilities that are situated more than 200 metres from residential premises not associated with the facilities.

The SA Shooting Park is more than 200 metres from the nearest proposed residential area within the site, and therefore it is not designated as an activity of environmental significance under the South Australian EPA regulations.

3.6 Construction vibration assessment criteria

There are no specific criteria for assessment of construction vibration in South Australia. Instead, the German Standard DIN 4150-3 1999 "Structural Vibration Part 3: Effects of Vibration on Structures" and the NSW DEC "Assessing Vibration - A Technical Guideline" are referenced as a guide for this assessment.

3.6.1 Building (structural) damage

The German Standard DIN 4150-3 1999 "Structural Vibration Part 3: Effects of Vibration on Structures" [4] provides guideline criteria for evaluating the short and long-term effects of vibration on structures. The standard provides recommended maximum levels of vibration over a range of frequencies measured that reduce the likelihood of building damage caused by vibration. The recommended ground vibration limits for transient vibration to ensure no structural damage to residential and industrial buildings are presented numerically in Table 4.

Table 4: Acceptable ground vibration levels at building foundations

Type of structure	Guideline values for vibration velocity (mm/s) at the building foundation at the frequency of		
	less than 10Hz	10 to 50Hz	50 to 100Hz
Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50
Dwellings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20
Structures that, because of their particular sensitivity to vibration, do not correspond to type 1 or 2 and have intrinsic value (e.g. buildings under a preservation order)	3	3 to 8	8 to 10

3.6.2 Human comfort (perception) vibration criteria

Human comfort vibration criteria are based on NSW DEC "Assessing Vibration - A Technical Guideline" [10]. The guideline provides building vibration levels associated with a low probability of disturbance to building occupants. The acceptable vibration dose values for intermittent vibration are summarised in Table 5.

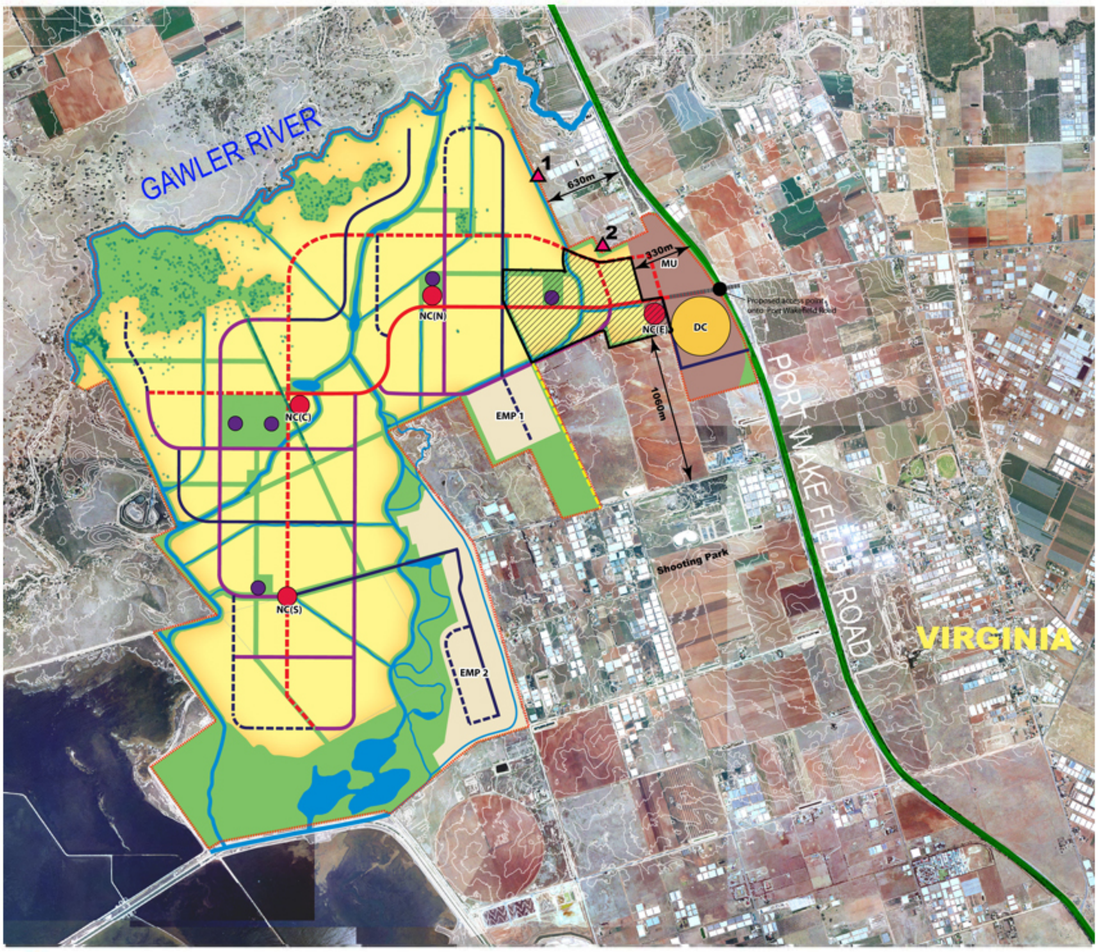
Table 5: Acceptable vibration dose levels for intermittent vibration ($m/s^{1.75}$)

Location	Day time (7am – 10pm)		Night time (10pm – 7am)	
	Preferred value	Maximum value	Preferred value	Maximum value
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

4. Assessment and Recommendations

4.1 Traffic noise from Port Wakefield Road

A Port Wakefield Road traffic noise impact assessment was carried out based on the forecast traffic volume and composition data provided by Parson Brinckerhoff [5] and the results of our continuous noise monitoring conducted at approximately 20m from road edge on the eastern side of the Port Wakefield Road between 11 and 19 December 2007.



Boundary chosen to represent the typical residential relationship to Pt Wakefield Rd and Shooting Park

Figure 6: Noise sensitive receiver relative to Port Wakefield Road

A summary of the traffic volumes and composition along Port Wakefield Road is shown in Table 6.

Table 6: Traffic volumes along Port Wakefield Road adjacent to the Buckland Park Site

Year	Road Section	Note	AADT (24hr, 1-way)	Day (15 hours)		Night (9 hours)	
				Cars	CVs	Cars	CVs
2006*	North of Angle Vale Road	Northbound	4648	3664	647	286	51
		Southbound	4840	3816	673	298	53
	South of Angel Vale Road and North of Park Road	Northbound	5427	4310	644	411	61
		Southbound	5636	4477	669	427	64
	South of Park Road	Northbound	5427	4310	644	411	61
		Southbound	5636	4477	669	427	64
2007^	North of Angle Vale Road	Northbound	4787	3774	666	295	52
		Southbound	4985	3930	694	307	54
	South of Angel Vale Road and North of Park Road	Northbound	5590	4440	663	423	63
		Southbound	5805	4611	689	440	66
	South of Park Road	Northbound	5590	4440	663	423	63
		Southbound	5805	4611	689	440	66
2031*	North of Angle Vale Road	Northbound	10415	7133	2345	705	232
		Southbound	10521	7211	2363	713	234
	South of Angel Vale Road and North of Park Road	Northbound	27585	22757	2345	2251	232
		Southbound	27945	23067	2363	2281	234
	South of Park Road	Northbound	26760	22007	2345	2176	232
		Southbound	28245	23340	2363	2308	234

* *Data provided by Parson Brinckerhoff.*

^ *Estimated Year 2007 traffic data along Port Wakefield Road based on Year 2006 traffic data (volume and composition) provided by PB with the assumptions that the annual traffic growth rate was 3% and the traffic composition remain the same as Year 2006.*

A simple acoustic model of the Port Wakefield Road with respect to the proposal was developed using the SoundPLAN 6.4 computational noise modelling software. The road traffic noise levels were predicted in accordance with the CoRTN (Calculation of Road Traffic Noise), based on the following:

- Traffic counts and percentages of commercial vehicles provided (as outlined in Table 6).
- The speed limit of 110km/hr for Port Wakefield Road.
- Flat terrain throughout the site.
- A 2.5dB factor has been added to the predicted noise levels at the nearest residences on Buckland Park development to account for façade reflections.

The model created in SoundPLAN computational modelling software was calibrated using the results of our continuous traffic noise monitoring data at the noise logging site 2 (refer to Table 1). The calibrated noise model was then used to predict the Year 2031 Port Wakefield Road traffic noise using the Year 2031 forecast traffic data. Results of the prediction is summarised in Table 7. Traffic noise contours were generated and attached in Appendix C.

Table 7: Predicted Port Wakefield Road Traffic Noise Levels at the nearest proposed residential boundary

	Predicted Port Wakefield Road traffic noise level dB(A)			
	Proposed residential location 1*		Proposed residential location 2*	
	Day time, $L_{Aeq,\ 15hr}$	Night time, $L_{Aeq,\ 9hr}$	Day time, $L_{Aeq,\ 15hr}$	Night time, $L_{Aeq,\ 9hr}$
Year 2031	52	48	54	50

* *Refer to Figure 6.*

Results of our assessment revealed the following:

- The L_{Aeq} day-time and night-time traffic noise levels for Year 2031 predicted at the nearest future residential area within the Buckland Park Masterplan would meet the DTEI L_{Aeq} day-time and night-time traffic noise limits respectively. In addition, commercial buildings within the mixed use area would provide further shielding for residents from Port Wakefield Road noise, reducing actual road traffic noise experienced at those residences.
- Ground vibrations due to traffic from Port Wakefield Road would be negligible given the distance between the proposed new residential areas and Port Wakefield Road.

Based on the information provided by PB, results of our assessment in Table 7 shows that Port Wakefield Road traffic noise levels at the nearest residential area within the Masterplan would comply with the DTEI criteria. We note that care must be taken during the detail design stage for the commercial development facing Port Wakefield road. The façade (e.g. wall, windows, etc) of the commercial buildings should be selected to provide sufficient sound insulation to achieve AS2107 recommended indoor background noise levels.

4.2 Noise from Mixed Use and Employment Areas

Noise from the Mixed Use and Employment areas may affect neighbouring residential areas, particularly if the areas are adjoining. It is envisaged the Mixed Use and Employment Areas will be used for a range of light industrial, commercial, retail activities.

Potential noise impacts from industrial, commercial and retail activities are:

- Noise from refrigeration plant and air-conditioning plant servicing the commercial / industrial buildings.
- Noise from ventilation systems (e.g. kitchen exhaust fan, car park exhaust fan, etc).
- Noise from entertainment activities at the commercial area (e.g. noise from beer garden, pubs, taverns, karaoke centre, etc).
- Noise from loading/unloading activities.
- Noise from emergency generator.
- Noise from waste water treatment plant, pump, machinery, blowers.

The Masterplan shows residential areas located at least 50m away from Employment areas. If these areas are occupied by light-industry, with noise limits as per the EPA Regulations (refer to Section 3.2.1) at their premises boundary, it is considered that noise from these activities would not significantly impact on the nearby residents.

The Masterplan shows that there will be residential areas next to the Mixed Use areas. To ensure the noise levels emitted from future commercial or retail premises at the nearest noise sensitive boundaries achieve the EPA day- and night-time noise criteria, care must be taken in the detail design of each stage. It is recommended this is achieved through Design Guidelines and Planning Controls included in any Development Plan Ammendment, which should include as a minimum the following clauses:

- Comply with EPP “indicative noise limit” for a “residential” premises, at the nearest residential boundary less 5dBA (to allow for cumulative effects).
- Careful locate noisy outdoor mechanical plant (e.g. refrigeration unit, AC plant, kitchen exhaust fan, car park exhaust fan, etc).
- Consideration of the façade construction (e.g. wall, windows, etc) of the residential buildings close to commercial area.
- Careful consideration of the design of any hotels or restaurant building envelopes such that any entertainment/music noise is contained within the premises (e.g. thicker and double glazing, installing acoustic seals to the windows and doors, adequate construction of walls, and careful sealing of building envelope junctions).
- Limiting truck deliveries, loading and unloading activities to the day-time and less sensitive hours (between 7:00 a.m. and 7:00 p.m.). In the case where this is not possible, and loading/unloading activities is to operate during the EPA stipulated night-time (i.e. between 10:00 p.m. and 7:00 a.m.), site boundary wall can be constructed to block the line of sight shielding to nearby residents.
- Implementation of noise treatment such as acoustic barriers, silencers, acoustic louvers and acoustic enclosures.

4.3 Noise from local traffic

The proposal will generally introduce increased traffic volumes both within the site and its surrounding area. The Masterplan shows “residential” areas are located to the west of Pt Wakefield Rd and away from the proposed “Mixed Use” areas. Noise resulting from local traffic would not be significant and is not expected to affect the amenity of existing and future residences.

The proposed “residential” areas located adjacent to the proposed “Mixed Use” areas could be potentially impacted by commercial vehicles movements. To reduce traffic noise impact and protect the amenity of residents, we recommend the following should be included in detailed design and incorporated into Design Guidelines and future planning controls.

- Provide sufficient buffer distance (at least 20m) between the two different land use areas.
- Locate noise-sensitive spaces such as bedrooms away from the proposed commercial development (e.g. such that the bedrooms do not face the major road and commercial buildings).
- Install thicker glazing for windows to the residential building facing the major road.
- Limit truck deliveries, loading and unloading activities to day time and less sensitive hours (between 7am and 7pm).
- Commercial vehicles and trucks should travel at slowest suitable speed with a minimum of engine revving during operations, and the use of truck exhaust brakes should be restricted. These can be managed through street design and signage.

The proposed arrangement of land uses within the Masterplan, and their relationship to arterial roads is consistent with the situation faced with most arterial roads throughout metropolitan Adelaide.

4.4 Noise from fixed domestic machines

The operation of a fixed domestic machine (such as air-conditioning plants, etc) may create a potential noise impact on the neighbouring residents. To reduce the noise impact from these machines, we recommend:

- Careful selection of equipment (i.e. select a low or quiet noise equipment).
- Careful orientation of outdoor noisy equipment/machine and noise sensitive receivers to avoid creating a layout with noise sources directed towards neighbouring receivers.
- Installation of noise control measures (e.g. enclosure, barrier, etc) such that they do not impact on the nearby residents.

These matters can be addressed in Design Guidelines and planning controls.

4.5 Noise and vibration impact during construction stage

Construction noise

Construction of the project would generally involve machinery such as excavators, graders, rollers, loaders, truck, cranes, generators and the like. Noise from the operation of this equipment may result in elevated ambient noise levels at surrounding sensitive receptors, especially during night time when background noise is lower. The magnitude of the noise and vibration during the construction phase would vary and depending on the type and size of construction plant used onsite, the number of machines operating, and the intensity and location of the activities onsite.

We have identified the existing residential properties in the site's vicinity. These residences (as shown in Figure 7) may be affected during the proposal's construction stage.

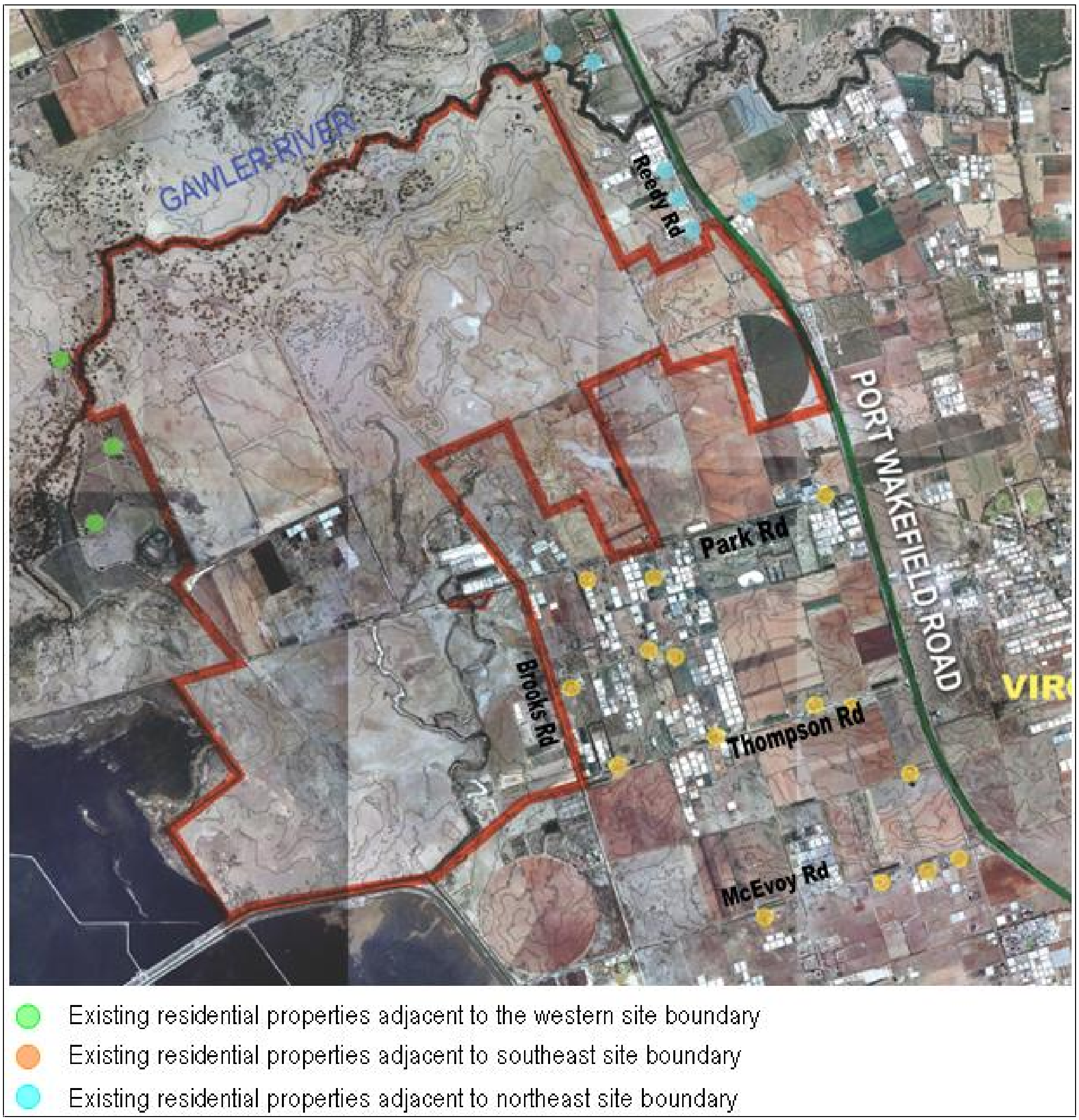


Figure 7: Potential affected noise sensitive receivers around the site

A summary of the approximate distance between the potentially affected residential properties and the site is outlined in Table 8.

Table 8: Construction area vs. Sensitive Receptors

Existing residential properties adjacent to	Description	Approximate distance between the site boundary and the closest sensitive residential receivers (m)
Western site boundary	This rural site is primarily bounded by vacant land. Only 3 remote residential properties were identified. Minimal impact is expected.	> 130m
Southeast site boundary	The site is presently surrounded by agricultural/horticultural activities and non-sensitive land uses. Some residential dwellings were identified along Park Rd, Thompson Rd, and McEvoy Rd which are likely to be affected during construction phase. The nearest noise sensitive receiver is the dwelling on Brooks Rd next to the site boundary.	> 90m
Northeast site boundary	The site is currently zoned for horticultural land use, and only few residential properties were identified. The nearest noise sensitive receiver is the dwelling along Reedy Rd next to the site boundary.	> 70m

Noise from the construction activities may occasionally be discernible at these nearby sensitive receptors when work occurs close to the site's boundaries and exceeds the levels outlined in the EPA regulations. Based on experience, noise levels of 65-85 dB(A) are expected from general construction activities.

