Appendix 2 – Bioscience Wetlands Assessment

Bioscience

GEOMORPHIC WETLANDS SWAN COASTAL PLAIN DATASET

REQUEST FOR MODIFICATION

Lots 13, 14, 21 and 22 Southern River Road

&

Lots 18, 19 and 20 Matison Street

Southern River Precinct 3

City of Gosnells

July 2009

Prepared by Bioscience Pty Ltd

Report Authors: Peter Keating, B.Sc (Hons) PhD and Andrew Jackson, B.Sc. (Hons)

Integrating Resource Management

Bioscience

BIOSCIENCE PTY LTD ACN 054 829 131
625 WARTON ROAD FORRESTDALE WESTERN AUSTRALIA 6112
PO BOX 5466 CANNINGVALE WESTERN AUSTRALIA 6155
TELEPHONE (08) 9397 2446 FACSIMILE (08) 9397 2447
EMAIL bioscience@biosciencewa.com.au
WEBSITE www.biosciencewa.com

GEOMORPHIC WETLANDS SWAN COASTAL PLAIN DATASET REQUEST FOR MODIFICATION

Lots 13, 14, 21 and 22, Southern River Road and Lots 18, 19 and 20 Matison Street, Southern River Precinct 3, City of Gosnells.

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e ti e S ar

The land encompassed by Matison Rd, Southern River Rd, Landor St (road reserve) and a local authority drain in Southern River is currently marked in the Geomorphic Wetlands Swan Coastal Plain dataset as being almost all dampland, of which the majority is classified as Resource Enhancement Wetland.

This classification is not consistent with field observations, and the area had not been previously examined in detail. The Department of Housing which owns the majority of the land commissioned Bioscience to undertake a detailed assessment of wetlands. The two other land owners agreed to become part of the study so the entire area could be considered.

Studies undertaken include surveying the land to obtain accurate surface contours and the installation of 25 piezometer monitoring bores. During installation, soil profiles were logged, photographed and samples collected for laboratory analysis. Depth to groundwater was determined and is now being routinely monitored. Water samples were collected for analysis of water quality parameters, and soil was examined for hydritic parameters including redox potential, organic carbon and sulphur, pH and acid sulfate properties and evidence of sedimentation. The vegetation throughout the site was mapped and vegetation condition was scored.

Data collected from the site was then used to model groundwater height and flow through the area. The modelling considered more extensive and longer term data from nearby Department of Water monitoring bores, and other recent studies on hydrology and drainage in the area by JDA. The model projected the average groundwater maximum, and maxima likely in 1 in 10 year and one in 100 year rainfall scenarios. The “average” projections were field proofed in July 2009 and the model recalibrated.

By considering the hydrology, the presence of hydritic soils, and the nature and condition of vegetation present on the site, Bioscience concludes that the current wetland boundaries and management category are inconsistent with field observations.

The data indicates that in the past two wetlands existed on the site, one was a sumpland on the northern part of Lots 21 and 22 and the other was a basinal wetland running in a southwest to northeast direction on Lots 18, 19 and 20 in areas less than 21m AHD. However, since the construction of the Local Authority drain with an invert some 0.9m below the (previous) maximum groundwater level, the hydrology of the site has changed significantly. This drain has resulted in decreased groundwater levels and thus a reduction in the size of the original wetland areas. As a consequence of both the lower groundwater, and land use in the area which has included clearing and grazing, the vegetation has become altered. The wetland flora is mostly in decline in former wetland areas, with a succession towards upland flora in those areas which have remained largely undisturbed.

Bioscience proposes a new wetland boundary which is determined by the area where groundwater inundates near the surface at least one year in ten. The area so defined, as assessed by Bulletin 686 is classified as a Multiple Use Wetland. Fringing bushland outside the wetland, particularly to the north west has not been as profoundly disturbed by land use and is in very good condition with high conservation value. Bioscience has advised the Department of Housing that urban development of the area should preserve this good bushland as a corridor with the wetland area which would serve a drainage function.

a gr nd

The Department of Housing (DoH) in collaboration with two private land owns intend to develop seven adjoining lots of land, collectively 21.42 hecatres, in Southern River towards urban subdivision. To this end, DoH engaged Unbanplan to prepare a revised structure plan for submission to the City of Gosnells. In undertaking desk top reviews of previous environmental assessments and from his own field work, the principal of Urbanplan, Ian Brashaw, formed the view that the location and extent of wetlands on the existing City of Gosnells Structure Plan were not in accord with his direct observations. Consequently, Urbanplan asked Bioscience to visit the site and to recommend what work was needed to more accurately define wetland areas.

A scope of work was presented and accepted by Urbanplan and the Department of Housing. This involved undertaking sufficient field work to provide an initial appraisal to determine the merit or otherwise of a more detailed study. Based on the findings of this work, Bioscience advised that much of the area marked as either resource enhancement or multiple use wetlands were in fact not wetlands at all. The Department of Housing commissioned Bioscience to undertake a detailed investigation to provide adequate technical information and data to prepare a formal request to the Department of Environment according to the “Protocol for Proposing Modifications to the Geomorphic Wetlands Swan Coastal Plain dataset” (2007). This request, contained in this report, seeks to substantially reduce the extent of wetlands and to revise their management category.