It is anticipated that at any given time during construction phase, the construction machinery will move from one area to another within the site as the construction of the project progresses, and would only operate at maximum capacity (i.e. maximum sound power levels) for short temporary basis. At other times, the machinery may generate a lower sound level while carrying out activities that do not require full capacity. We therefore consider that the construction noise impacts will not likely to cause an increase in long-term sound levels and are expected to be minor.

Noise impacts may be associated with construction vehicle traffics. Traffic due to workforce movements and delivery of materials will increase the ambient noise levels at residences adjoining access routes. It should be noted that transport movements will be managed through the Construction Traffic and Transport Management Plan to minimise the potential noise impact.

Construction vibration

It is understood that no blasting activities would occur during the construction, and the ground vibration resulting from the construction works will potentially associated with the excavation, compacting and pile driving activities. The major vibration sources will include the operation of bulldozers, excavators, vibratory rollers, and piling rig.

The actual ground vibration levels due to construction work are difficult to be predicted accurately due to the dependence of vibration transmissibility on soil type (soft or hard), intervening geology (i.e. the coupling loss between the soil and the building foundation), and the building foundations, etc.

From experience, vibration levels generated by construction equipment will generally be below both human comfort criteria and building damage criteria for sensitive buildings further than 40m, and therefore no vibration exceedance at receivers in close proximity to site is expected.

Given the buffer distance of at least 70m between the nearest residential properties and the project boundary, vibration levels resulting from construction activities are not expected to be noticeable at most residence locations or cause any structural damage. The vibration impact is expected to be minimal and readily be achieved at the surrounding residence locations. However, it should be noted that care has to be taken to prevent excessive vibration when working close to residential properties.

Recommended amelioration measures

During all forms of construction work, the ambient noise levels may potentially be exceeded, resulting in elevated noise levels at sensitive receptors, especially when background noise is lower. To mitigate potential noise impacts associated with construction of this proposal, it is recommended the Construction Management Plan include the following measures:

- Provide advance notice to, and regular communication with, existing residents before and throughout the construction period.
- Install a temporary acoustic barrier / fence along the boundary of the proposed construction area providing line of sight shielding to the nearby residents. The temporary barrier may be constructed of lapped gapless timber (e.g. 20mm thick timber overlapped 25mm or 25mm thick plywood, or 6mm compressed fibre cement, or material with equivalent density). The barrier shall be impervious, continuous and have no gaps/holes/cracks over the entire length.
- Excessively noisy machinery should preferably not be operated before 9:00 a.m. and should be located as far as possible from the noise-sensitive premises. Where possible and practicable, noise machinery should have appropriate mufflers, silencers and/or enclosures fitted to reduce noise transmission.
- Avoid the coincidence of noisy plant/machine working simultaneously close together and adjacent to sensitive receivers.
- Where needed, obtain an exemption from the EPA to exceed the Environmental Protection (Noise) Policy. This will cost about $500 and take about 2 months from the date of lodgement to obtain. These are routinely issued to facilitate construction activities.
- Conducting noise and vibration monitoring when working close to potential affected sensitive receivers to ensure that the levels satisfy the EPA criteria. In addition, the monitoring will enable noise and ground vibration records to be kept and used for reference in the event of a complaint.
- As far as practical, all operations causing relatively high levels of noise and vibration should be carried out at a time to cause the least annoyance to neighbours. Restrict construction time between 7:00 a.m. to 5:00 p.m. Monday to Friday and 7:00 a.m. to 1:00 p.m. Saturday with no work being carried out on Sundays.
- The use of light machinery (e.g. smaller excavators and rollers) during operation near the southern boundary (closest to the residential buildings).
- All construction vehicles and trucks will enter and leave the site in accordance with site entry controls. Avoid heavy vehicle movement if possible along McEvoy road and Thompson Road where there is a potential traffic noise impact to the residents along the road.
- Work with the construction manager to provide a public relations policy, adhering to the requirements of any EPA exemption (ie, maintain a record of complaints and actions taken to resolve).
- Ensure all equipment is limited to a sound pressure level at 15m of 85dBA (under worst case operating mode), either by fitting silencers/shrouds to existing equipment or by using updated equipment (equipment should be no more than 5 years of age).
- Where possible, locate any stationary constant noise sources such as air compressors, generators, cranes etc. as far as possible from adjacent or nearby premises, and if necessary provide additional screening.

5. Conclusion

A noise and vibration impact assessment of the proposal at Buckland Park as described in the Masterplan has been conducted.

The assessment has considered the following sources of noise during the operation phase of the proposal:

- Traffic noise from Port Wakefield Road at the nearest boundary of proposed residential boundary was predicted for year 2031, and was found to be within the DTEI Road Traffic Noise Guidelines 2007. Therefore, no mitigation is required.
- Noise from activities surrounding the site, including the Shooting Park, are unlikely to cause an adverse impacts on the proposal due to the distance from the nearest boundary of proposed residential areas and the Shooting Park.
- Noise from future industrial, commercial and retail activities within the proposed Mixed Use and Employment Areas, and its potential impacts on proposed residential areas will be addressed through detailed design and planning controls to ensure compliance with the SA EPA Act and authority requirements.
- Noise from local traffic and fixed domestic machines is not anticipated to significantly affect the proposed residential areas. However, care has to be taken during detail residential design stage, such as careful orientation of outdoor noisy equipment, installation of thicker glazing for windows, etc. This can be addressed in Planning Controls and Design Guidelines.

During construction, noise and vibration will be controlled through the preparation and application of a Construction Noise and Vibration Management Plan to ensure compliance with the "SA Environment Protection (Noise) Policy and Explanatory Report" 2007, and relevant guidelines such as the DIN 4150:1986 Part 3 "Structural vibration in buildings – Effects on structures".

6. References

1. South Australia Environment Protection Authority, *"Environment Protection (Noise) Policy and Explanatory Report"*, 2007.
2. Road Traffic Noise Guidelines by Department for Transport, Energy and Infrastructure (DTEI) (2007).
3. City of Playford Development Plan, consolidated 15 February 2007.
4. DIN 4150:1986 Part 3 "Structural vibration in buildings – Effects on structures".
5. Traffic volumes and composition on Port Wakefield Road for Year 2006 (survey data) and Year 2031 (forecast data), provided by Parson Brinckerhoff through email on 14 January 2008 and 21 May 2008 respectively.
6. Guidelines for Community Noise, World Health Organization (WHO), 1999.
7. South Australian Government (2003), EPA guidelines, "Development proposal assessment for venues where music may be played".
8. South Australian Environment Protection Act 1993.
9. Australia Government Atlas website, www.atlas.sa.gov.au.
10. "Assessing Vibration: A Technical Guideline" by the Department of Environment and Conservation NSW.

Appendix A

Glossary of acoustic terminology

Appendix A

Glossary of acoustic terminology

Sound Pressure	Sound or sound pressure is a fluctuation in air pressure over the static ambient pressure.
Sound Pressure Level	The sound pressure relative to a standard reference pressure of 20µPa ($20x10^{-6}$ Pascals) on a decibel (dB) scale.
dB	The decibel (dB) is the unit used for sound level measurement.
dB(A)	Unit of sound level, in A-weighted decibels. The human ear is not equally sensitive to all frequencies of sound. The A-weighting approximates the sensitivity of the human ear by filtering these frequencies. A dB(A) measurement is considered representative of average human hearing.
L_{Aeq}	The A-weighted equivalent continuous sound pressure level, used to quantify the average noise level over a time period.
L_{A10}	The A-weighted sound pressure level exceeded for 10% of the measurement period. It is usually used as the descriptor for intrusive noise level.
L_{A90}	The A-weighted sound pressure level exceeded for 90% of the measurement period. It is usually used as the descriptor for background noise level.
$L_{Aeq(15hr)}$ ($L_{Aeq\ day\text{-}time}$)	The noise descriptor $L_{Aeq(15hr)}$ (or $L_{Aeq\ day\text{-}time}$) refers to the A-weighted energy averaged equivalent noise level over a 15 hour day time period between 7am and 10pm.
$L_{Aeq(9hr)}$ ($L_{Aeq\ night\text{-}time}$)	The noise descriptor $L_{Aeq(9hr)}$ (or $L_{Aeq\ night\text{-}time}$) refers to the A-weighted energy averaged equivalent noise level over a 9 hour night time period between 10pm and 7am.
L_{Cpeak}	The highest instantaneous C-weighted sound pressure level over the measurement period. It is usually used for high impulsive noise measurement.
L_{Amax}	The maximum A-weighted sound pressure level for the measurement period

The subjective response to changes in noise levels can be described as follows:

A 3dB(A) change in sound pressure level is just noticeable or perceptible to the average human ear; a 5dB(A) increase is quite noticeable and a 10dB(A) increase is typically perceived as a doubling in loudness.

Appendix B

Detail noise logging results

Appendix B

Table B1: Daily noise logging results for Site 1

Monitoring period	Day (7am – 10pm)				Night (10pm – 7am)			
	L_{eq}	L_{max}	L_{A10}	L_{A90}	L_{eq}	L_{max}	L_{10}	L_{90}
	dB(A)				dB(A)			
11-Dec-2007	52	65	54	45	30	39	33	26
12-Dec-2007	46	64	48	39	34	49	35	27
13-Dec-2007	44	64	45	35	35	49	37	29
14-Dec-2007	50	64	53	44	39	52	40	33
15-Dec-2007	45	66	44	34	38	54	39	31
16-Dec-2007	50	68	51	41	34	49	35	25
Average	**48**	**65**	**49**	**40**	**35**	**49**	**37**	**29**

Table B2: Daily noise logging results for Site 2

Monitoring period	Day (7am – 10pm)				Night (10pm – 7am)			
	L_{eq}	L_{max}	L_{A10}	L_{A90}	L_{eq}	L_{max}	L_{10}	L_{90}
	dB(A)				dB(A)			
11-Dec-2007	64	79	67	52	61	82	64	41
12-Dec-2007	63	80	67	52	61	79	64	39
13-Dec-2007	64	79	67	52	61	78	64	41
14-Dec-2007	64	79	67	54	60	78	63	41
15-Dec-2007	63	79	66	52	58	77	61	39
16-Dec-2007	62	79	65	52	58	77	61	38
17-Dec-2007	64	80	67	53	60	79	63	39
18-Dec-2007	66	80	69	55	60	79	63	40
19-Dec-2007	65	80	68	55	61	79	64	40
Average	**64**	**79**	**67**	**53**	**60**	**79**	**63**	**40**

Table B3: Daily noise logging results for Site 3

Monitoring period	Day (7am – 10pm)				Night (10pm – 7am)			
	L_{eq}	L_{max}	L_{A10}	L_{A90}	L_{eq}	L_{max}	L_{10}	L_{90}
	dB(A)				dB(A)			
18-Jan-2008	55	78	51	41	44	60	45	37
19-Jan-2008 *	57	79	55	44	45	65	45	35
20-Jan-2008*	57	79	56	44	45	64	43	34
21-Jan-2008	56	78	55	44	45	65	45	33
22-Jan-2008	57	80	54	43	44	63	44	32
Average	**56**	**79**	**54**	**43**	**45**	**63**	**44**	**34**

* *Days that shooting occurred*

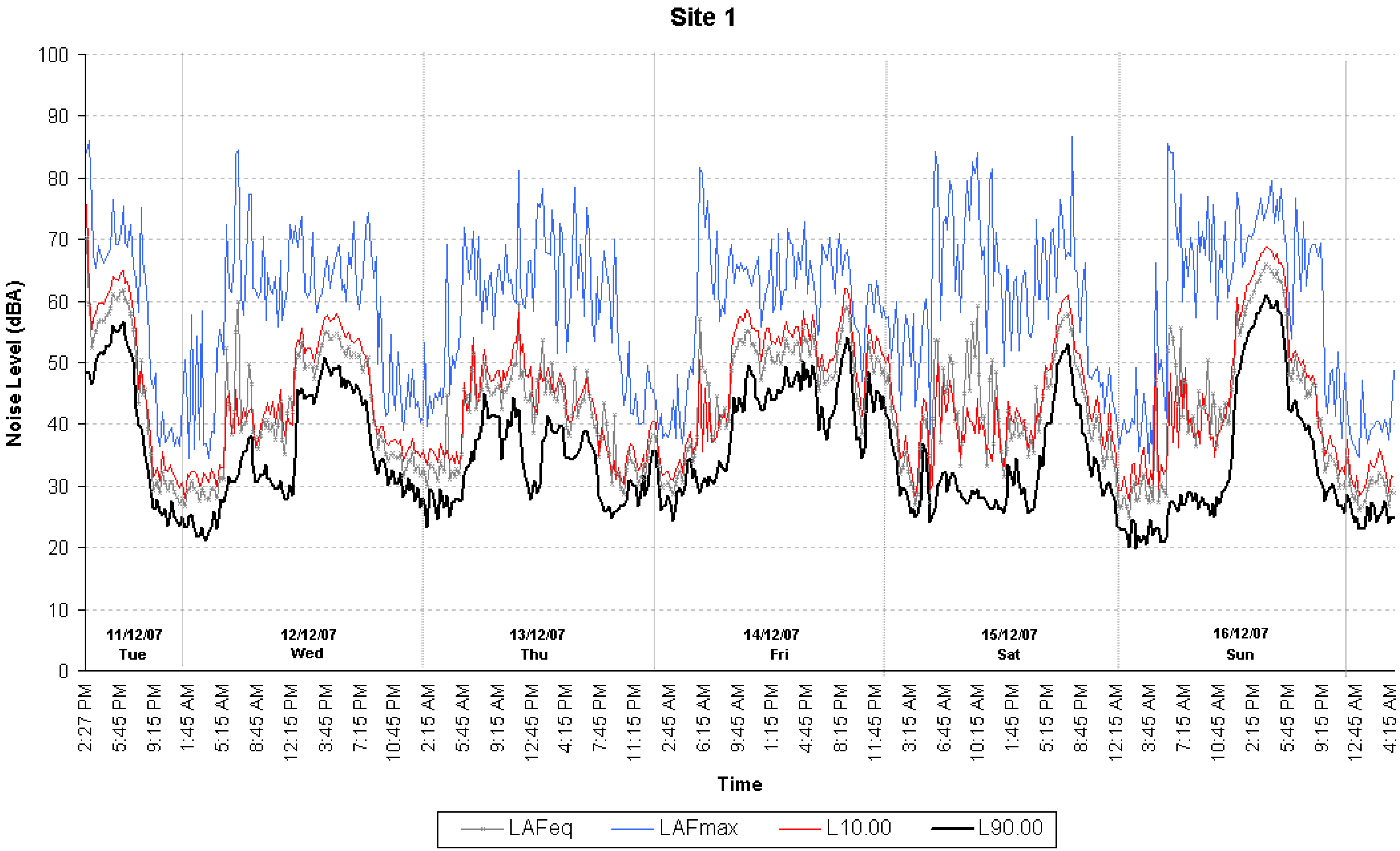


Figure B1: Detail results of noise logging at Site 1

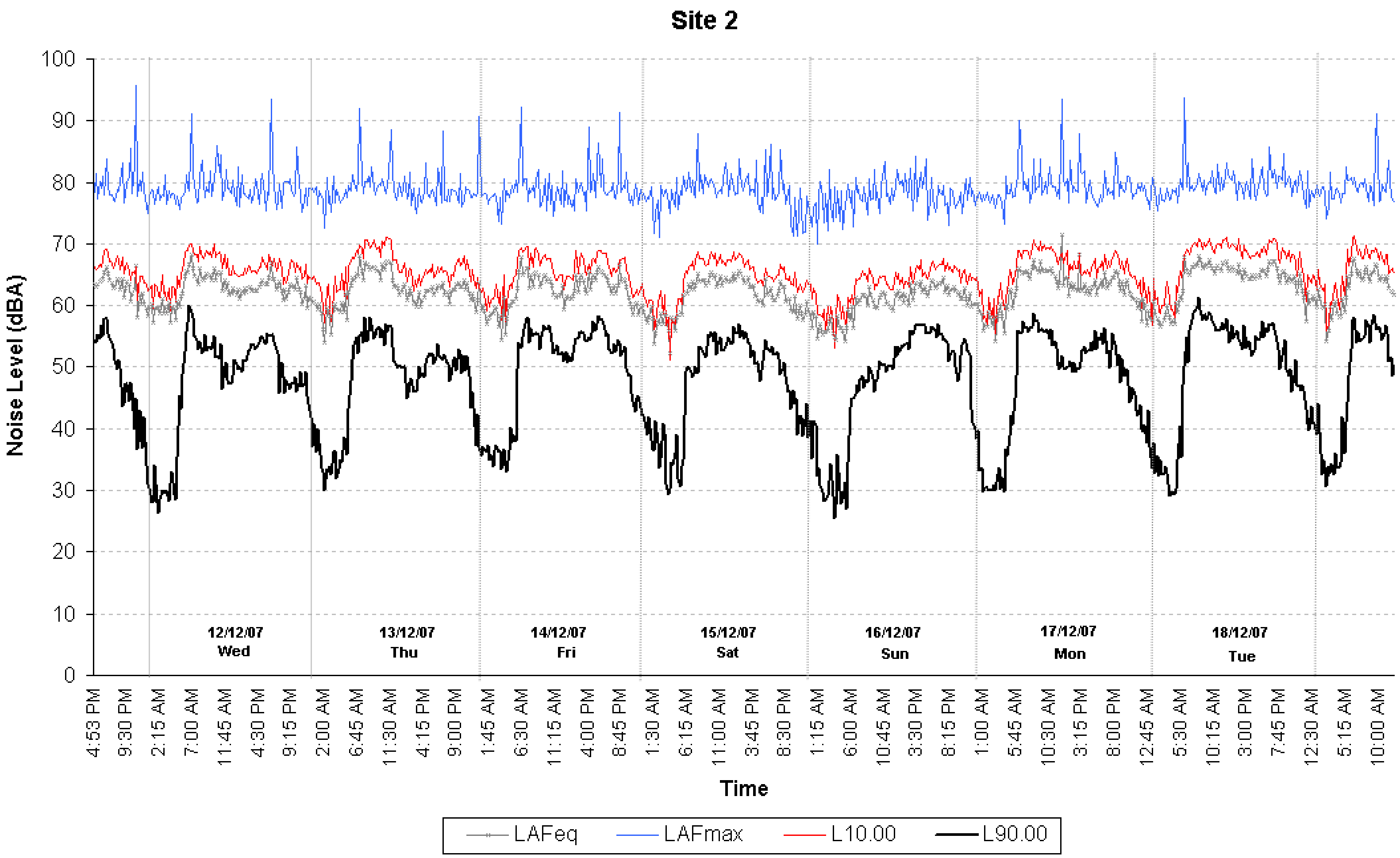


Figure B2: Detail results of noise logging at Site 2

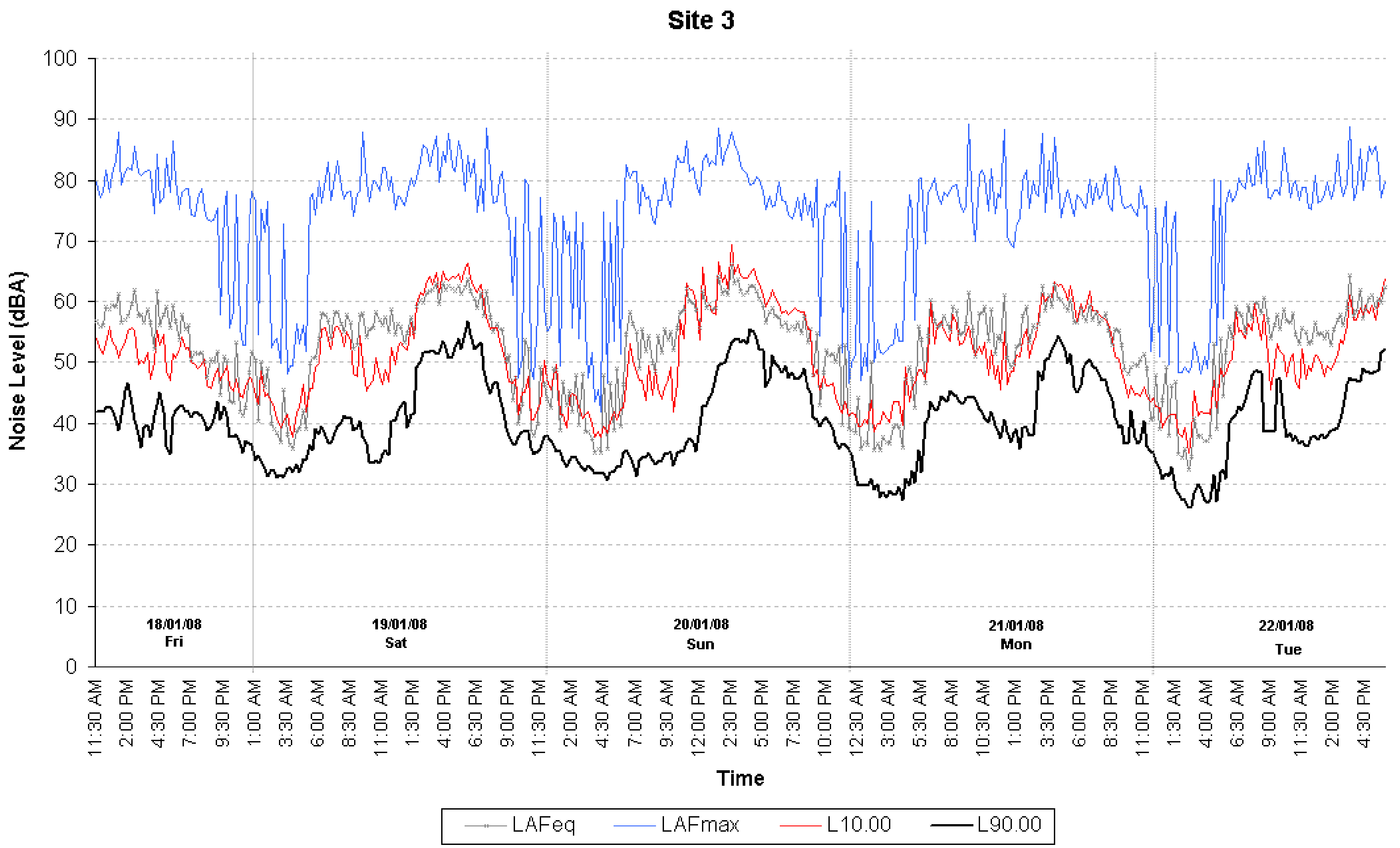


Figure B3: Detail results of noise logging at Site 3

Appendix C

Noise contours

Appendix C

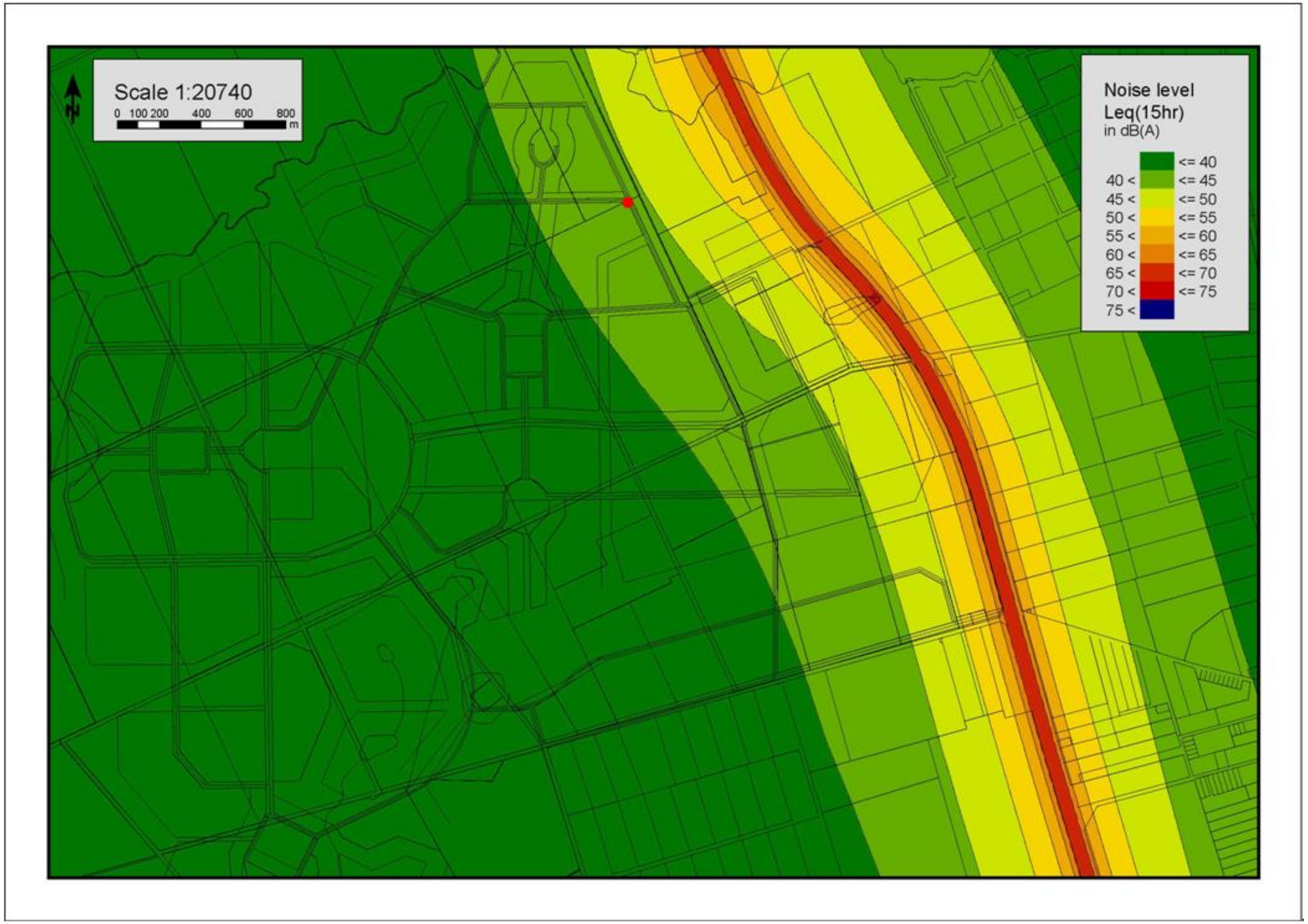


Figure C1: Traffic noise contour - Year 2007 (Day time)

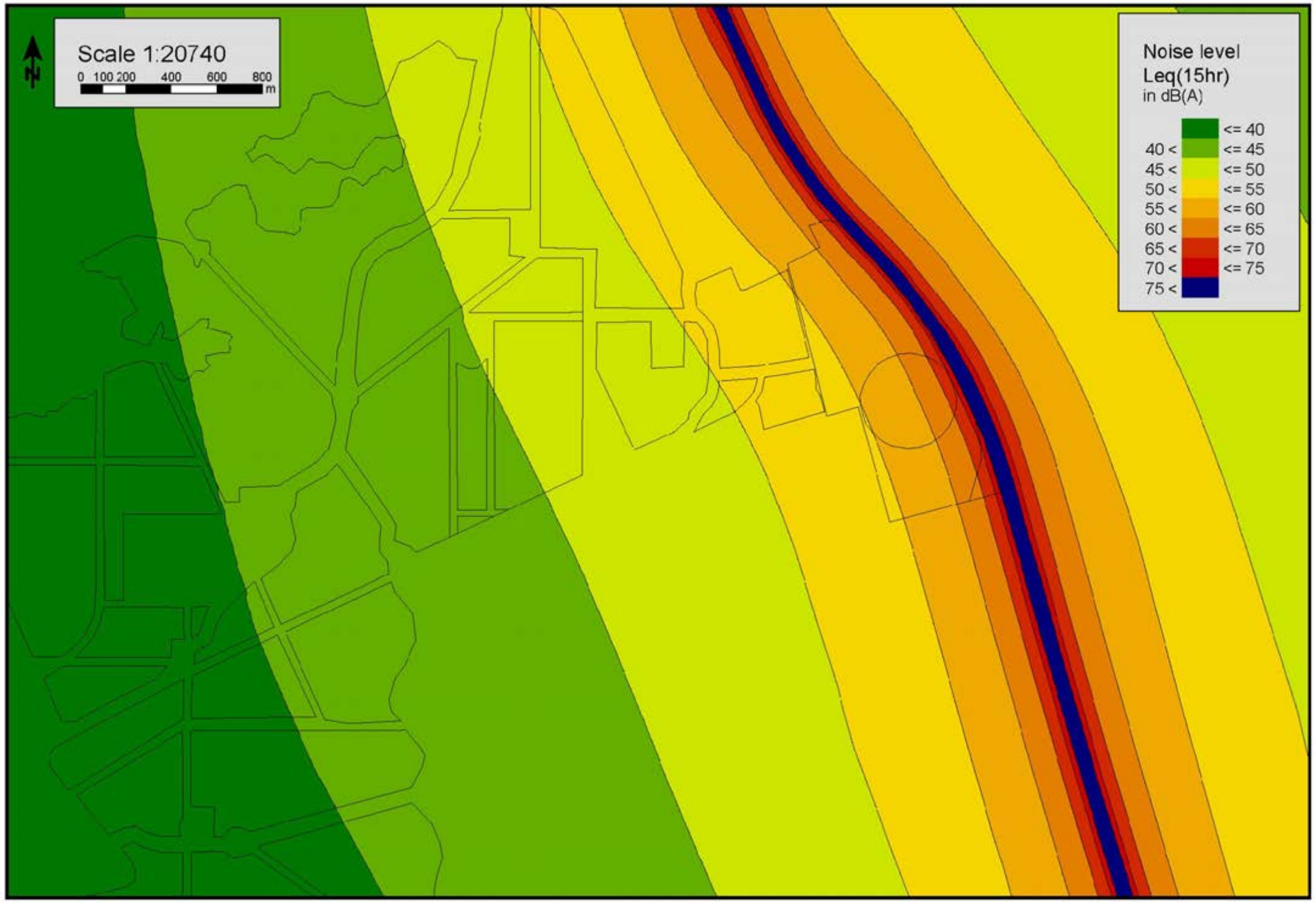


Figure C2: Traffic noise contour - Year 2031 (Day time) (* with façade reflection factor of +2.5dB)

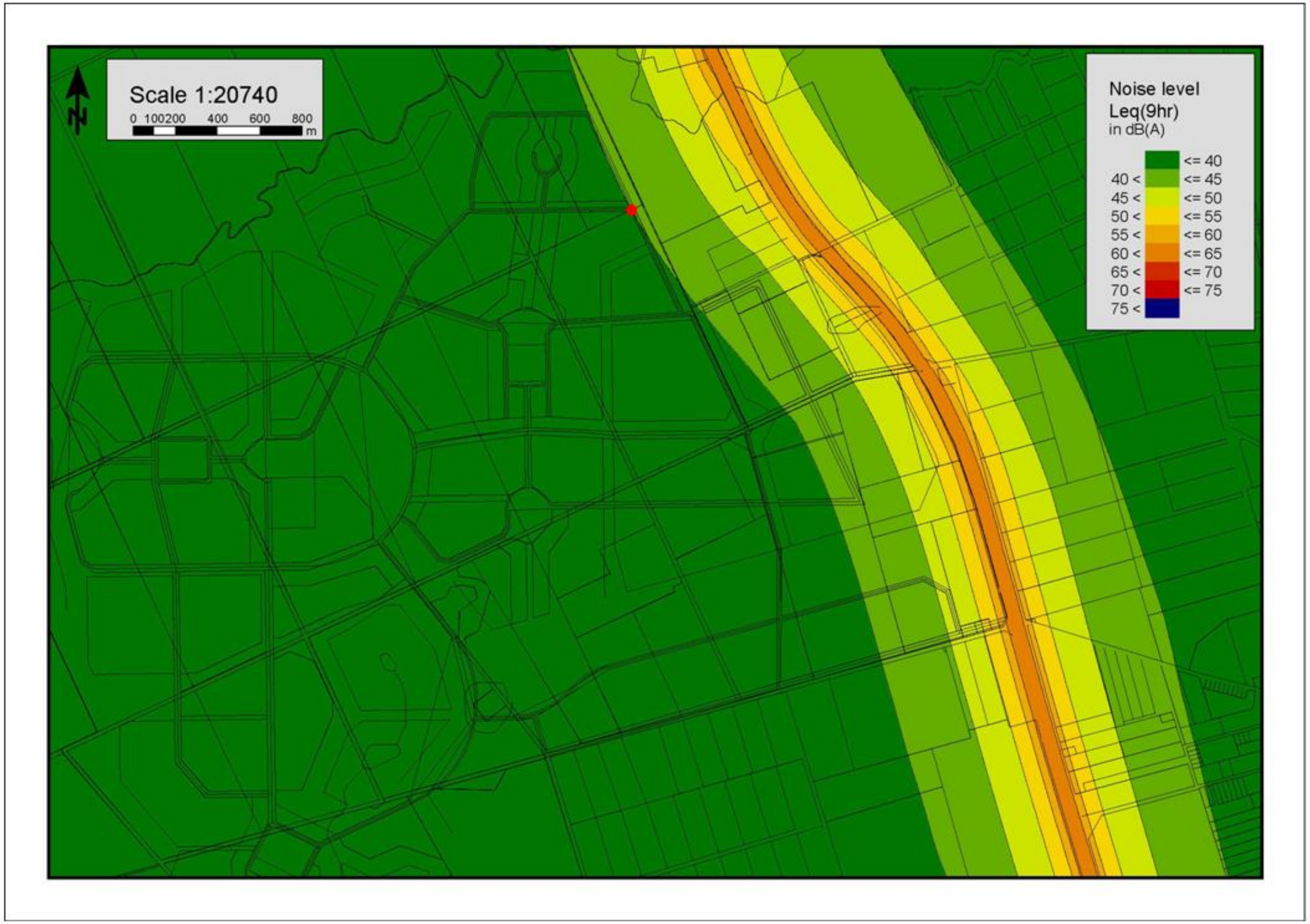


Figure C3: Traffic noise contour - Year 2007 (Night time)

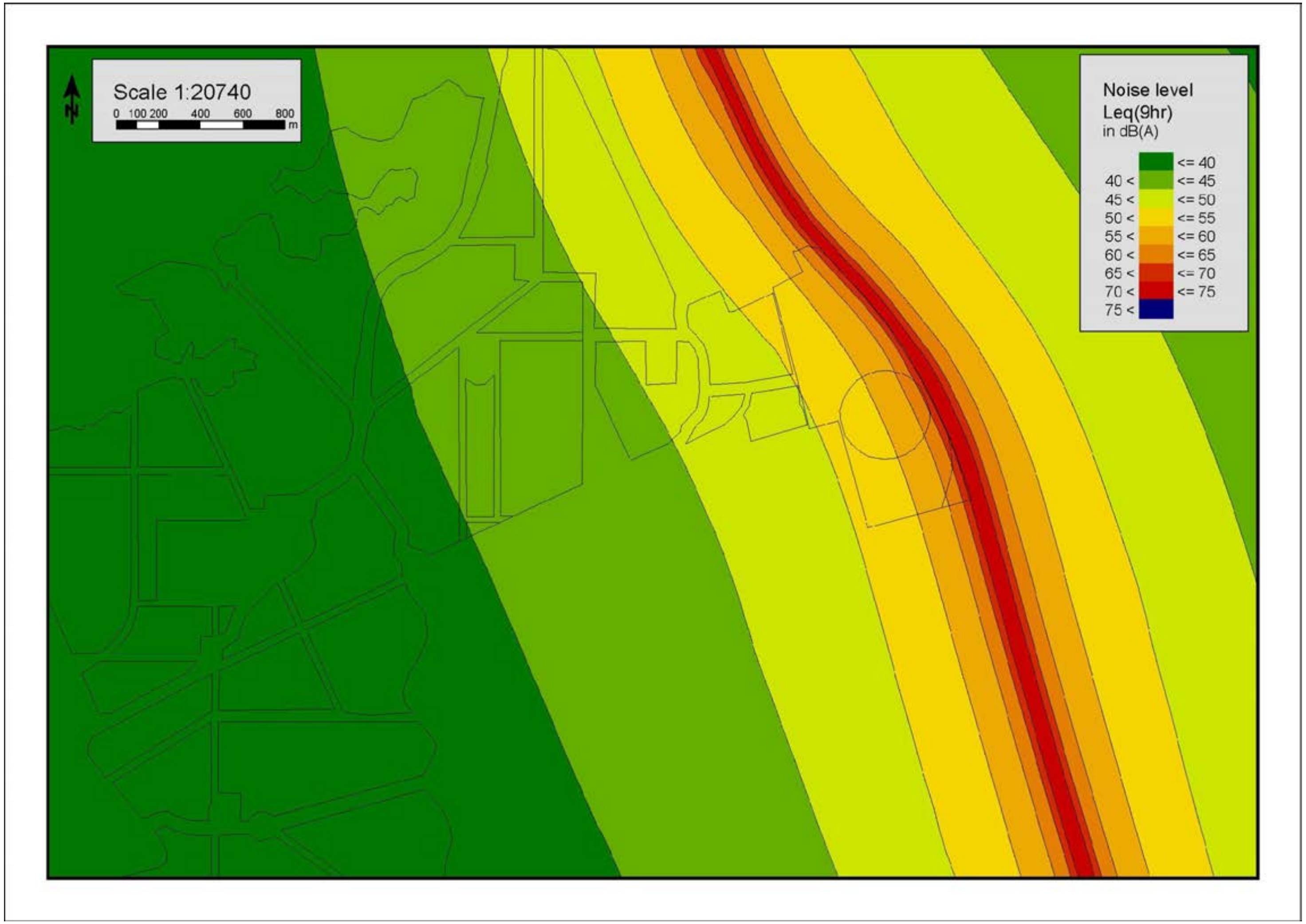


Figure C4: Traffic noise contour - Year 2031 (Night time) (* with façade reflection factor of +2.5dB)

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Air Quality Assessment
Buckland Park Proposal
Walker Corporation / DayCorp

4 November 2008
Reference 31495
Revision 2

Connell Wagner

Document Control

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Rev No	Date	Revision Details	Typist	Author	Verifier	Approver
0	02/10/08	Draft – Client Review (Walker Corporation)	AK	AK	NCM	NCM
1	28/10/08	Second Draft	AK	AK	NCM	HL
2	4/11/08	Final	AK	AK	NCM	HL

Contents

1. General

1.1 Introduction

Walker Corporation Pty Ltd and Daycorp Pty Ltd propose an urban project on a 1,308 hectare site at Buckland Park, between Virginia and Port Gawler (refer to Figure 1.1). The proposal will transform the site into a new urban area consisting of dwellings, town centre, commercial, community and recreational facilities.