Site es ri ti n

Lots, 13, 14, 21 and 22 Southern River Road and Lots 18, 19 and 20 Matison Street are located approximately 20km south southeast of Perth CBD, within the City of Gosnells (Figure 1). The subject site is located on Swan Coastal Plain within the Bassendean dune system, which is an area characterised by low dunes of siliceous sand interspersed with poorly drained areas or wetlands. Two soil types occur within the site (Figure 2):

- Bassendean B1 Phase which are described as extremely low to very low relief dunes, undulating sand plains and discrete sand rises with deep bleached grey sands sometimes with a pale yellow B horizon or a weak iron-organic hardpan at depths generally greater than 2 m.
- Pinjarra P1b Phase which are described as being flat to very gently undulating plain with deep acidic mottled yellow duplex soils. Moderately deep pale sand to loamy sand over clay: imperfectly drained and moderately susceptible to salinity in limited areas.

Generally the area has a low relief with minor variations in topography. The site has a gentle slope from the centre of lots 13 and 14 at approximately 23m AHD towards the northern areas of lots 22 and 21 in addition to the central areas of lots 18, 19, and 20 down to approximately 20m AHD (Figure 3). Current geomorphic wetlands mapping indicates two wetlands are located within the site; the first is a multiple use wetland (UFI 15288) and the other is a resource enhancement wetland (UFI 13963) (Figure 4).

According to the Perth Groundwater Atlas (2004), groundwater flows in a north easterly direction towards Southern River and minimum groundwater levels tend to be around 19m AHD (May 2003 data) and are thus 2 – 4 m below the surface (Figure 4). Two local authority drains has been constructed, one along the north eastern boundaries of lots 20 and 22 and the other along the south western boundary of lot 18. Both direct water to the nearby Forrestdale main drain, thence Southern River. The site is currently subject to the Southern River Interim Integrated Land and Water Management Plan 2007.

In the past the land was used for agriculture purposes with some of the land cleared and fenced for grazing. More recently, land use has been for rural living with some evidence of minor home industry use. With the exception of lots 18 and 20, dwellings have been demolished and the land is currently vacant and unused.

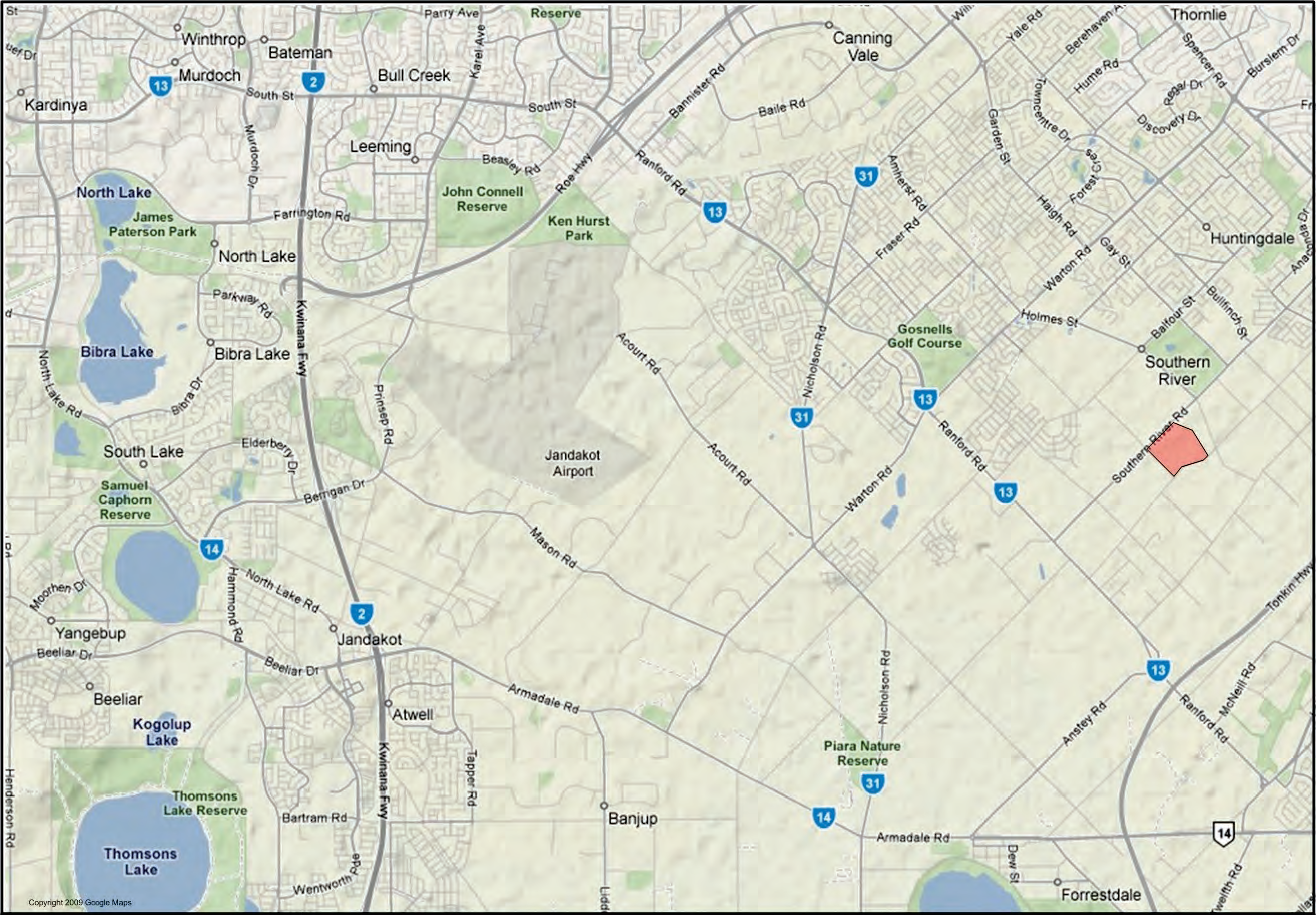

Figure 1 - Site Location of Lots 13, 14, 21 and 22 Southern River Road and Lots 18, 19 and 20 Matison Street

Legend

Site Location

Figure 2 – Soil Types Mapped by the DoA.