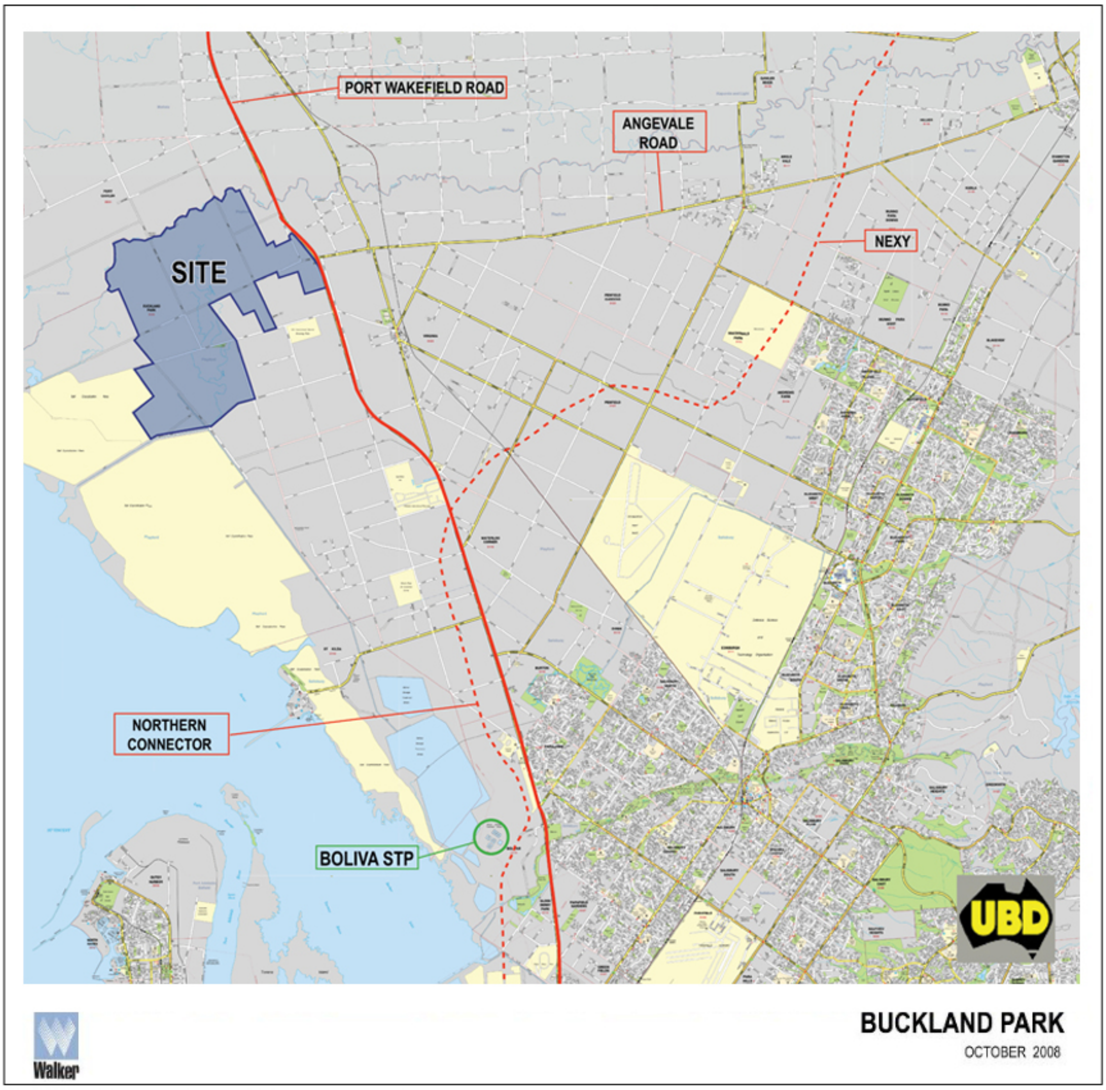


Figure 1.1 Location of the proposal.

This report was prepared to satisfy the requirements outlined in the Development Act (1993) and seeks to address the environmental impact with regards to odour, fugitive emissions, biological aerosols (bio-aerosols) and spray drift as noted in the Guideline for Preparation of an Environmental Impact Statement on the Proposed Buckland Park Country Township Development (dated August 2008). This document was issued by the Development Assessment Commission (DAC), South Australia.

The report presents the findings of an environmental odour and bio-aerosol survey as well as outcomes predicted by an odour dispersion model. The impact of pesticide application on nearby agricultural lands and the resulting spray drift on the site was also assessed. The evaluations made in this report are based on the latest Masterplan.

Walker Corporation Pty Ltd engaged Connell Wagner to undertake an Air Quality study for the proposed development noting the presence of a large composting facility 1 kilometre from the southern boundary of the proposal. This composting site is owned and operated by operated by Jeffries Pty Ltd. The Buckland Park composting facility is one of the largest and most efficient such facilities of its kind in Australia.

This report outlines the steps taken to complete an assessment of the worst case impact of odour from this facility as well as risks posed to the community from the dispersion of dust and micro-organisms associated with the composting process. An odour and bio-aerosol survey was initially conducted after gaining access to the Jeffries Pty Ltd composting facility. This was followed by an evaluation of the local meteorological conditions and air dispersion modelling to determine compliance between the Buckland Park master plan and regulatory odour limits stipulated by EPA SA.

1.2 Sensitive Receivers and Odorous Facility

The proposed Masterplan layout for Buckland Park is shown in Figure 1.2. The proposal involves the construction of 12,000 dwellings a district centre, schools, shopping and commercial facilities, sports and recreation facilities, staged over a period of 25 years.

Reference is drawn to the distance from the Jeffries composting facility to the boundary of the nearest proposed residential area. The odour criteria defined in Table 1.1 must be met at the nearest residential boundary, which is located approximately 1.7 km from the Jeffries facility. All EPA air quality legislation that pertains to this project is described in Section 2.

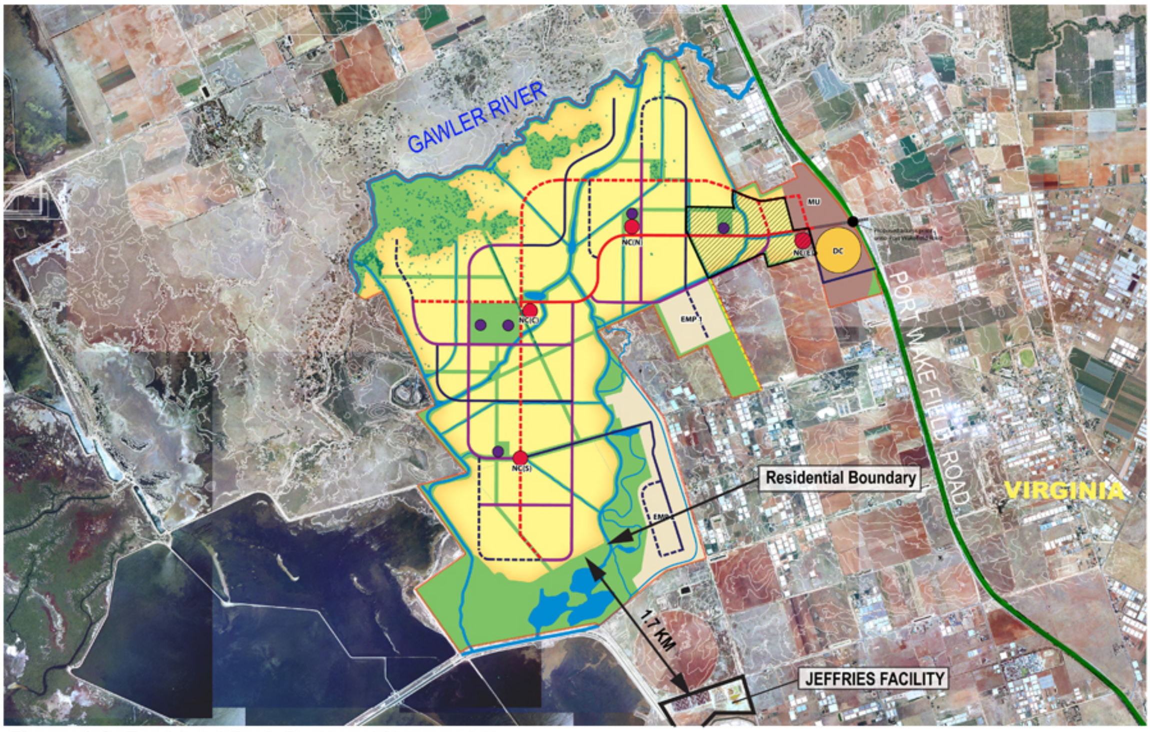


Figure 1.2: Buckland Park Proposal Masterplan

Table 1.1 EPA SA Odour Assessment Criteria.

Number of People	Odour Units (OU) (3-minute average, 99.9 Percentile)
2000 or more	2
350 or more	4
60 or more	6
12 or more	8
Single Residence (less than 12)	10

1.3 Fugitive Emissions

Fugitive emissions are assessed through the analysis of the air quality assessment within the Public Environmental Report (PER) submitted by Jeffries Pty Ltd (2003).

1.4 Spray Drift

EPA SA describes spray drift as the movement of a pesticide to an off-target area by transport through the air in vapour, spray or droplet form. The EPA document, Guidelines for Responsible Pesticide Use outlines several methods through which off-target spray drift can be minimised. Aerial pesticide application on agricultural crops takes into account the prevailing meteorological factors such as wind speed, rainfall and humidity. These meteorological characteristics are discussed for this site specifically in Section 5.

Chemical sprays over agricultural land surrounding the site have the potential to drift over people, properties and sensitive waterways leading to contamination. Spray drift can occur when, chemicals such as pesticides are sprayed using tractors, boom sprayers and/or aerial spraying from low flying light aircraft. The impact of spray drift effects are considered as part of this air quality assessment in Section 6.4.The impact assessment for this analysis was based on the analysis of the likely deposition level of pesticides on off site targets. Since there are no regulatory quantified safe guidelines for deposited chemical pesticides the analysis was based on a conservative scenario using the US EPA approved model AgDRIFT and the distance from the edge of the sprayed target at which off site deposition levels are negligible.

1.5 EIS Guidelines

The EIS guidelines relevant to the assessment considered in this report include the following:

- **4.3.34.** Describe how all potential sources of air pollution will be controlled and monitored.
- **4.6.19.** Describe the impacts to residents of the proposed development of any odour and fugitive emissions drift from the Jeffries composting operation on adjacent land.

2. Impact Assessment Criteria

2.1 Odour

The criteria used to assess the potential odour impacts from the proposal are governed by EPA Guideline 373/07 which provides criteria for the management of odour emissions. This guideline specifically addresses the use of computer dispersion modelling to determine the likely odour impacts at the site boundaries and hence determine appropriate buffer distances between the source(s) and receivers. The following section summarises the EPA directive with regard to appropriate odour assessment.

2.1.1 EPA Guideline 373/07: Odour Assessment using Odour Source Modelling

The EPA expects proposals which are likely to be impacted by odour emissions to employ best practice odour management techniques. Computer dispersion simulation can be considered a viable tool to assess the worst case - but representative - potential odour impacts likely to be experienced by the nearest sensitive receivers.

The principal legislation dealing with odour in South Australia is the Environment Protection Act 1993 (the Act). In particular, Section 25 imposes the general environmental duty on all persons undertaking an activity that may emit odour to take all reasonable and practicable measures to prevent or minimise any resulting environmental harm. In addition, causing an odour may constitute environmental nuisance, an offence under Section 82 of the Act. The odour criteria in South Australia are based in principle on compliance with the general environmental duty to avoid environmental nuisance using 'best available technology economically achievable' (BATEA).

This EPA Guideline also requires the following odour management objectives to be met by the odourous facility to meet Public Expectations.

- Minimise odour emissions and impact
- Ensure that neighbouring sensitive land uses are not exposed to unacceptable levels of odour from odourous facility.
- Appropriate facility management strategies are put in place so as to ensure levels of odour at sensitive land uses are within the accepted criteria.
- Application of ongoing risk evaluation and hazard management strategies given developments in odour impact and potential health effects.

Regulatory Model

The EPA SA recommended model for odour dispersion modelling is AUSPLUME V.5, a Gaussian plume model run over at least 12 months of representative meteorological data. The term representative is with respect to the long term average meteorological conditions in the local region. The dispersion model used to analyse the odour dispersion for this project is the US EPA approved Gaussian plume Industrial Source Complex Short Term 3 (ISCST3) model. ISCST3 is considered to be an equivalent model to AUSPLUME as they are both based on the Gaussian plume dispersion principle. The ISCST3 model is discussed further in Section 6.1.

Odour Criteria

Odour criteria are dependant on the number of exposed individuals, hence they are subject to population density. With an increase in the number of exposed individuals the probability of the presence of individuals among the population who are particularly sensitive and will be adversely affected is obviously greater; hence the requirement for more stringent criteria. The South Australian odour criteria is based on the 99.9th percentile three-minute averaged ground level concentrations at sensitive receptors, not including houses on the property of the development. The EPA SA odour criterion is tabulated in Table 2.1.

Table 2.1 EPA SA Odour assessment criteria.

Number of People	Odour Units (OU) (3-minute average, 99.9th Percentile)
2000 or more	2
350 or more	4
60 or more	6
12 or more	8
Single Residence (less than 12)	10

2.2 Ambient Air Quality National Environment Protection Measures

2.2.1 Pollutants

The primary pollutants under consideration for the construction dust emissions are particulates of average aerodynamic diameter less than 10 micrometers (10 µm) – PM_{10} and Total Suspended Particulates (TSP) compounds. Another group of compounds known as $PM_{2.5}$ particles are defined as those with average aerodynamic diameter < 2.5 µm; these compounds are particularly harmful to health due to their small size and hence are able to gain access to lung tissue more easily than larger particles. However the emissions of these compounds will have a minor air quality impact in comparison to PM_{10} and TSPs.

These compounds are separated into these two distinct categories due to their differing influences on the quality of life of residents who are exposed to excessive levels of these pollutants. PM_{10} compounds are of particular interest as they are respirable and tend to accumulate in human lung tissue at excessive levels and are known to have various serious pathogenic effects on exposed individuals.

TSPs have been grouped as the family of aerosols that have aerodynamic diameters less than 100 µm. These aerosols are not known to have any significant pathogenic impacts, but are a concern due to their nuisance impacts from their airborne presence as well as by means of wet and dry deposition. A criterion level has not been set for these compounds by the South Australian EPA nor the Federal Government Environment Protection and Heritage Council (EPHC). The criterion used to assess the air quality impacts of ground level concentrations of TSPs are those listed by the NSW DEC (2005) which sets limits on the maximum annually averaged concentration and the maximum allowable monthly deposition rates above the current background level.

2.2.2 Criterion

Federal

The Environment Protection and Heritage Council (EPHC) incorporate the National Environment Protection Council (NEPC). The EPHC/NEPC has developed National Environmental Protection Measures (NEPMs), which outline agreed national objectives for protecting and managing aspects of the environment. The Ambient Air Quality NEPM sets standards and goals at levels that protect human health and wellbeing, aesthetic enjoyment and local amenity. The standards are defined as concentrations either in parts per million (ppm) or, for particulate matter, micrograms per cubic metre (µg/m^3). The goals in the Air NEPM specify a maximum permissible number of days per year when the standards may be exceeded and a timeframe of 10 years (1998 – 2008) within which these goals must be met.

Table 2.2 Ambient Air Quality National Environment Protection Measures – Criteria Pollutants (EPHC, 2003).

Pollutant	Averaging Period	Maximum Concentration ($\mu g/m^3$ @ STP*)	Maximum Allowable Exceedances (days/yr)
Coarse particulates (PM_{10})	1 day	50	5

* The guideline defines STP as 25°C and at an absolute pressure of one atmosphere.

The primary criterion of concern for the purposes of this assessment is that specified for coarse particulates (PM_{10}), the emissions of all other criteria pollutants listed in Table 2.2 from the Jeffries facility will be negligible to zero.

In May 2003, the NEPC made a variation to the Ambient Air Quality NEPM which strengthens air quality standards to help protect Australians from the adverse health impacts of small respirable pollutant particles. The variation introduces advisory reporting standards for fine particles 2.5 micrometres or less in size (known as $PM_{2.5}$). The advisory reporting standards will assist in gathering sufficient data nationally on fine particles, with the information used to inform the review process for the Ambient Air Quality NEPM. Although fine particulates are generally not considered explicitly in most construction air quality assessments, their emissions have been estimated and the impacts are considered.

Table 2.3 Ambient Air Quality National Environment Protection Measures $PM_{2.5}$ – Investigative Level (EPHC, 2003).

Pollutant	Averaging Period	Maximum Concentration		Maximum Allowable Exceedances (days/yr)
		ppm	$\mu g/m^3$ @ STP*	
Fine particulates ($PM_{2.5}$)	1 day 1 year	n/a	25 8	Not established

* The guideline defines STP as 25°C and at an absolute pressure of one atmosphere.

State

The principal piece of legislation addressing pollution in South Australia is the Environment Protection Act 1993 (the Act). In particular, section 25 imposes a general environmental duty on all persons undertaking an activity that pollutes or might pollute the environment, requiring them to take all reasonable and practicable measures to prevent or minimise any resulting environmental harm. Regulation of air pollution is primarily governed through the Environment Protection (Air Quality) Policy 1994 (Air Policy). The Schedule to the Air Policy specifies the maximum pollution levels that may be discharged from chimneys (stacks).

In the absence of statutory guideline levels set by EPA SA with regards to maximum allowable ground level concentrations of TSP aerosols and the allowable monthly deposition rates, the NSW DEC guidelines are stated.

To demonstrate that no adverse effects will occur at ground level due to emissions from a proposed or existing facility the proponent is required to use computerised pollutant dispersion modelling techniques to predict the maximum resultant ground level pollutant concentrations. Proponents are required to show that these maximum concentrations are less than the design ground level concentrations specified within the document (EPA 386/06), at all locations at all times.
The design ground level concentrations (DGLCs) adopted by the Environment Protection Authority (EPA) are based on protecting public health and amenity, or other environmental factors if they are more sensitive than human health. The listed DGLCs are by no means an exhaustive list of pollutants hence the EPA has recommended that for analytes other than those listed in the document the air quality assessor is required to search for peer reviewed literature to determine an appropriate DGLC for the pollutant under consideration or demonstrate to the satisfaction of the EPA that the emissions of

the analyte will have no health, environmental or amenity impacts. The EPA SA guideline document does not state air quality guideline levels for TSPs. Hence the NSW DEC "Approved Methods for the Modelling and Assessment of Air Pollutants Guidelines" (2006) guidelines will be used to assess impacts based on published allowable ground level concentrations and deposition rate data. The allowable limits are shown in Table 2.4.

Table 2.4 NSW State Air Quality Guidelines (DEC, 2005).

Pollutant	Averaging Period	Maximum Concentration (μg/m^3)	Maximum Allowable Deposition (g/m^2/month)
Total Suspended Particulates (TSP)	Annual	90	-
Deposited Dust	-	-	2* 4^

* Maximum increase in deposited dust level
^ Maximum total deposited dust level

3. Jeffries Pty Ltd Odour/Microbiological Survey

3.1 Composting Process

The composting process relies on presence and activity of micro-organisms at every stage. Temperature monitoring is an indirect measure of microorganism activity. A host of micro-organisms breakdown organic matter and in doing so produce CO_2 and heat. Water and aeration assist in managing the heat in each phase. As temperatures and the degree of decomposition change, so too does the composition of the microorganism populations. The composting process and the generation of odour is primarily dependant on the following parameters:

- age of pile
- temperature of pile;
- degree of aeration;
- survival of pathogens and microbes in windrow.

A layout plan of Jefferies Facility is displayed below in Figure 3.1.

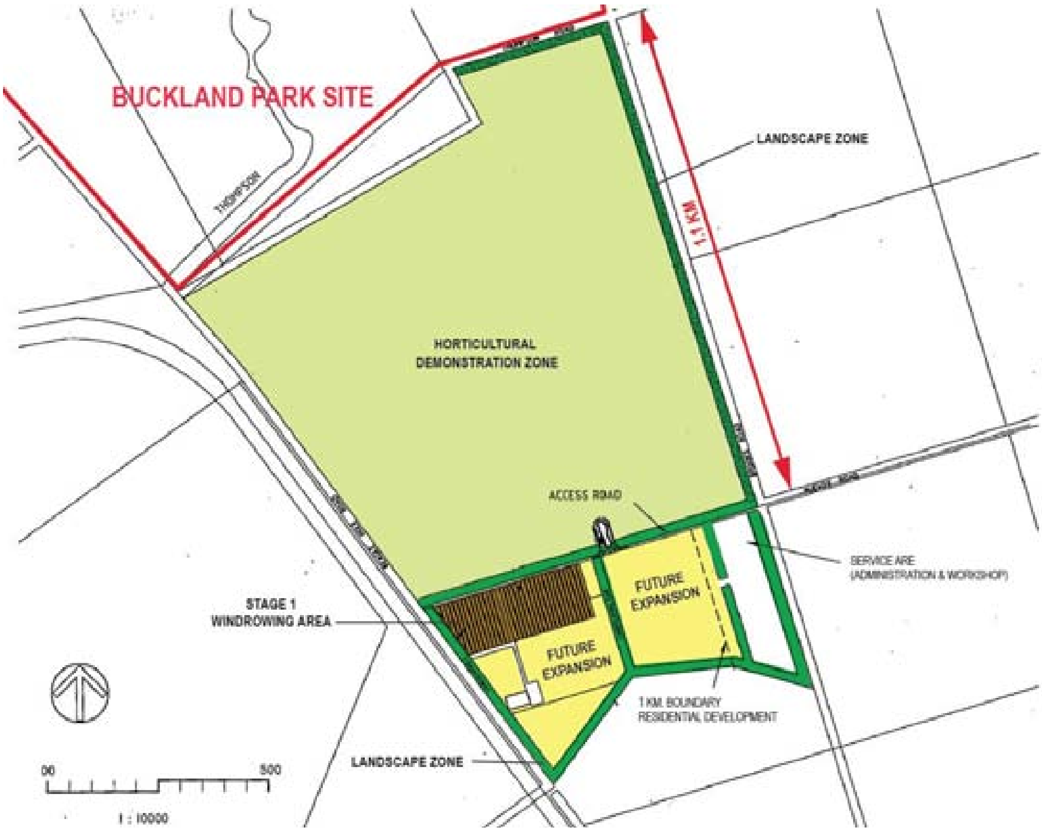


Figure 3.1: Jefferies Layout Plan (Rodenbury, Davey and Associates, 2008)

3.2 Odour Sampling

Odour samples were taken from numerous windrows of differing age, composition and biological condition. The flux hood sampling protocol was used to collect the samples in a sealed plastic bag. Figure 3.2 shows the equipment that was used to take the odorous sample from the compost windrow. The sampling procedure itself, involves many steps. Firstly, nitrogen gas (N_2) had to be introduced into the flux hood at a rate of 5L/min for a period of 25 min before the odorous sample could be taken. This was followed by the sampling process that involved drawing air from the hood using a pump into a sealed plastic bag inside the sealed sampling drum. The process takes approximately 40 min to yield one sample.

This procedure was duplicated for every case, to avoid erroneous results. In all, ten samples were taken from compost windrows of differing age, composition, aerobic condition and moisture content. This was done to get a good spread of cases that would allow the assessors to gauge a more thorough understanding of what the worst case odour concentration from the facility would be.

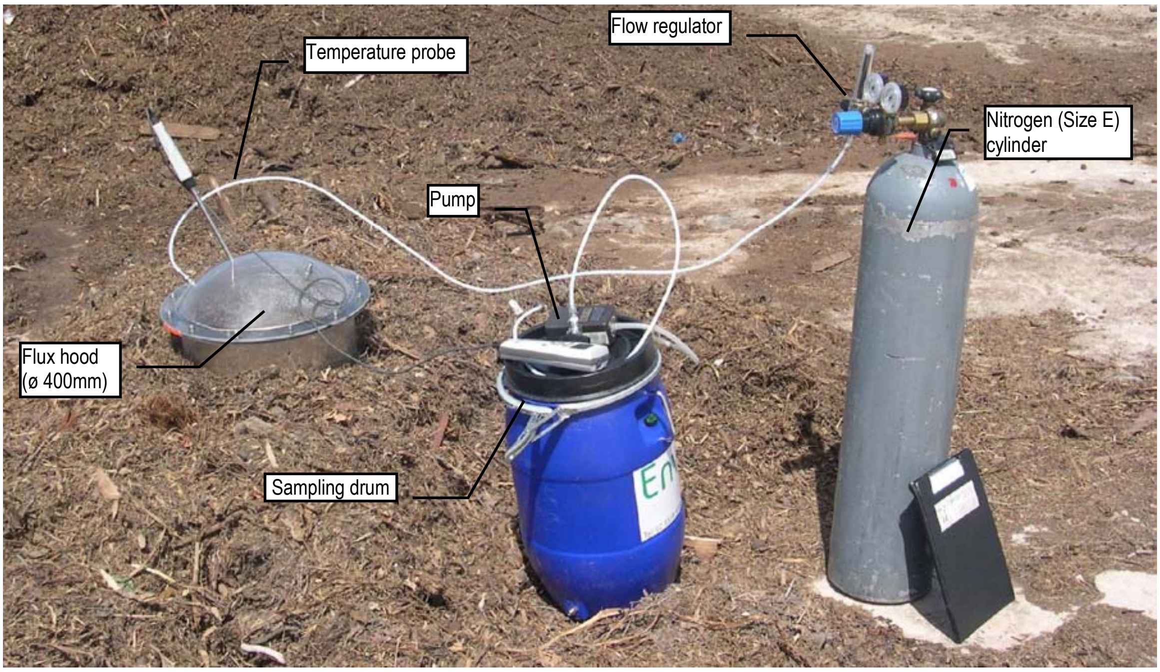


Figure 3.2 Odour sampling equipment.

Samples from the various windrows at this facility were taken based on the age of the windrow (i.e. from time of delivery to the facility) and their composition. The majority of the windrows consisted solely of solid green organic waste (e.g. leaf litter etc.) but, there was a minority that consisted of between 20 and 30% liquid organic waste with the balance being composed of green waste. The latter of the two compositions was noticeably denser and more odourous.

The concentrations of each of the odourous samples were evaluated through the process of dynamic olfactometry. This process involves exposing a human panel to the sampled odourous air. The sample is then titrated through several dilutions of clean non-odourous air until the odour threshold of 50% of the panel members is established. The odour concentration is then quantified in terms of OU, with OU being defined as the number of dilutions to threshold. The results from this analysis are presented in the specific units of OU/m^3.

It is apparent from the results shown in Table 3.1 that odour concentrations observed are highly dependant on the age of the windrows. Empirical studies on open air windrow composting have shown that with increased pile age a marked decrease in odour intensities is observed. Bildingmaeir (1995) has shown that odour concentrations decrease to up to 1/10th of their first week level in just four weeks. This is verified by observing the difference in odour concentrations between sample #5 and #8 in Table 3.1. Nevertheless the highest odour concentrations are attributable to the windrows composed of the hybrid composition of green and liquid organic waste. This was as expected as this windrow was noticeably more odourous than all the other piles during the site visit.

Table 3.1 Results of dynamic olfactometry.

#	Source Description	Odour Concentration (OU/m^3)	Surface Odour Emission Rate (SOER) (OU/m^2/s)
1.	**Butanol threshold (43 ppb)**	1417	0.94
2.	**20-80% Green waste/Liquid Organic**	3643	2.42
3.	**20-80% Green waste/Liquid Organic***	4141	2.75

#	Source Description	Odour Concentration (OU/m^3)	Surface Odour Emission Rate (SOER) ($OU/m^2/s$)
4.	**Fresh turned (aerobic windrow)**	514	0.34
5.	**Green organic waste (week 1)**	3078	2.04
6.	**Green organic waste (week 1) (wet)**	2008	1.33
7.	**Green organic waste (week 3)**	346	0.23
8.	**Green organic waste (week 5)**	410	0.27
9.	**Green organic waste (week 5)***	609	0.40
10.	**Green organic waste (week 8)**	855	0.57
11.	**Green organic waste (week 8)***	722	0.48

* Duplicate sample
The sensory performance criteria for the detection of butanol in dynamic olfactometry (conducted according to AS4323.3:2001) is between 20 – 80 ppb. The session undertaken for this test the butanol threshold was stated to be at 43 ppb.

3.2.1 Standing Water

Standing water becomes an issue for composting facilities with poor drainage and poor water balancing. The odour from standing water is caused by the formation of anaerobic conditions in a pond, decomposition of organics and the emissions of hydrogen sulphide compounds. The sampling process assessed this through the wetting of a compost windrow (sample #6). However the right anaerobic conditions were not achieved. This requires an extended period of water stagnation which results in the formation of H_2S.

The Jeffries Facility has a supervised clay liner pond that water sheds into and evaporates from to allow for the formation of an optimum water balance to form, taking into account both water run off from the facility operations and the annual rainfall. On average the area of the evaporation pond allows for 2 metres of evaporation in a year that more than allows for the rainfall. Furthermore the compost windrows are on an elevated area that allows for excess water to drain from the four corners and through a network of trenches. This system enables water to be directed to the areas where it evaporates. This design thus enables the avoidance of stagnant water pools forming. The described site design is a critical part of the Jeffries environmental licence condition. The potential for odour from stagnant water is thus considered to be negligible given conformance to design specifications.

3.3 Microbial Sampling

Composting is a natural process that relies on micro-organisms (fungal/mould spores and certain types of bacteria called actinomycetes) to grow and subsequently putrefy waste material. As a result, very large numbers of micro-organisms are present in compost and any handling of the material that generates airborne suspended particulates creates a bio-aerosol. To encourage efficient composting, the piles of material (called windrows) have to be well aerated and therefore are turned regularly. At the end of the process, the compost is screened (sieved) to produce a quality soil supplement. Both of these composting processes results in the emission bio-aerosols from the windrows.

The composting process relies on micro-organism presence and activity at every stage. Temperature monitoring is an indirect measure of micro-organism activity. A whole host of micro-organisms breakdown organic matter and in doing so produce CO_2 and heat. Water and aeration assist in managing the heat in each phase. As temperatures and the degree of decomposition change, so to does the composition of the micro-organism populations.

There are three phases that green organic material passes through to reach a stable, fully composted product. The rapid temperature rise to 40 - 60°C may occur within 2 - 3 days. This is the moderate temperature phase and some plant pathogens and pests are killed during this phase. The composting product however then advances to the high temperature phase that ensures pathogen and pest death. Temperatures in this phase are maintained at 60 - 70°C for a minimum of 8 weeks. During the cooling or stabilising phase temperatures are lowered to below 40°C and recolonisation by many beneficial organisms occurs. At the same time it is possible for recontamination of the stable product at its surface by organisms ubiquitous in dust. These may include some fungal spores.

The microbial sampling was conducted so as to capture the dispersed fungal spores at the composting site (S), upwind (U) and downwind (D) (prevailing south easterly wind) of the site as shown in Figure 3.3. The sampling was conducted by holding adhesive agar plates face up to the wind for a continuous period of 15 minutes contemporaneously at each of the three locations. Following the sampling procedure a microbe count was made. An impact analysis was then conducted by considering the difference in the microbial count from that recorded at point S to that recorded at points U and D which represent the ambient level of microbial spores in the air at any one time. The results of this sampling are tabulated below (Table 3.2).

Figure 3.3 Locations where microbial samples were taken (U – upwind and D downwind of composting site).

Table 3.2 Results of microbial sampling (* - duplicate sample).

Site	Colony Forming Units (CFU/plate)	Sampling Time (during day)
U1	50	11:30 am
S1	93	
U2	47	1:20 pm
S2	200	
U3	56	4:30 pm
S4	120	
D2	84	4:45 pm
D2*	97*	

4. Meteorological Model Description and Inputs

4.1 TAPM

The CSIRO developed Air Pollution Model (TAPM) is a prognostic meteorological and air dispersion model and was used to account for the effects of coastal fumigation in this region and the development of the pre-processing spatially varying hourly meteorological data. The TAPM numerical model produces meteorological data, upper air information and temperature profiles for the simulation period in three dimensions for all the grid points across the domain. The gridded meteorological data generated by TAPM is calculated from the synoptic information determined from the six hour interval limited area prediction system (LAPS). This final meteorological data is representative of the local topography, land use, surface roughness and temperature effects caused by water bodies.

The TAPM nesting grid or mesh was determined for this model via the consideration of the required terrain resolution in the radius of influence (approximately 10 km). Due to the generally flat non elevated terrain in this region a minimum terrain resolution of 900 m was considered to be sufficient to yield an accurate simulation of the local meteorological parameters.

In this instance, TAPM was used to develop site-specific meteorological data that would enable an accurate assessment of odour dispersion within this region. There is some conjecture regarding TAPM’s ability to predict the frequencies of low wind speeds at 10 m at night time, thus contemporaneous meteorological data from the RAAF Edinburgh Bureau of Meteorology (BoM) automatic weather station was assimilated with the meteorological simulation.

Table 4.1 TAPM input parameters.

	Meteorology
Site Centre:	34° 41' 29.6" S 138° 31' 26.3" E
UTM Zone:	54S
UTM Coordinates:	Easting 271650 m Northing 6161488 m
Dates	2002 (GMT +7.7)
Grid	20 x 20 x 25
Nesting	20 – 10 – 2.7 – 0.9 km
Meteorology assimilated with 2002 BoM data from RAAF Edinburgh (#23083) (15 km SE of site). Radius of influence ~ 20 km (due to low flat terrain/low wind speeds).	

5. Meteorology

5.1 General Meteorology

A constant discharge of contaminants from a source that results in ground level pollutant concentrations changes according to the prevailing meteorological (particularly the wind and atmospheric stability) conditions. Meteorology is fundamental to the dispersion of pollutants because it is the primary factor that determines the dilution effect of the atmosphere. Therefore, it is important to carefully consider the development of meteorological data when assessing pollutant dispersion.

Plume rise at the release point is affected by ambient temperature and relative humidity at the release point. Plume rise is not a significant concern for this assessment given the source is non-elevated and not buoyant. The important consideration of plume dispersion over distance is primary influenced by:

- wind speed, profile and turbulence intensity (which are affected by terrain);
- temperature gradient which is determined from atmospheric stability (which in itself is determined from wind speed, cloud cover and solar radiation) (discussed in Section 5.3) and
- mixing height, which is the depth of the atmospheric boundary layer.

Observed meteorological conditions were simulated for a full year, with 2001 being selected as the reference year. A cursory assessment of the appropriateness for using 2001 as the test year follows through comparison of 2001 conditions with long term average conditions using publicly available data from the closest BoM automatic weather station (AWS), located at RAAF Edinburgh. The long-term average meteorological data for this site is presented in Table 5.1.

Table 5.1 Long Term Meteorological Data for RAAF Edinburgh.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temperature (°C)	29.8	29.9	26.9	22.9	19.2	15.8	15.3	16.5	18.8	21.9	25.5	27.8
Mean daily minimum temperature (°C)	16.4	16.5	14.4	11.6	9.1	6.8	6.0	6.5	8.1	10.0	12.7	14.8
Mean 9am wind speed (km/hr)	14.2	11.7	11.9	12.8	12.1	11.9	13.1	15.5	17.7	18.5	16.3	16.0
Mean 3pm wind speed (km/hr)	23.1	21.0	20.6	19.1	17.6	17.7	18.9	21.3	22.5	22.6	22.6	24.0
Mean monthly rainfall (mm)	21.3	16.1	23.9	30.8	43.3	53.6	52.6	49.7	48.1	41.5	25.4	21.8

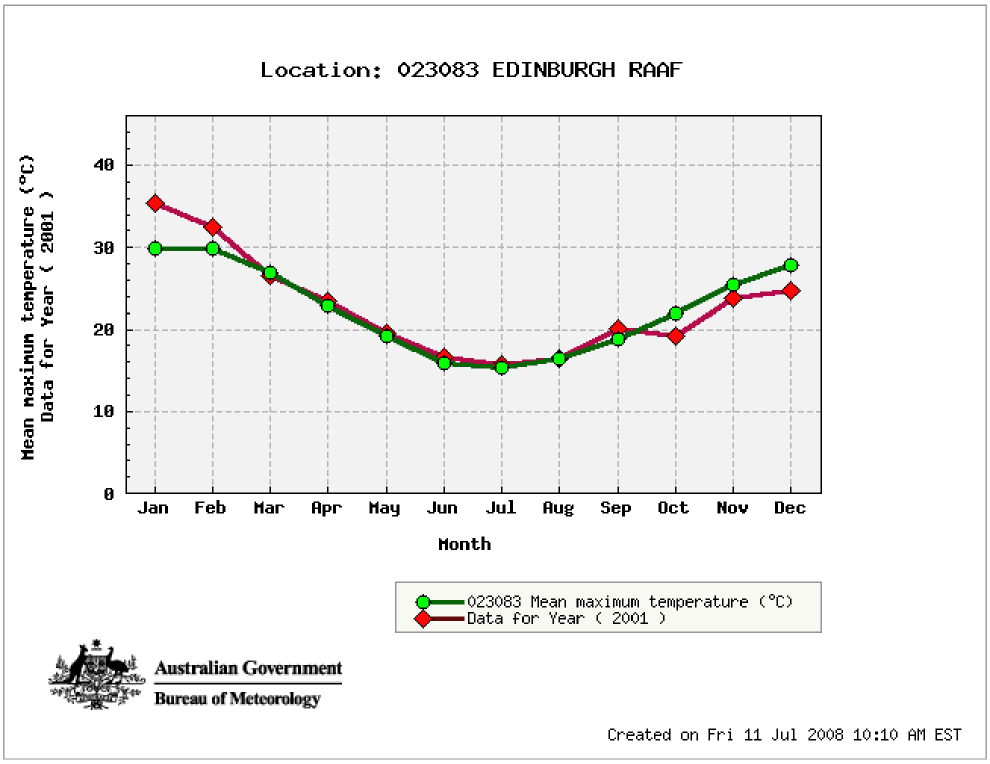
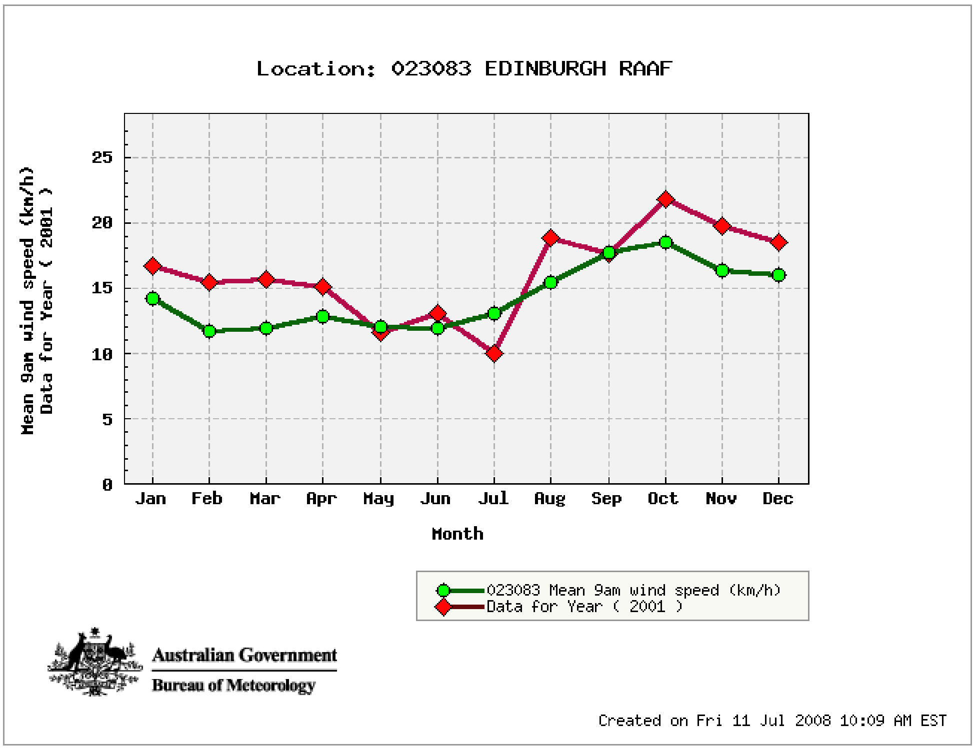


Figure 5.1 Comparison of monthly mean maximum temperatures (2001) to long term average conditions.