Legend

Pinjarra P1b Phase

Bassendean B1 Phase

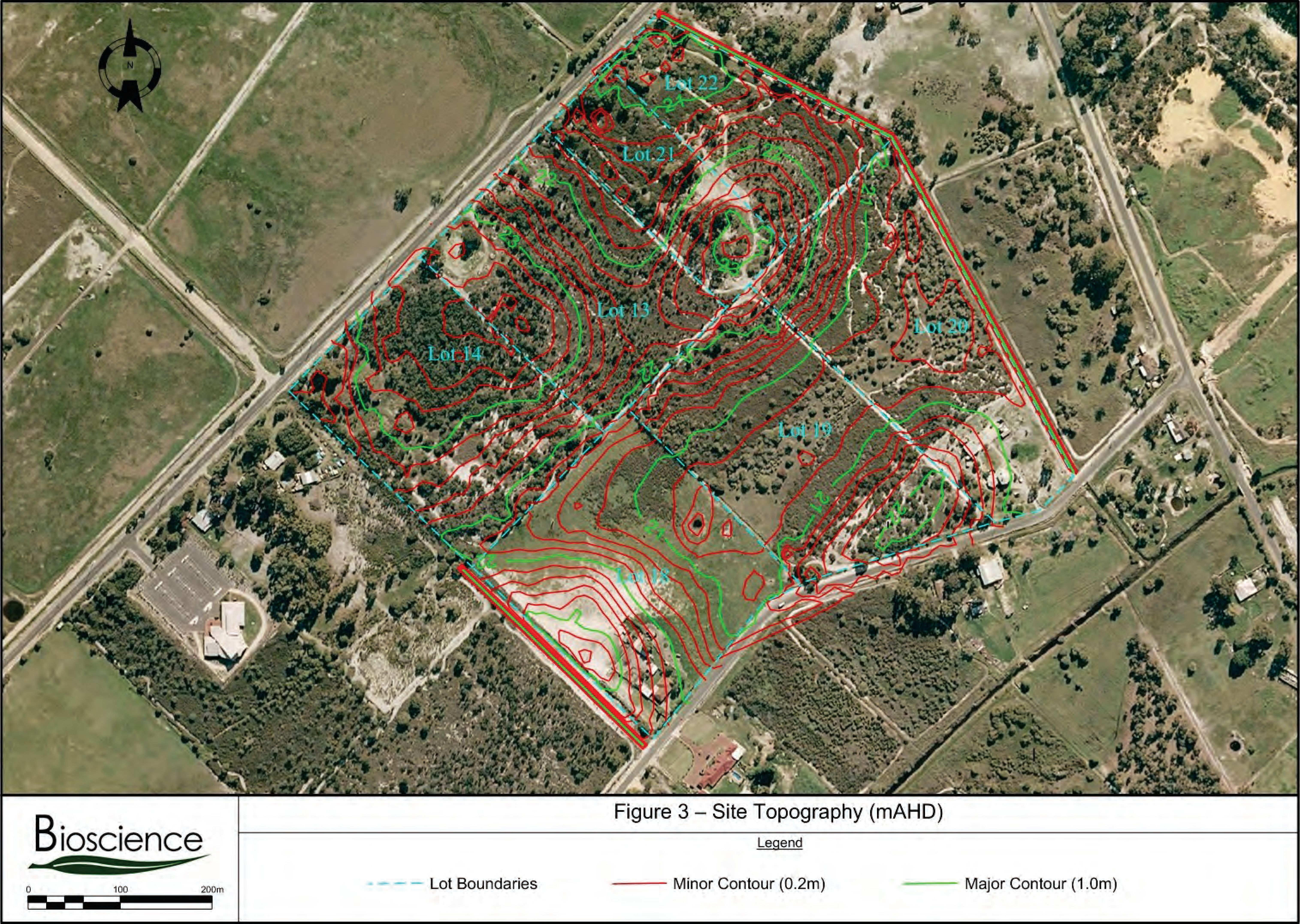

Figure 3 – Site Topography (mAHD)

Figure 4 – Current DEC Wetlands and Department of Water Regional Groundwater Data

Note: Data from the online Perth Groundwater Atlas, accessed at www. water.wa.gov.au

etlands

Wetlands are defined as areas where the soil becomes inundated or waterlogged, either permanently or seasonally, with fresh or saline water. Where natural soils become waterlogged, their chemistry changes, due mainly to soil microbes and plant roots removing oxygen at a rate greater than it can be replenished from the atmosphere. The altered chemistry is manifest as decreasing redox potential, the gradual accumulation of organic carbon, and depending on soil mineralogy, the potential accumulation of reduced iron and sulfur. Such soils are not conducive to the growth of many plants, so a selection occurs for those plant species which have special adaptive mechanisms to cope with anaerobic soil. As such, wetlands develop a characteristic vegetation community.

Driven by the recognition of the importance of wetlands in the Swan Coastal Plain ecosystem, and the fact that European settlement had caused a rapid loss of wetlands, studies were initiated in the late 1980's to 1990's to map wetlands in the Perth area, and to assign management categories in order for them to be protected from future decline.

Initially five management categories were assigned, but later this was condensed into three categories:

- **Conservation Category Wetlands (CCWs)** have high conservation significance where the wetland functions, values and attributes are to be protected by preventing activities which may cause their decline. The surrounding land is likewise protected in order to provide a buffer against threats to the wetland function and attributes. The management objective is to preserve and protect all the ecological, hydrological and social functions.
- **Resource Enhancement Wetlands (REWs)** are those which retain functions, values and attributes which, although somewhat compromised and degraded, have conservation significance and are still worthy of preservation. The management objective is to restore the values and attributes of such areas towards those of Conservation category Wetlands.
- **Multiple Use Wetlands (MUWs)** are areas where wetland functions, values and attributes have been seriously degraded such that they no longer serve any substantial ecological role. They are typically cleared of native vegetation and do not support wetland fauna. The management objective is to preserved hydrological functions, but otherwise they can be developed for more beneficial use.

The definition, location and management category of wetlands was originally determined and published in 1996 in Hill *et al*, Wetlands of the Swan Coastal Plain Volumes 2a and 2b (1996). Since that time, maps have been converted to digital format as the Swan Coastal Plain Wetlands Geomorphic Dataset which is administered by the Wetlands Office of the Department of Environment and Conservation.

It was recognised in 1996 that groundwater levels change over the longer term, so new wetlands can form and old wetland can dry, thus losing their wetland characteristics. It was also recognised that some of the original wetland mapping was done on a broad scale, and may prove in time to have the boundaries imprecisely mapped or the management categories inappropriate. Protocols have thus been progressively developed by the DEC wetland office whereby application can be made to have the wetland geomorphic dataset modified by boundary changes or management categories moved upward or downward in the light of new and more detailed data.

4.1. Wetland Criteria

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The fundamental basis for defining a wetland is that it is wet. Definitions are somewhat varied, but the key feature is groundwater levels are either above the surface level, as in lakes, or at or very near the surface such that the surface soil is waterlogged or saturated. Given that about 80% of plant roots occupy the top 30 cm of soil and over 95% occupy in the top 65 cm of soil, it is when groundwater approaches this biotic zone near the surface that impacts producing wetland conditions occur.

On the Swan Coastal Plain there is a seasonal variation in groundwater levels between summer and winter, typically in the order of 1 to 1.5 m. Over the longer term, the annual maximum and minimum groundwater levels can move upward or downward. As such there are many wetlands which may only be waterlogged or inundated for a part of the year, whereas there are also permanent lakes. Some wetlands may only be inundated rarely.

The determination of depth to groundwater is conveniently and accurately measured by using piezometers or groundwater monitoring bores. Because of seasonal variation, a single recording will only provide limited information, thus ongoing measurement is required. In the Perth area, the Department of Water maintains and routinely monitors a large number of bores in the superficial and deeper aquifers. Data from such bores provides a better long term picture of the annual variation in levels, and the pattern of longer term trends.

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When soil is waterlogged, oxygen becomes rapidly depleted. This leads to altered chemical conditions. Whereas moist aerated soil promotes oxidative reactions (acid conditions i.e. rusting), waterlogged soils provide reductive conditions (alkaline conditions i.e. the deposition of metals from metal salts). The oxidation/reduction potential of soil is rapidly and conveniently measured using a redox meter.

Reducing conditions limit the oxidative breakdown of organic matter produced by plants, so water logged soils typically become blacker and peaty with the progressive accumulation of organic carbon. Other chemical reactions, such as the reduction of organic sulfate to sulfide, and the deposition of iron minerals like jarosite and pyrite can also occur resulting in acid sulfate conditions.

Hydritic soils can thus be quantitatively measured by their redox potential and by measuring carbon and sulfur. It is important to note however that the soil parent material will also influence the chemical changes associated with waterlogged conditions. In particular, the acidic quartz sands of the Bassendean formation tend to be less reactive to hydritic conditions than more alkaline soils and soils containing significant clay fractions. The latter tend to become mottled with blue/green layers forming under anaerobic conditions. This is because of the relatively larger surface area to mass ratio of clay soils, and the generally more chemically reactive surface of clay compared to quartz.

A further quantitative measurement of hydritic conditions is the same parameters used to measure acid sulfate soils. This includes the SPOCAS suite (Suspension Peroxide Oxidation Combines Acidity and Sulfate) which provides a comprehensive test, not only of hydritic conditions, but of the post-Holocene geochemical conditions which gave rise to those conditions.

Finally, where soils remain inundated for extended periods, combinations of biological and physico-chemical phenomena lead to the accumulation of characteristic sediments. These can be composed of the remains of aquatic plants and organisms, mineral precipitates or clays and silts washed into the lake or waterbody by flood events. Sediments provide a preserved history of wetlands and the geophysical conditions they have experienced.

etland egetati n

Many native plants can not tolerate waterlogged soils for long, thus even though they may germinate, they do not establish in the longer term in wetlands. Other plants have developed special adaptations to deal with waterlogging. Most typically, this involves the development of parenchyma, which are tubes within roots which allow air from the surface to reach deep underground. However such adaptations only allow plants to survive for a certain amount of time. Wetlands with permanently inundated lakes do not have substantial trees or shrubs growing within the permanent lakes. Lake develop aquatic plants which have completely different means of extracting nutrients from the environment, and do not form hard, lignotuberous structures, thus do not contribute to the creation of humus.

There are surprisingly few plants which only ever grow in temporarily inundated habitats. These include the bulrush *Typha*, the *Hydrocotyle* pennyworts and the swamp paperbark, *Melaleuca raphiophylla*. There are many more plants which are not found in wetlands at all as they are quite intolerant of anaerobic soil. These include many, but not all Banksias, and many but not all of the tall eucalypts. In the Perth area, such inundation-intolerant species tend to be restricted to the higher sandy ridges of the Swan Coastal Plain and to the Darling Scarp.