Figure 5.1 shows that the 2001 monthly mean maximum temperature correlates well with the long term average conditions in this area. This is indicative of 2001 being a climatologically representative year.

(a)



(b)

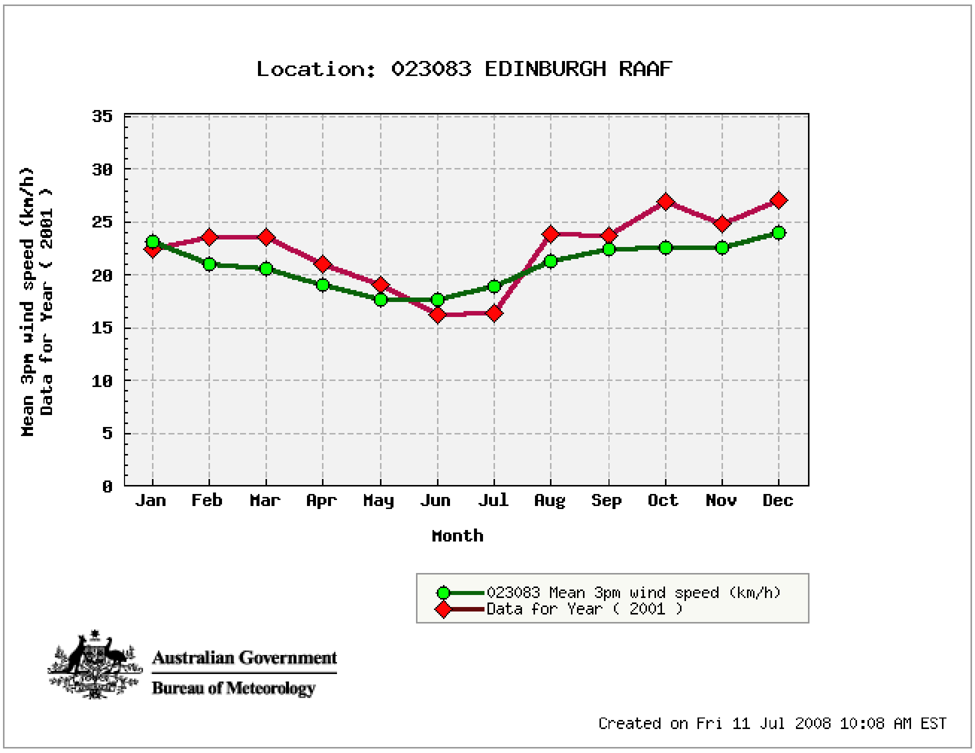


Figure 5.2 Comparison of monthly mean wind speed conditions (2001) to long term average for (a) 9 am and (b) 3 pm conditions.

The comparison of average wind speeds through the 9 am and 3 pm conditions in Figure 5.2 shows that average wind speeds have generally been greater than the long term average. This is indicative of the enablement of a conservative scenario where higher wind speeds would result in pollutants being dispersed further from the source towards sensitive regions. The dominant wind speeds magnitudes and directionality is discussed in the next section.

5.2 Wind

This section will detail the local wind conditions that will effect odour dispersion in this area. As the terrain is fairly simple and flat the meteorological conditions were seen not to vary significantly through the modelling domain. The annual wind rose that was generated from the TAPM simulation data is shown in Figure 5.3. This wind rose shows that the region is dominated by winds blowing from the north east as well as the south west quadrants. Winds from the other cardinal directions are seen to be fairly negligible with the exception of the westerlies. The analysis of both the wind rose and the wind class frequency distribution (Figure 5.4) show that more than 80% of winds occurring in the region have magnitudes less than 5 metres/second (m/s). This is an important consideration as low wind speeds inhibit dispersion of pollutants and lead to the accumulation of local concentrations. However a frequency of higher speeds is necessary for ground level emissions to be dispersed over long distances towards sensitive regions.

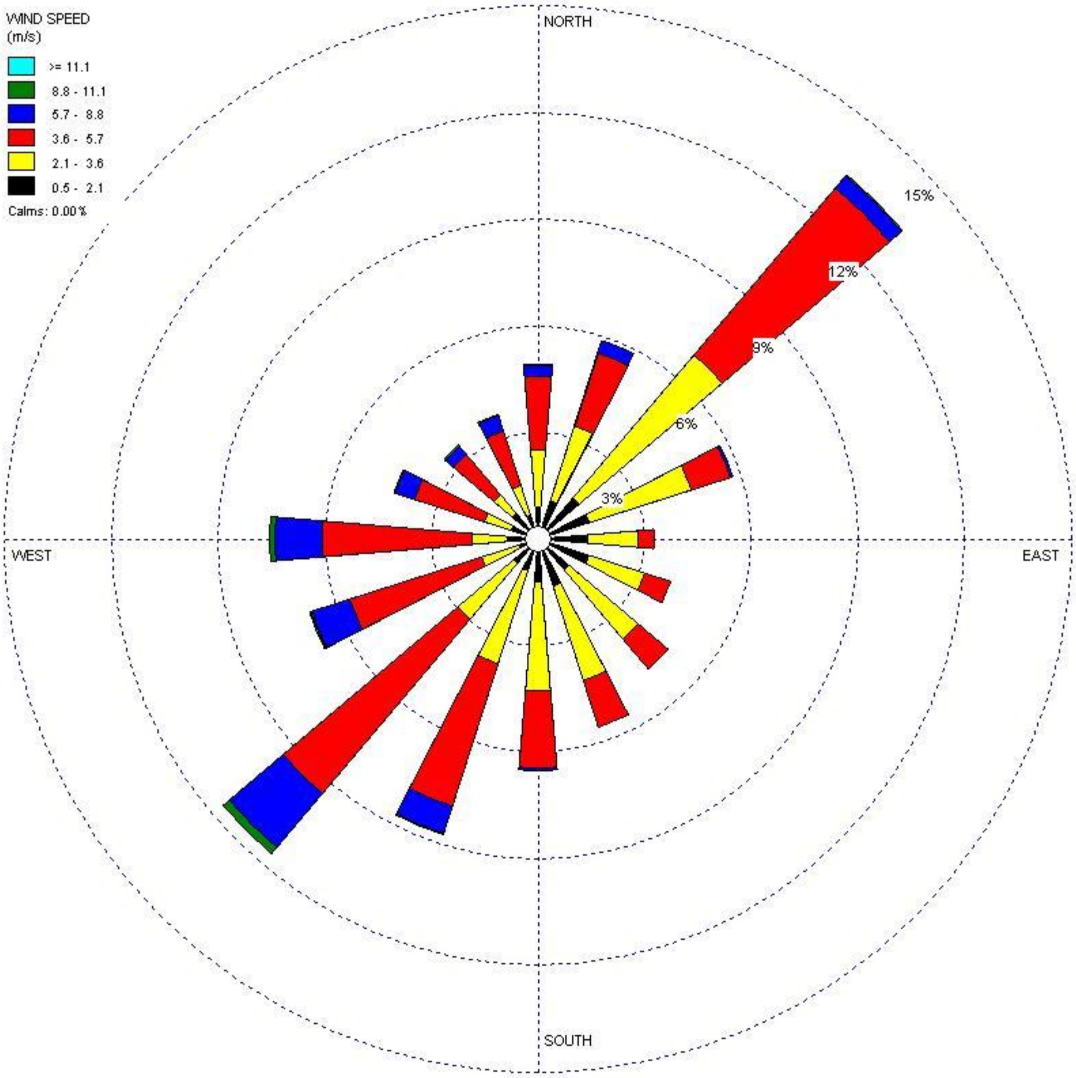


Figure 5.3 Buckland Park site-specific annual wind rose.

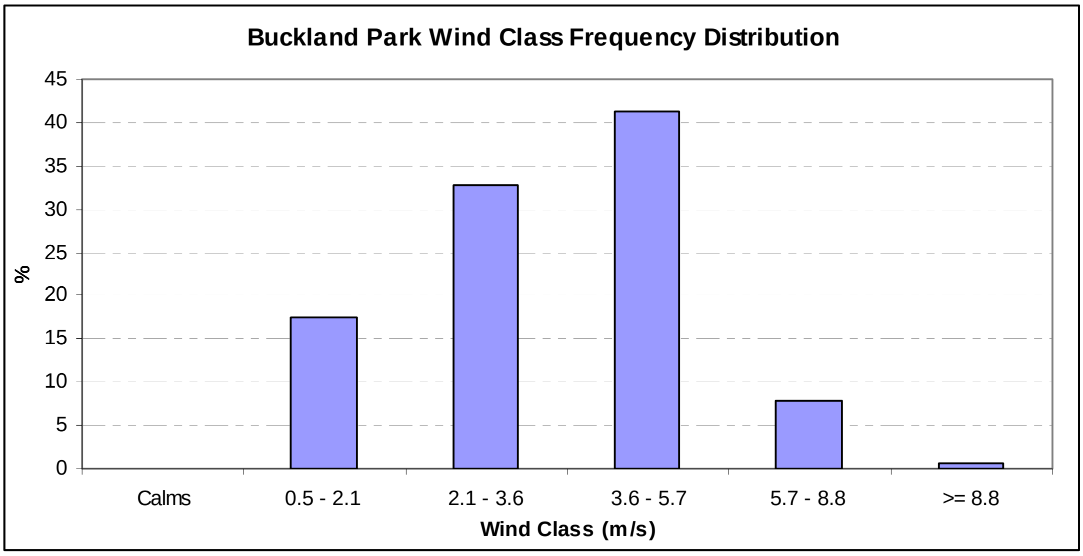


Figure 5.4 Wind class frequency distribution.

5.3 Atmospheric Stability

The degree of stability in the atmosphere is determined by the temperature difference between an "air parcel" and the air surrounding it. This difference can cause the "air parcel" to move vertically and this movement is characterised by four basic conditions that describe the general stability of the atmosphere. In stable conditions, this vertical movement is discouraged, whereas in unstable conditions the "air parcel" tends to move upward or downward and to continue that movement. When conditions neither encourage nor discourage that movement beyond the rate of adiabatic heating or cooling they are considered neutral. When conditions are extremely stable, cooler air near the surface is trapped by a layer of warmer air above it, with this condition being called an inversion, which results in virtually no vertical air motion.

The Pasquill-Gifford (P-G) stability category scheme is normally used. Stability class under the P-G scheme is designated a letter from A-F (and sometime G), ranging from highly unstable to extremely stable. There are a number of methods for determining stability classes, with Turner's method the most common. This method estimates the effects of net radiation on stability from solar altitude, total cloud cover and ceiling height. The stability class is estimated as a function of wind speed and net radiation as is apparent in Table 5.2.

Table 5.2 Stability Categories

Wind Speed [a] (m/s)	Day-time incoming Solar radiation (mW/cm²)				1 hour before sunset or after sunrise	Night-time Cloud cover (octas)		
	>60	30-60	<30	Overcast		0-3	4-7	8
< 1.5	A	A-B	B	C	D	F or G[b]	F	D
2.0 – 2.5	A-B	B	C	C	D	F	E	D
3.0 – 4.5	B	B-C	C	C	D	E	D	D
5.0 – 6.0	C	C-D	D	D	D	D	D	D
> 6.0	D	D	D	D	D	D	D	D

[a] Wind speed is measured to the nearest 0.5m/s.

[b] Category G is restricted to night-time with less than 1 octa of cloud and a wind speed less than 0.5m/s.

The stability class rose together with the frequency distribution of stability class for this site is shown in Figure 5.5 and Figure 5.6 respectively. The area is seen to be dominated by neutral and stable conditions, with stability class D being dominant. This trend is reflected in the stability class rose where the regions north east of the composting facility are dominated by stable and neutral conditions (stability class D and E). The high frequency of relatively stable meteorological conditions is as a result of generally low wind speeds in the area. Significant cloud cover in the area resulting in minimal solar radiation also causes reduced heating or cooling of the surface, leading to neutral conditions.

The frequency distribution of stability class with time of day is shown in Table 5.3. Neutral and stable stability classes are observed through the night time, as expected. Throughout the day however the stability class shifts from neutral-stable to neutral-unstable due to the convective nature of the boundary layer. The convection arises from the solar irradiation of the earth's surface, resulting in enhanced mixing. The frequency distribution of stability versus wind speed is shown in Table 5.4. The wind speeds are observed to follow the expected outcome with stability class as is observed from other sites which have a similar climate. The processed surface data appears to provide reliable data based on atmospheric stability class.

Therefore it is believed that the wind speed and stability class conditions are predicted with sufficient accuracy to enable a conservative air quality assessment based on the worst case meteorological conditions.

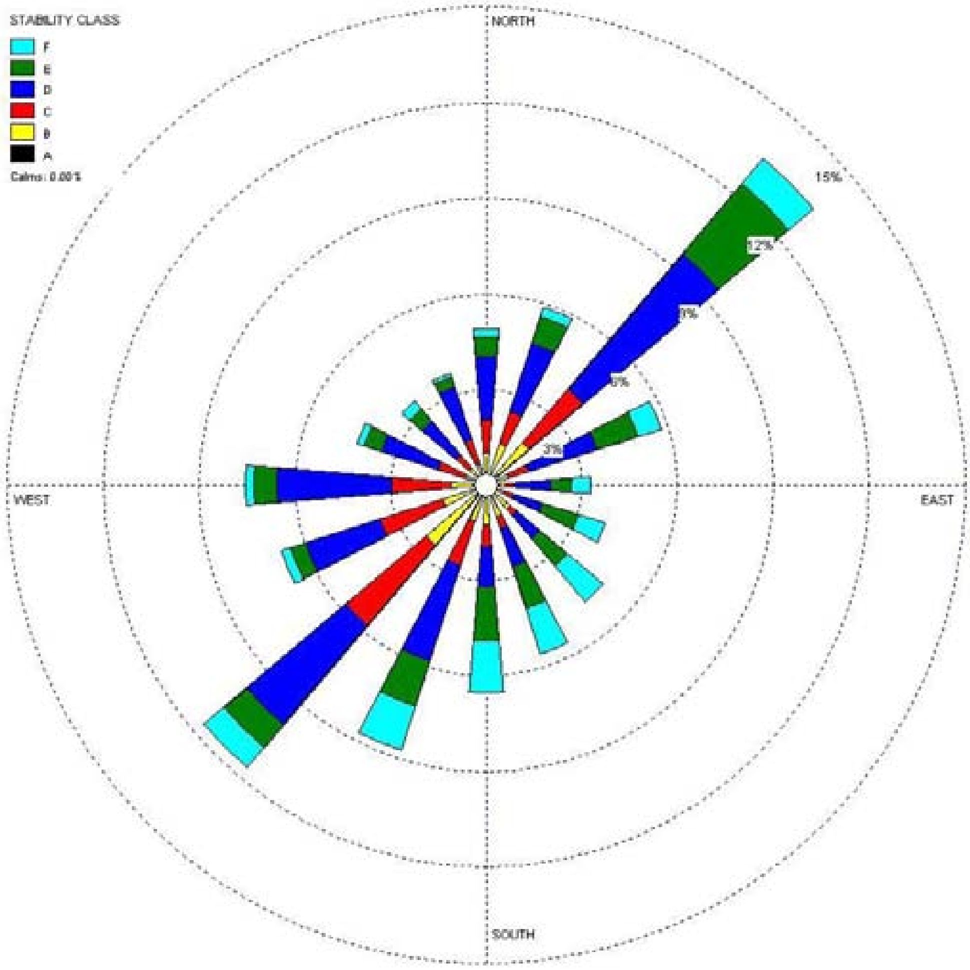


Figure 5.5 Stability class rose.