There are many plants which can survive temporary inundation, and generally need prolonged moist conditions to germinate and grow. These are considered as wetland indicator species. However; almost all can grow outside wetlands, however are most commonly found in areas where the water table varies from between 0.5 and 2 m below the soil surface. Such areas are not wetlands according to the hydrological definition of a wetland adopted by WA regulations or that described by Tiner. The WA Herbarium describes the habitat of such species not at wetlands, but as “winter wet depressions”. Accordingly, wetland plants can be a useful indicator of wetlands, but as they are not obliged to live in waterlogged soil, they are not a reliable criterion for identifying wetlands. A far more useful indicator of a wetland is the absence of upland species (i.e. Banksia/Eucalypt) from a wetland area, as their biological limitation prevents their survival in waterlogged/inundated areas.

Some of the more common plants on the Swan Coastal Plain which fit the category of wetland indicators are the Moonah paperbark *Melaleuca priessiana*, teatrees such as *Astartea affinis*, and *Pericallyma ellipticum* and many of the monocot sedges such as *Lepidospernum, Schoenus* and *Baumea.*

From a vegetation unit point of view, the distinguishing feature which separates wetland from non-wetland vegetation communities is that wetlands have lower species diversity. This is because, whereas many plants capable of living in wetlands can also do well outside of wetlands, many more species can not grow in wetlands. In the floristic survey of the Swan Coastal Plain by Gibson et al (1994), the species richness (a measure of the average number of species in a 10 m x 10 m quadrat) was found to be significantly lower in wetlands than in non-wetland areas (typically 14 – 25 species in wetlands versus 40 – 60 in non-wetland habitats). However, wetland conditions are not the only factor causing flora biodiversity loss. Anthropogenic disturbance is a key factor in vegetation condition decline, so low diversity of itself is not an indicator of wetland conditions.

4.2. Application of Criteria

Notwithstanding that the three broad criteria of wetlands are generally accepted worldwide as defining wetlands, for defining a wetland boundary the application of any individual of the three criteria is not necessarily precise or definitive. In Western Australia, threshold values have not been set and the judgement is historically somewhat more subjective.

The distance from the surface to groundwater is clearly relevant, however an objective (i.e. measurable) threshold distance is not defined in any WA policy or guidance documents other than those referring to the situation in the United States by Tiner (1999).

In the USA, a wetland is defined for regulatory purposes as "7 days of inundation or 14 days of saturation within 1 ft of the soil surface or more during the growing season in most years." Figure 2.3 of Tiner (1999) illustrates the hydrological regime across the year in 6 different wetland types, and in each of these, the water table is at or above ground level for a part of the time (Figure 5). Importantly, a distinction is draw between finer soils which promote a greater capillary rise, and coarse soils which have little capillary rise of water. It is noteworthy that Bassendean sands present on the site are considered coarse to medium texture sands (according to geotechnical standards), thus have a fairly small capillary rise of about 100 mm.

There is graphical guidance in Chapter 2 of Volume 2a of Hill *et al* (1996) which suggests a wetland boundary is where capillary water rises to the surface during the most extreme seasonal groundwater rise.

Hydritic soils and sediments can unequivocally define the location and depositional history of the parts of wetlands with history of substantial inundation, but they are not useful for defining the boundary of temporary wetlands. The mineralogy of hydritic soils and sediments stretches back into geological timescales, whereas for practical delineation we can only consider the late Holocene era at most. It is also noteworthy that Tiner describes four soil types which, although inundated, may not experience reducing conditions. Of these, the only one relevant to Western Australia's Swan Coastal Plain are soils with little or no organic matter and moderate to high amounts of calcium carbonate. Such soils exist in the Quindalup formations closer to the coast than Southern River.

Using vegetation as a wetland criteria is problematic, not only because the tolerance of individual native species to inundation is outside the bailiwick of classic botany, but as with any phenotypic trait, there is likely to be wide differences between individuals within the same population. The presence or absence of an individual plant can not define a wetland boundary, however the boundary of a vegetation unit can provide a more reliable, though diffuse indicator.

To define wetland boundaries, frequently the application of all wetland criteria can at best only provide a diffuse area, rather than a precise line as in a cadastre. In a practical sense, and for wetland management purposes, it is thus not surprising that cadastral boundaries tend to be adopted, particularly in defining or demarking the management category of wetlands.

Figure 5 - Hydroperiods of various wetlands as per Figure 2.3 of Tiner *et al* 1999.

n estigati ns nderta en

To address the specific ground conditions on the subject land as the basis for ground truthing the wetland classification, a range of desk top studies were undertaken before field investigations began.

5.1. Desktop Study

Previous wetland mapping was examined in detail. Prior to 1993, the site was classified as a MUW via the application of Bulletin 374. As a result of the research conducted as part of the 1993 wetland vegetation assessment project, areas of this MUW were sub-classified by remnant vegetation. Consequently, as of Hill *et al* (1996) two wetlands were marked within the site, a MUW (i.e. No. 155, aka WIN No. 40204644804) and a CCW (i.e. No155-V5, aka 40207644742) (Figure 6).

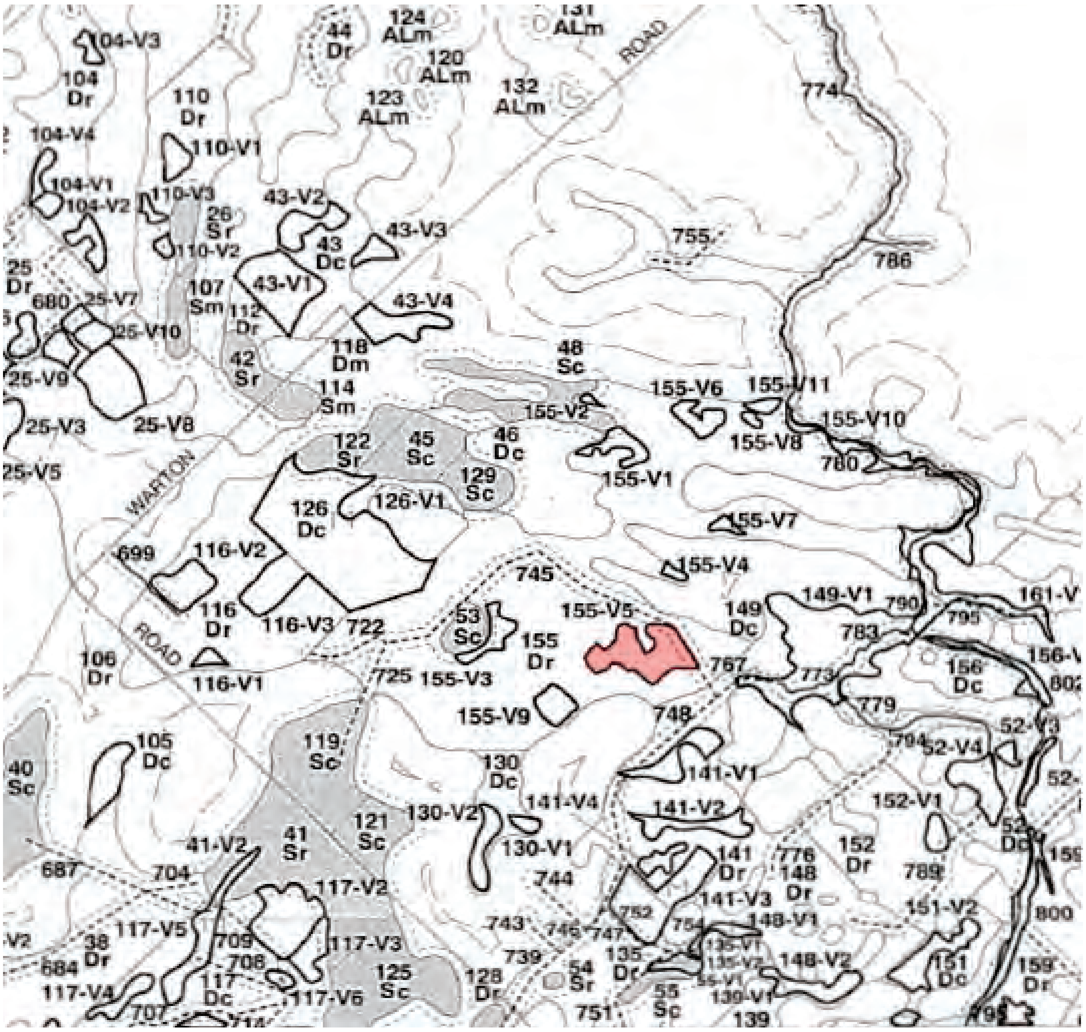

Figure 6 – Wetland classification and boundary as per Hill *et al* (1996)

A more recent search on the Shared Land Information Platform (SLIP) database indicated that currently two wetlands are on the site, with the same boundaries as per Hill *et al* (1996), however in Hill *et al* (1996) the wetlands are described as being a MUW and CCW, whereas the SLIP portal records them as being MUW and a RHW (UFI number 15288 and 13963, respectively) (Figure 4 and 6).

A search of Aboriginal Heritage Sites indicated that no relevant sites are present with Lots 13, 14, 21, and 22 Southern River Road or lots 18, 19 and 20 Matison Street.

It is also noteworthy that detailed hydrological investigations have been undertaken in the surrounding area as a part of the development of generic local planning processes. The detailed work by Jim Davies and Associates (JDA 2002) formed a core of the Department of Waters progressive development of Urban Water Management Strategies.

Although a number of environmental investigations (e.g. ENV Australia 2006) and vegetation studies (Trudgen *et al*) have been undertaken for the City of Gosnells, none to date have specifically addressed the issues of wetland boundaries and classification for the site.

5.2. Bulletin 686

As required in “Protocol for Proposing Modifications to the Geomorphic Wetlands Swan Coastal Plain dataset” (2007) a site investigation as per EPA Bulletin 686 (1993) was conducted to determine the conservation status of the site. Bioscience maintains that the site, in contra to current mapping, only two wetland like areas exists within the site, however due to clear differences in vegetation, one has been slit into two for the Bulletin 686 investigation purposes.

A total of 3 Bulletin 686 investigations were undertaken on the site (Appendix 1). Investigation 1A was undertaken in the centre of Lot 19, where vegetation has previously been cleared. The collective scores for Part IIB and Part III of this area were 7 and 5, respectively. 1B was undertaken immediately north of 1A, and scored 11 and 5 for Part IIB and Part III, respectively. Area 2 was located to the north of Lot 22, and scored 7 and 3 for Part IIB and Part III, respectively.

As per appendix 2 of the Bulletin 686, the scores were plotted on the X and Y axis, the intersection of the axes indicated that as per our investigation the classification of all tree sites are consistent with each being a multiple use wetland. Area 1B was within a “transitional zone” however the supplementary questions moved it into the MUW category.