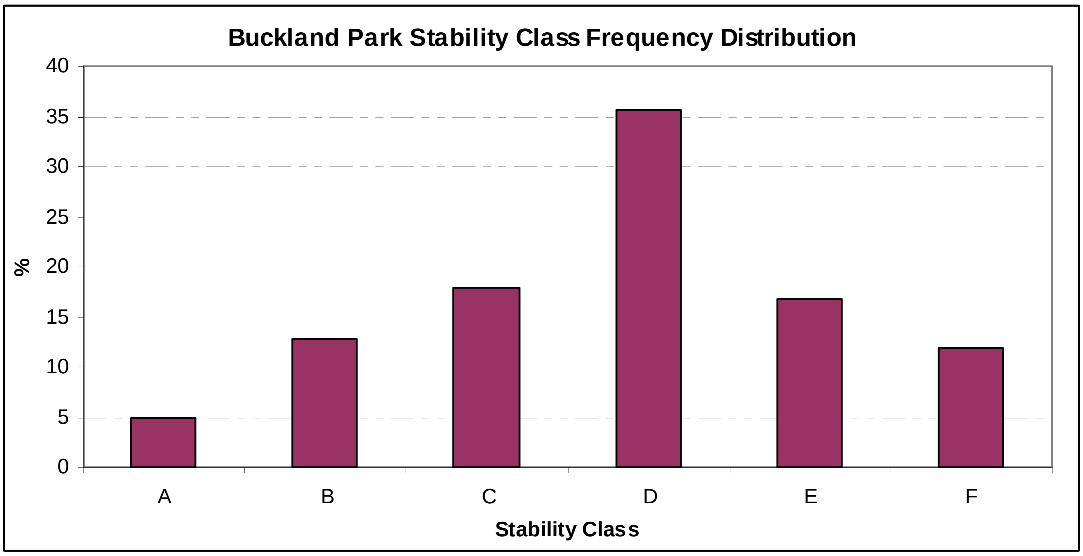


Figure 5.6 Stability class frequency distribution

Table 5.3 Frequency distribution of atmospheric stability class versus time of day

Hour of Day	Stability Class					
	A	B	C	D	E	F
1	0	0	3	129	134	99
2	0	0	7	144	131	83
3	0	0	6	156	133	70
4	0	0	5	161	140	59
5	0	0	8	202	113	42
6	0	0	13	282	54	16
7	0	10	88	247	17	3
8	5	82	122	156	0	0
9	39	121	138	67	0	0
10	77	139	114	35	0	0
11	89	139	103	34	0	0
12	95	136	100	34	0	0
13	68	140	126	31	0	0
14	42	137	150	36	0	0
15	14	123	176	52	0	0
16	6	73	206	80	0	0
17	1	19	152	193	0	0
18	0	0	44	272	26	23
19	0	0	0	229	67	69
20	0	0	0	113	154	98
21	0	0	1	103	141	120
22	0	0	4	112	121	128
23	0	0	3	120	118	124
24	0	0	2	128	126	109

Table 5.4 Frequency distribution of atmospheric stability class versus wind speed

Speed (m/s)	A	B	C	D	E	F	G
0-2.0	196	123	133	486	300	168	0
2.0-4.0	240	599	370	1003	646	875	0
4.0-6.0	0	397	944	1225	529	0	0
6.0-8.0	0	0	124	256	0	0	0
8.0-10.0	0	0	0	146	0	0	0

5.4 Mixing Height

The mixing height is the height of the turbulent boundary layer of air near the earth's surface within which ground level emissions are rapidly mixed. A plume emitted above this height will remain isolated from the ground until the mixing height reaches the height of the plume. A plume emitted below this height will be mixed subject to the stability class and wind climate. The height of the mixing layer is controlled by convection (resulting from solar heating of the ground during the day) and by mechanically generated turbulence as the wind blows over rough ground (hence the importance of land use data).

The mixing height at the Buckland Park site was estimated using gridded surface and upper air meteorological data that was generated by TAPM. TAPM is able to generate detailed, three dimensional gridded (in x, y and z) meteorological data up to a level of eight kilometres above sea level from preprocessed synoptic meteorological data.

The estimated mixing height for this site rises in the morning from just after sunrise until mid afternoon. After this time, the mixing height remains at a relatively stable value until returning to a lower level early in the evening. This diurnal variation of atmospheric structure is consistent and expected with that found at sites, with a similar climate to that of this region. This diurnal variation is shown in the hourly mixing height profile for the full year in Figure 5.7. Large values for mixing height occur in the summer months due to the greater convective effects, in terms of irradiation of the Earth's surface. The minimum mixing heights predicted by TAPM are very low compared to inland sites and this is evidence of the coastal location and inherent evidence of conservativeness of the predicted meteorological data. It can therefore be said that the generated meteorological data will enable a worst case assessment of pollutant dispersion, in terms of both odour and dust impacts. The development of data that represents low mixing height levels in coastal regions is especially important for ground based emission sources, as the odour and dust sources in this case are. The main change throughout the year is the length of the period of strong convection and the variation in the wind speed and directionality. The data shown below demonstrates the conservativeness in the predictions given the low depth of the mixing layer through the winter months. The prediction of these conditions is expected to enable a worst case assessment of pollution dispersion from the Jeffries Facility.

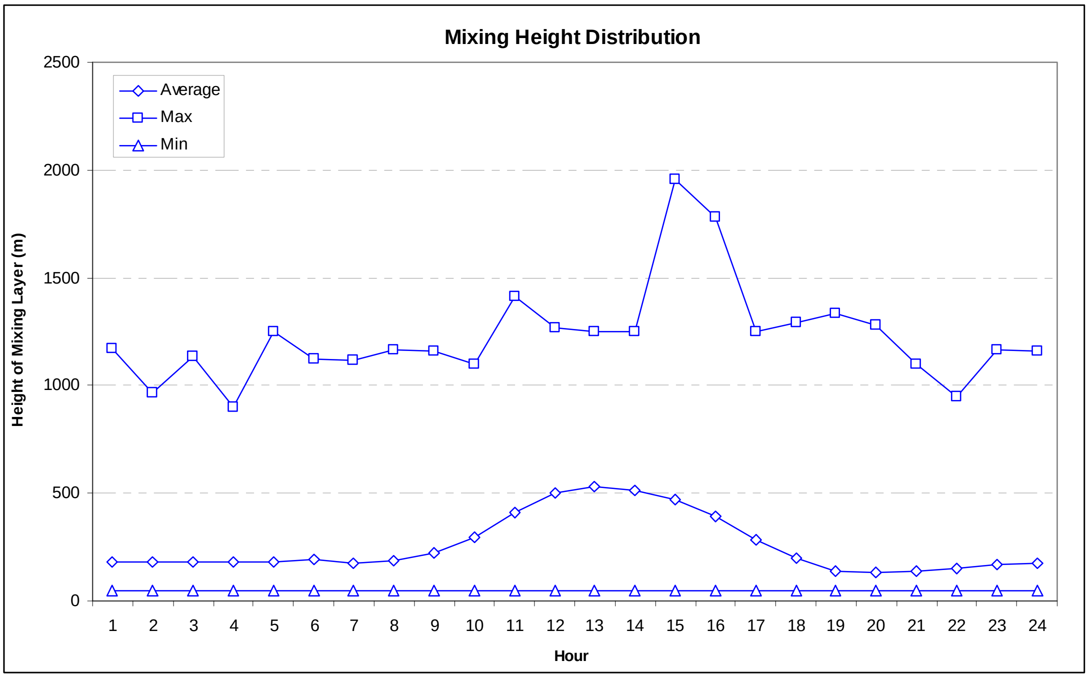


Figure 5.7 Hourly mixing height distribution simulated through reference year.

6. Dispersion Modelling & Impact Assessment

6.1 Dispersion Model

The US EPA Gaussian plume model ISCST3 (Industrial Source Complex Short Term 3) was used to assess the dispersion of odour from the composting windrows at the Jeffries facility. This model is equivalent to the EPA SA approved AUSPLUME that is also based on the Gaussian dispersion principle. These numerical tools are steady-state plume models that incorporate air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources and both simple and complex terrain. The model calculates the concentration of pollutants downwind of the source based on the assumption that the concentrations follow a Gaussian distribution about the centreline of the plume and the local meteorology is spatially invariant and constant through each time period.

This assumption leads to inaccuracies in simulated dispersion results for complex, undulating terrain but it is considered reasonable for the assessment of this site due to the lack of terrain complexities within the modelling domain (i.e. flat terrain). This locality is approximately 6km from the ocean and is therefore sufficiently removed from the ocean to not be significantly influenced by coastal fumigation.

The EPA has previously accepted the odour assessment for the Jeffries facility which was also based on AUSPLUME.

The model calculates downwind odour concentrations in the area surrounding the facility on an hourly basis for the period through which the pre-processed meteorological data is input. The site specific hourly meteorological data input, which included detailed parameters such as wind speed, wind direction, stability classes and mixing heights was generated by TAPM.

Odour dispersion from the windrows was assessed based on the odour sampling and analysis that was carried out for the various compost compositions (see Table 3.1). The area modelled was approximately 300 m by 100 m which was considered to sufficiently represent all the windrows on the site. The parameters that were used to define this source are listed below in Table 6.1.

Table 6.1 Area Source parameters – dispersion model.

Coordinates(UTM Zone: 54)	[273356, 6158407] m
Coordinates (UTM Zone: 54)	[273356, 6158407] m
Release Height	1 m
Length of X Side	300
Length of Y Side	100
Orientation Angle from North	5°

The worst case odour emission rate was calculated based on the average of the worst case odour concentration measured through the monitoring program. This worst case figure was recorded for the sample taken from the windrow that was composed of 80% green waste and 20% liquid organic waste. Another scenario that was simulated was for the highest odour concentration measured for a windrow which consisted of green waste wholly, as the mixed composition windrow was taken to be not part of normal practice at this facility. The last scenario modelled was one where the emission rate from the area source was assumed to be an approximate arithmetic average of the concentrations of all the samples taken from all the windrows at the facility which were of varying organic composition, age and moisture content. The emission rates for these three cases are tabulated in Table 6.2.

Table 6.2 Odour Dispersion: modelled scenarios.

Scenario	Description	SOER (OU/m²/s)
1	Worst case: mixed composition windrow (80% green waste 20% liquid organic)	2.58
2	100% Green waste windrow Age: one week	2.04
3	Average measured concentration across varying windrow composition, age and moisture content	1.08

6.1.1 Odour Dispersion Results

The results from the analysis are assessed against the EPA criteria outlined in Table 1.1 for a region which is expected to have a population greater than 2,000 people, as is expected for this proposal. Hence, the criterion states that the 99.9th percentile 3 minute average odour concentration should not exceed 2 Odour Units (OU) at the nearest sensitive receiver (boundary to nearest residential area within proposal) as per the Masterplan.

This section details the predicted worst-case odour impact at the nearest sensitive receivers within the Masterplan as well as results from less conservative assessments, which are expected to yield results that are more realistic.

Scenario 1 was thought to be conservative as the analysis assumed all the composting windrows would consist of the 80% green waste 20% liquid organic mixture. This is not representative of the facility operations. Jeffries advised this composition was a non-standard composition. Scenario 2 and 3 are expected to be more realistic of the likely odour emissions, with Scenario 2 being conservative in its estimates.

The results for each of the three scenarios that were simulated for this odour assessment are shown in Table 6.3; compliance with the governing EPA criteria is shown for all three cases. The analysis of the contours that are generated from the simulation will give a better representation of the dispersion of the odour and the levels experienced within the region modelled.

Table 6.3 Odour concentration at sensitive receivers for scenarios modelled.

Scenario	3 min Averaged 99.9th Percentile Odour Concentration at Sensitive Receiver (OU)	Contour Reference
1	~ 2.2	Appendix A
2	~ 1.8	Appendix B
3	~ 1.0	Appendix C

6.1.2 Verification

The comparison of the contours predicted for Scenario 2 with that published in the Public Environmental Report for the 'Jeffries garden soils organics waste treatment and recycling research facility' (2003) (PER), show that the predictions made by the Connell Wagner model are conservative for this particular scenario.

It is reiterated that Scenario 2 provides an inherently conservative yet realistic analysis of the odour concentration at the residential area boundary.

6.2 Fugitive Emissions

Fugitive emissions from the Jeffries facility have already been assessed in detail in the Jeffries PER. The analysis of the dust contours that are shown in the specialist air quality report that is included within the PER demonstrate that the worst case impacts comply with the Federal National Environment

Protection Measure (NEPM) guidelines. Specifically the guideline that has to be complied with is that stipulated for respirable PM_{10} particulates (i.e. particles with aerodynamic diameter < 10 µm). The NEPM states that the PM_{10} daily averaged concentration should not exceed 50 µg/m³. The contours in Figure 6.1 demonstrate that this guideline is met at the boundary of the proposed Buckland Park site. Therefore, no further analysis is necessary.

The facility operators have committed to the following dust control provisions to minimise nuisance and exceedances of air quality criterion (Parsons Brinckerhoff, 2003):

- use of covered trucks for incoming material;
- primary processing in an enclosed building;
- windrow turning, grinding and tromelling operations is not conducted in extreme dry windy weather conditions if watering proves ineffective;
- maintenance of windrows at their optimum moisture content (~ 40-50%);
- watering of other operational areas with sprinkler systems in dry windy conditions;
- use of water trucks in unsealed trafficked areas during dry windy conditions;
- restrict vehicle speed within the site to 10 km/hr;
- monitoring of meteorology and dust concentrations on site, to be used to assist in dust control management.

The consistent implementation of these standard dust measures will lead to there being minimal air quality issues at the boundary of the Buckland Park residential area.

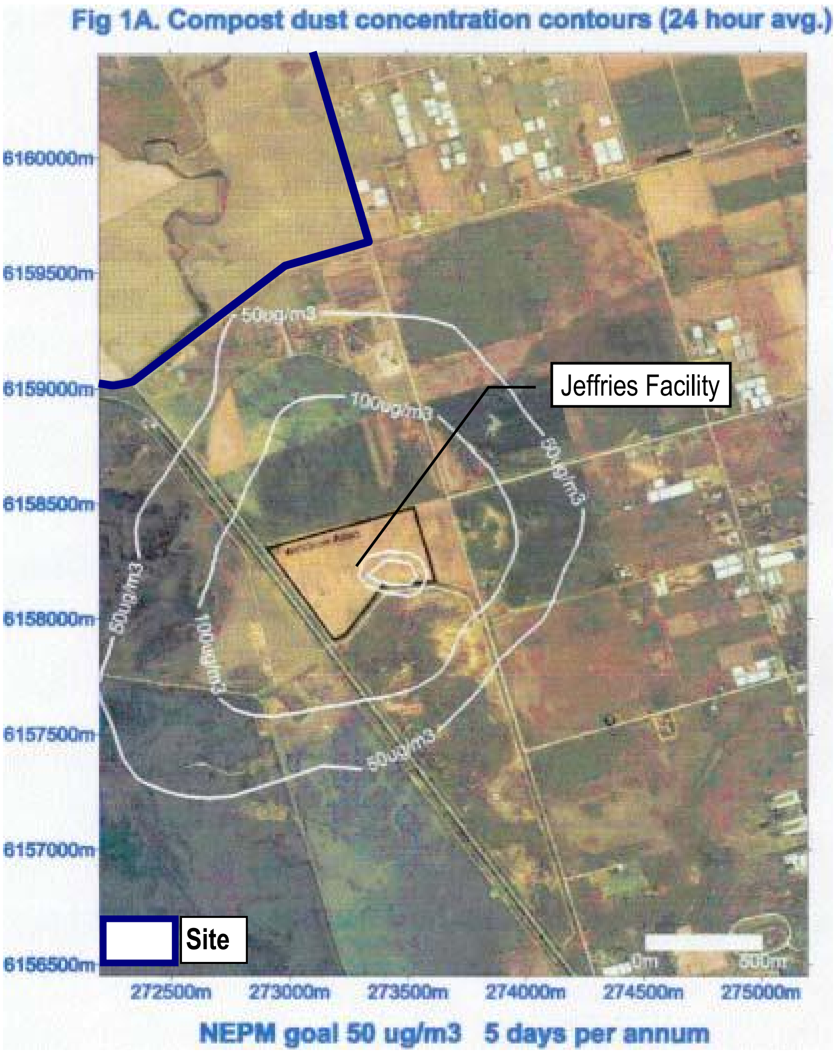


Figure 6.1 PM_{10} ground level concentration contours from dust generating activities at Jeffries Facility.

6.3 Bio-aerosol Impacts

The sampling of bio-aerosols and the results of the laboratory analysis was described in Section 3.3 (results shown in Table 3.2). These results show a trend where the number of colony forming units found on each plate upwind (U) of the composting site (S) is significantly less than that found on the plate during contemporaneous sampling at S, as expected. The levels measured at location U can be considered to be representative of the background levels of micro-organisms in the air, in this region. The bio-aerosol impact was assessed by observing the difference between the measured concentrations of micro-organisms on the agar plate at the composting site c.f. the downwind and the background (upwind) measured concentrations.

The results shown in Table 3.2 demonstrate that there is depletion in the CFU level per plate downwind of the site (towards background levels) in comparison with the CFU levels per plate recorded *at* the composting site contemporaneously. At 4.30 pm the sampled microbial levels on the agar plate at the composting site was approximately 120 CFU/plate, and at 4.45 pm the microbial levels on the agar plate 700 m downwind of the composting site was found to be approximately 90 CFU/plate. This is considered to be a statistically appreciable depletion in the agar plate sampled bio-aerosol concentration. It is reasonable to assume that this level will drop further with distance from the composting facility and back to background levels at the nearest sensitive receivers within the proposal. Therefore one can conclude that bio-aerosols emitted from this facility will have a negligible impact on the health of the future residents of the Buckland Park proposal.

6.4 Spray Drift

The AgDRIFT Tier I analysis was undertaken to quantify potential spray drift onto the proposed Buckland Park proposal. This methodology is designed to be reasonably conservative and incorporate recommended upper limits for relevant variables including the type of aircraft and operation, nozzle setup, meteorology, material properties of the test substance and application rate. All of these values were taken to be at the default that is pre-configured into the model; this is as shown in Table 6.4.

Table 6.4 AgDRIFT Tier I parameters.

GENERAL PARAMETERS - Aircraft Description/Operation Type Air Tractor AT-401	
Weight of Aircraft	26,683 N
Wing Semispan	7.48 m
Air Speed	53.6 m/s
Release Height	3.05 m
Nozzle Setup	
Number	42
Vertical Offset	- 0.35 m
Horizontal Offset	- 0.25 m
Boom Span	±5.7 m
Spacing (even)	0.28 m
Meteorology	
Wind Speed @	4.47 m/s @ 2 m
Wind Direction	Perpendicular to flight path
Surface Roughness	0.0075 m
Stability Class	D (neutral)
Relative Humidity	50 %
Temperature	30°C
Test Substance / Application	
Specific Gravity	1.0
Nominal Application Rate	100 ng/cm^2
Swath Width	18.29 m
Non-volatile Fraction	0.03
Number of Flight Lines	20

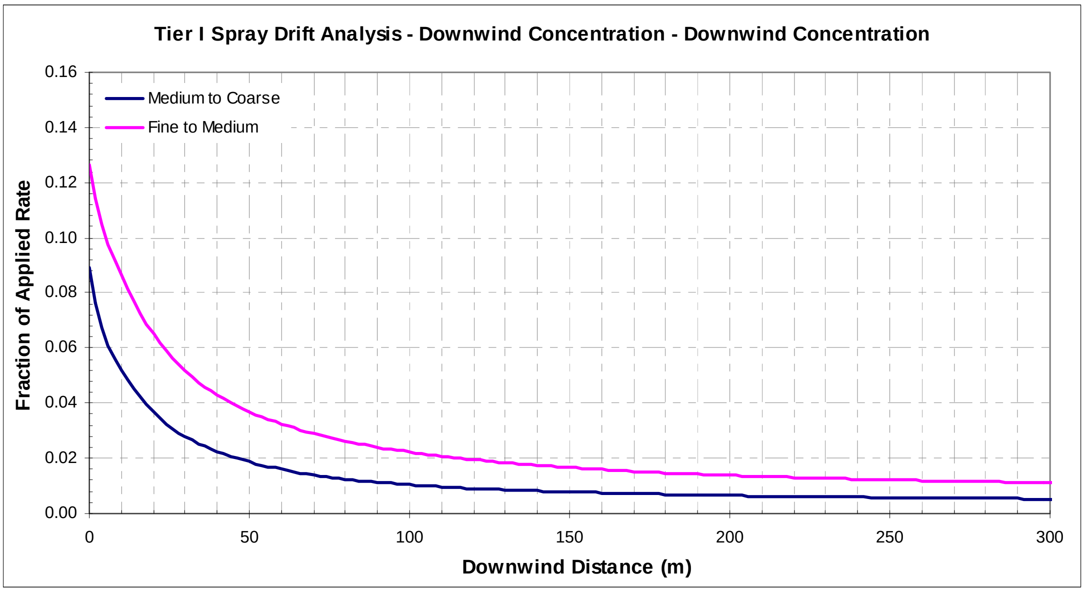


Figure 6.2 Tier I spray drift analysis results - downwind distance concentration.