5.3. Hydrology

Initially five piezometers were installed on the 31st October 2008 to traverse an area which demonstrated clear geomorphic, vegetation and surface soil evidence of being a wetland. These were placed to form an east-west, and a north-south transect. On the 9th April 2009 ten additional piezometers were then installed outside this core area. The proposed locations were firstly conveyed to the DEC's wetland office, and after discussions and their recommendations, the locations were modified where necessary to capture the most useful data. In July 2009, another ten more piezometers were installed, four on lot 18 and 6 on lot 20. The alignment of piezometers allows for transects with four or five pipes through any selected alignments crossing the wetland area.

All piezometers were installed using a hand auger and were made from 50 mm PVC pipe with 1m of slotted interval buried to at least 0.5 m below the water table in March, when the water table was expected to be at or near the minimum level. The initial five piezometers installed in October were deepened where necessary. After installation and development, water was collected (if present) from each piezometer for chemical analyses, and monthly measurement of depth from the surface was commenced.

Seven (i.e. DHW2, 4, 5, 6, 9, 14, and 15) of the piezometers did not intersect the March groundwater level due to an impenetrable layer formed by the indurated ferruginous deposit or "coffee rock" layer. Given such deposits typically only occur below the maximum water table, it is likely that as water levels rise, these piezometers will fill with water.

The site was surveyed by licensed surveyors who recorded the location and height of each piezometer to 1 mm, and who produced a surface contour map to 100 mm lines. The data from the surveying instruments was directly imported into CAD and GIS systems and into the hydrological modelling suite HydrogeoAnalyst v4.1.

Data was recovered from WIN databases of the four closest regional groundwater monitoring bores to the site. Previous hydrological studies (JDA) were also obtained and consulted.

5.4. Hydritic and Acid Sulfate Soils

During the installation of piezometers, soil was recovered and initially placed into core trays for stratigraphic recording, photography and sub sampling. Samples were placed into sealed plastic bags and conveyed to the laboratory for chemical analyses and microscopic inspection.

The chemical parameters measured as indicators of hydritic conditions were:

- redox potential (using a platinum redox probe with a Ag/AgCl reference and freshly calibrated using Zobell's solution)
- Total Carbon and Sulfur content (using LECO LC200 induction furnace)
- SPOCAS suite (forward and reverse titration to determine actual and total acidity, and the cationic species responsible).

Collected soil was also examined microscopically for evidence of sediments, particularly referring to the prior work on sedimentology of wetlands in the immediate area by Seminiuk and Seminiuk (2004, 2005, 2006).

5.5. Wetland Vegetation

The above lots were reviewed by ENV Australia in 2006 as part of a site assessment report commissioned by the City of Gosnells to assist with the planning of the area. Bioscience was commissioned by Urbanplan Pty Ltd, acting for the Department of Housing and Works who have acquired this land, to undertake a review of the current state of vegetation and wetlands.

Vegetation mapping was undertaken by Bioscience on 2 November 2008. The work involved reviewing previous studies, aerial photography and satellite imagery prior to visiting the site and undertaking transects through the entire area by walking parallel lines approximately 20 m apart. This work was done by a botanist and an environmental scientist with collectively over 30 years experience in dealing with the flora of the Swan Coastal Plain.

DEC's Protocol for requesting changes to wetlands calls for a "vegetation survey in accordance with EPA Guidance Statement number 51 *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* at the level of 'detailed survey'."

A detailed flora and vegetation survey has not been undertaken in this submission. The reasons include the fact that such detailed work must be undertaken across the rain and flowering season (winter and spring on the Swan Coastal Plain), and the guidance itself details the extent and level of survey required according to the potential for impacts, and may be reviewed upon the results of preliminary findings.

Given that a modification of the wetland geomorphic dataset is not itself an environmental impact, and that there is clear evidence of substantial prior disturbance of vegetation through clearing, fencing, grazing, and the introduction of weeds and rubbish, a decision was made to undertake vegetation work at what Guidance 51 describes as a level 1 survey. This involved vegetation unit mapping throughout the area, and vegetation condition reporting.

5.6. Site Photography

Several photographs were taken across the site on three site visits (09/04/09, 21/05/09 and 27/07/09) to provide visual justification for this proposal as required by DEC guidance. (Photographs 1 to 28). Several photographs were taken in series and photo-merged to give a panoramic view of the area, as a result the perspective of some of these images may be distorted. Photograph location and the field of view are provided in Figure 15; in addition the original photographs (at 10 megapixel resolution)and high quality panoramic are all located on the CD attached to this document.

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6.1. Hydrology

Groundwater is a fundamental determinant of wetlands. The hydrology of the Southern River area on a broad scale is characterised by flat land of Bassendean sand dunes with quite low relief hosting a superficial aquifer which is about 30 m thick. The Southern River itself acts as a local discharge point for this superficial aquifer and is thus the lowest local groundwater level. The Perth Groundwater Atlas (2004) shows the groundwater contours slope downwards in a north easterly direction parallel with the local alignment of the Southern River. The groundwater atlas suggests that groundwater is between 3 – 4 m below the surface across the site, based on May 2003 data when local groundwater would be approaching annual minimum levels (Figure 4).

M nit ring re Anal sis

The long term variation between minimum and maximum groundwater levels can be inferred from four Department of Water monitoring bores which are located approximately 1.2 km north (4880), 1.6km south (bore 4879), 2.1km north west (bore 4786) and 2.9km west (bore 4846) of the site. These bores were installed as part of the Lake Thompson project, or the Jandakot and lakes and wetlands monitoring projects and have been monitored constantly for about 30 years. Hydrographs are reproduced in Figures 7a, 7b, 7c and 7d. They show very similar seasonal trends in terms of the extent and timing of annual variation, with an average difference between minima and maxima of between 1.75 and 1.13m (4880 = 1.35m, 4879 = 1.75m, 4786 = 1.13m and 4846 = 1.13m). Minima occur mostly in May and maxima recorded mostly in October, with the minor variation accounted for by difference in season.