The predicted spray drift deposition profile downwind of the edge of the aerial application site is shown in Figure 6.2. This analysis has been conducted for two scenarios, the first being for droplets of 'medium to coarse' and 'fine to medium' aerodynamic diameters. The downwind spray drift deposition of droplets described as being 'medium to coarse' are seen to be less pronounced in comparison to the drift of droplets of size 'fine to medium'. The medium to coarse droplets undergo evaporation at a faster rate in comparison to the finer droplets therefore their downwind deposition is reduced. Upon the analysis of the graph above for the 'fine to medium' droplet case it is apparent that the deposited concentration 300 m from the edge of the crop is one hundredth of the initial application rate. The impact of spray drift through sensitive regions that are a distance greater than 300 m away is therefore considered to be negligible. This is the case for the Buckland Park proposal.

Given the nature of horticultural activities in the immediate vicinity of the site - that is glass houses and small market gardens, it is unlikely that farmers would use aerial spraying, which is expensive and more suited to large scale farms. Most pesticide application in the area would likely be conducted through boom spraying from tractors. The dispersion of pesticide from the application of pesticide through this method will lead to minimal spray drift intuitively given the fact that:

- chemical application is at a lower height;
- application device is moving at a lower speed.

EPA guidelines for responsible pesticide use, to minimise any off-target spray drift of pesticides include:

- Maintenance of careful records is recommended to avoid potential accusations of spray drift or chemical trespass.
- Discussion with communities in sensitive regions will help determine any concerns they have, identify any sensitive areas on adjacent property, therefore allowing the development of strategies to minimise the damage potential. It is important to make such an air quality management plan with regards to spray drift iterative following complaints or discussions with the receivers.
- The application of aerial pesticides on crops should be avoided during periods of heavy rainfall or following rainfall. This is recommended so as to minimise the potential of off-target flow of pesticides through moist soils and waterways.
- Spray drift is minimised during periods of mild temperatures, high humidity and low wind speeds that are blowing from the sensitive regions. Calm wind speed conditions however should be avoided as drift is unpredictable during these periods.
- Spray drift during periods of low humidity and when temperatures are above 27°C should be avoided as spray droplet size will decrease due to evaporation, leading to the exacerbation of drift. In addition volatile organic compounds could potentially vaporise and re-enter the atmosphere. This could potentially lead to conditions resulting in the creation of inversion layers and unstable atmospheric conditions, greatly increasing the probability and magnitude of drift.

The adherence to the guidelines stipulated by EPA SA will ensure minimal offsite drift of pesticidal compounds. Therefore the impact of spray drift from off site pesticide application on the Buckland Park proposal will be negligible.

7. Conclusion

This study has assessed the level of air quality that will be experienced by the future residents of the Buckland Park proposal. In particular, it has considered the impact of the discharge and dispersion of odourous compounds, fugitive dust emissions and bio-aerosols from the Jeffries Facility situated one kilometre south of the site and 1.7 kilometres from the nearest proposed residential area. The report also considered the impact of spray drift from application of pesticides on agricultural land unto the developmental site.

The odour dispersion analysis was conducted following an extensive odour survey of compost windrows from the Jeffries Facility. The CSIRO developed TAPM prognostic meteorological model was subsequently used to develop site specific meteorological data. The meteorological dataset generated was analysed and was shown to enable the worst case conditions for air dispersion into sensitive regions. The US EPA approved ISCST3 Gaussian plume dispersion model was used to assess the dispersion of odour. The results demonstrated that under the worst case conditions the 3 min average 99.9^{th} percentile odour concentration would be compliant with the EPA SA 2 OU limit at the nearest proposed residential area shown in the Masterplan. A management strategy that ensures the avoidance of anaerobic conditions in the composting windrows and formation of stagnant pools will minimise odour emissions from the Jeffries Facility. Such a management strategy has been implemented since the facility's inception. Therefore the proposal will not impose any additional operating requirements on the Jeffries Facility.

The impact of dust generating activities and wind erosion from stockpiles at the Jeffries composting Facility was assessed as part of the submission of the Public Environmental Report for the facility in 2003. The analysis of the daily averaged PM_{10} contours showed that the 50 $\mu g/m^3$ NEPM guideline is complied within the developmental boundary. Therefore the emissions of dust from the operations of the Jeffries Facility is not expected to lead to any exceedances of regulatory criterion at the residential boundary. Jeffries have also committed to a series of dust suppression, mitigation and control measures that minimises emissions and ensures that the activities of the plant do not lead to any criterion exceedances.

The microbial survey conducted at several sites adjacent to and at the Jeffries Facility showed that microbial levels returned to ambient concentrations approximately 500 m downwind of the source. The positioning of the Jeffries Facility is therefore not expected to have any impact on the health of the future residents of the Buckland Park proposal.

The spray drift analysis demonstrated that aerial pesticide spray from low flying aircraft onto agricultural land near the site is expected to lead to negligible levels of deposition of pathogenic pesticidal compounds on the proposed development.

The assessment has demonstrated the proposal as described in the Masterplan will not be impacted by odour, biological aerosols or dust impacts from the operations at the Jeffries Facility. All of the requirements stipulated within the EIA guidelines for this proposal have therefore been satisfied within this assessment. Additionally the impact of spray drift from the application of pesticides on agricultural land will have negligible to zero impact on the proposal. The assessment has demonstrated the proposal as described in the Masterplan will not have any impact on the operations of the Jeffries Facility and does not impose any additional operating requirements on the Facility.

8. Glossary

Adiabatic
A process is defined as *adiabatic* if it occurs without loss or gain of heat.

Bio-aerosol
A bio-aerosol is the term provided to particulate bound biological organisms such as fungi, bacteria, viruses and mycotoxins. Particulates are defined broadly as water droplets, dust and soil.

Mixing height
Mixing height is the depth of the unstable air in the planetary boundary layer and is used to predict the dispersion of smoke, plumes and pollutants.

Pathogen
A pathogen is a disease producing agent (including pollutants and micro-organisms).

PM_{10}
Particulates with an average aerodynamic diameter less than 10 µm.

$PM_{2.5}$
Particulates with an average aerodynamic diameter less than 2.5 µm.

Odour threshold
The odour threshold is the concentration of a gaseous substance, expressed in $\mu g/m^3$, which is discerned from odourless air by at least half of an odour panel. The odour threshold per definition has an odour concentration of 1 OU/m^3. Therefore 2 OU/m^3 means the odorous air must be treated with two parts of clean non-odourous air to reach the human odour threshold.

Total Suspended Particulates (TSP)
Particulates with average aerodynamic diameter that is less than 100 µm.

Windrow
A row or line of compost heaped to a height of approximately 1.5 metres and length greater than 100 metres.

9. References

EPA SA 2007 'EPA Guidelines Odour assessment using odour source modelling', EPA 373/07. http://www.epa.sa.gov.au/pdfs/guide_odour.pdf

EPA SA 2005, 'EPA Guidelines for Responsible Pesticide Use'. http://www.epa.sa.gov.au/pdfs/guide_pesticides.pdf

European Commission International Symposium, 'The Science of Composting' pp71 - 79 (W Bildingmaier - 'Odour Emissions from Composting Plants').

Planning SA Dept of Transport and Urban Planning, 'Assessment Report For the Public Environmental Report for the Jeffries garden soils organic waste treatment and recycling research facility, Buckland Park', Nov 2003

Rodenbury Davey Associates, 'Environment Management Plan for a Recycled Organics Resource Centre at Buckland Park', 2008

Appendix A

Scenario 1 – 2 OU Contours – 2.58 OU/m^2/s

Appendix A

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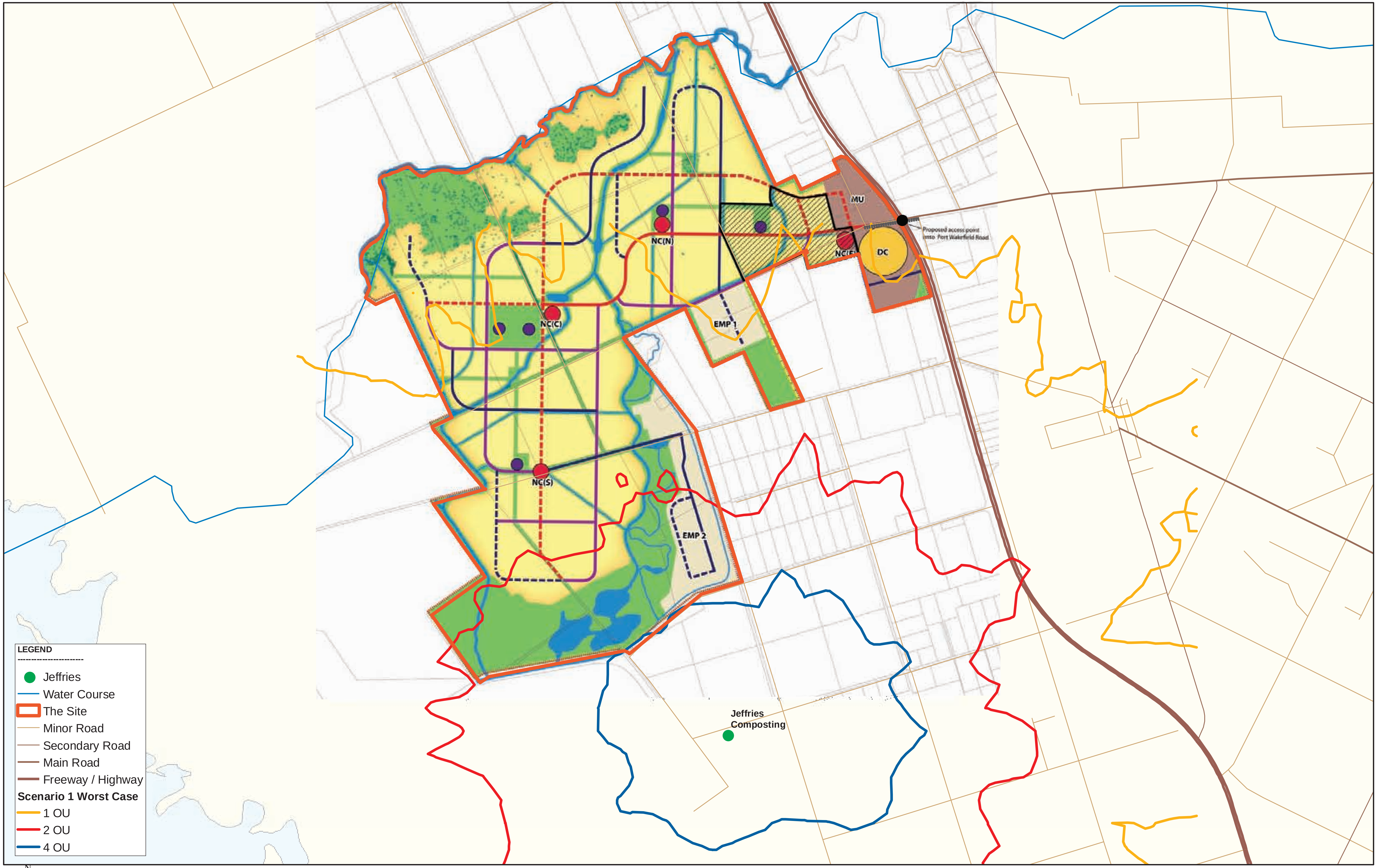

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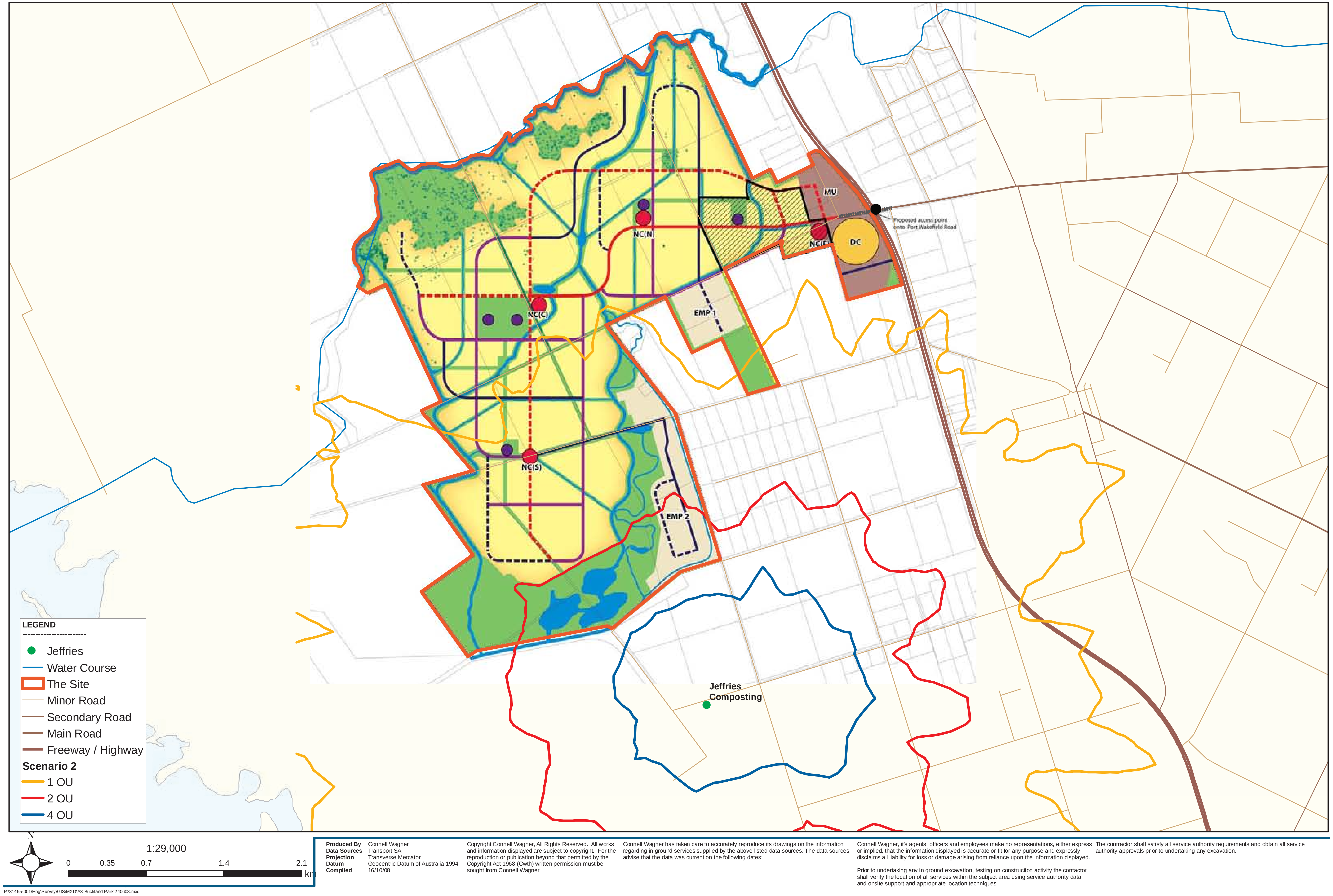
Appendix B

Scenario 2 – 2 OU Contours – 2.04 OU/m^2/s

Appendix B



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Appendix C

Scenario 3 – 1, 2 & 4 OU Contours – 1.04 OU/m²/s

Appendix C

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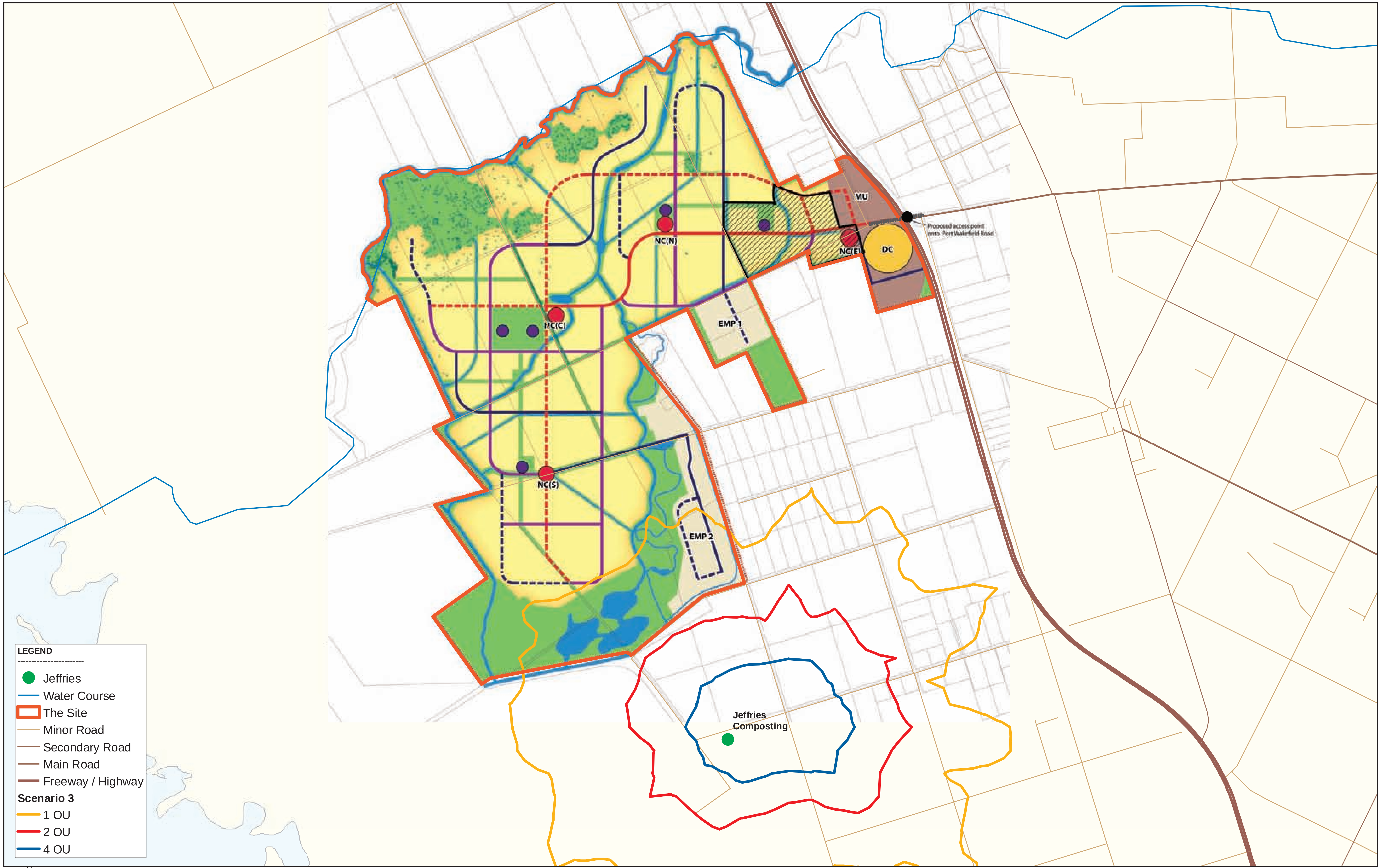

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