Unlike many other bores in the Perth area, these show no significant long term trend to water level decline. This is unsurprising as they are not near any public drinking water abstraction zones, and there is little commercial irrigation in the vicinity.

The 1.75m and 1.35m difference between maxima and minima in the north and south bores is somewhat greater than the typical 1 m variation in Bassendean sand-hosted superficial aquifers as reported by Davidson (1995). Such variation can be due to either different soil types, for example clay rather than sand, or due to different hydrological gradients. The soils encountered during piezometer installation, with few exceptions, were medium textured Bassendean sand (see later and Appendix 1). This suggests the area has the same hydraulic conductivity as elsewhere. The DoW data bores thus recharge and discharge more extensively that other areas, reflecting their nearly equal proximity to local discharge points with 4880 near Southern River and 4879 near the Forrestdale Main Drain.

The site itself has two local authority discharge drains, one along the north eastern boundaries of lots 22 and 20 and the other on the south western boundary of lot 18. The invert of this drain was determined by survey, and is considerably higher than either the Forrestdale drain or the Southern River inverts, thus would be expected to have a lesser impact on the seasonal groundwater range compared to the records from DoW bores 4880 and 4879 (as the relative hydraulic gradient is less) but may be slightly more than bore 4846 and 4786. On balance, we conclude the seasonal groundwater range on the site is likely to be 1.4 m for most years. Ongoing monitoring will progressively eliminate the uncertainty of this estimate.

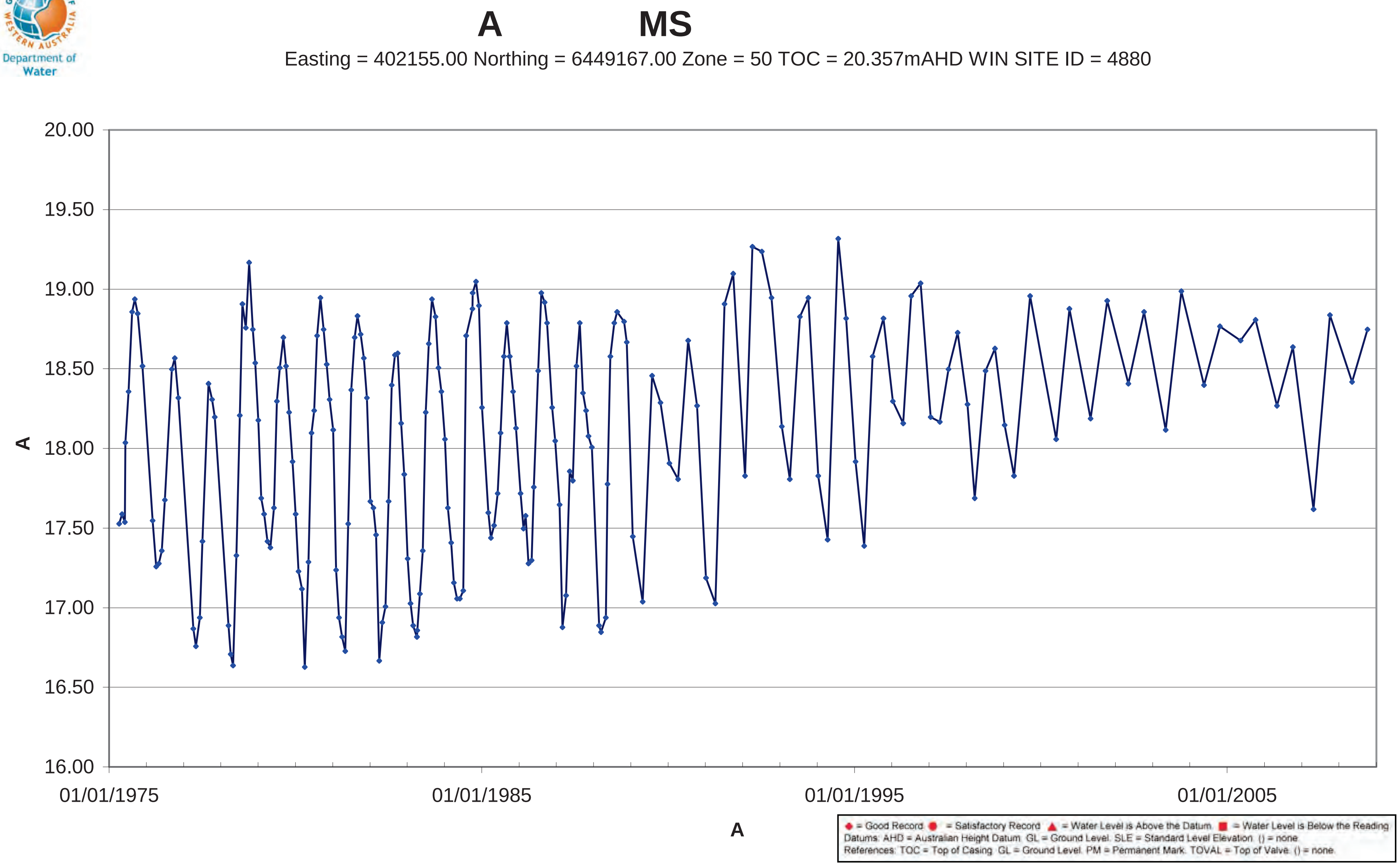


Figure 7a - Hydrograph of Bore 4880 located 1.2 km due north of the site.

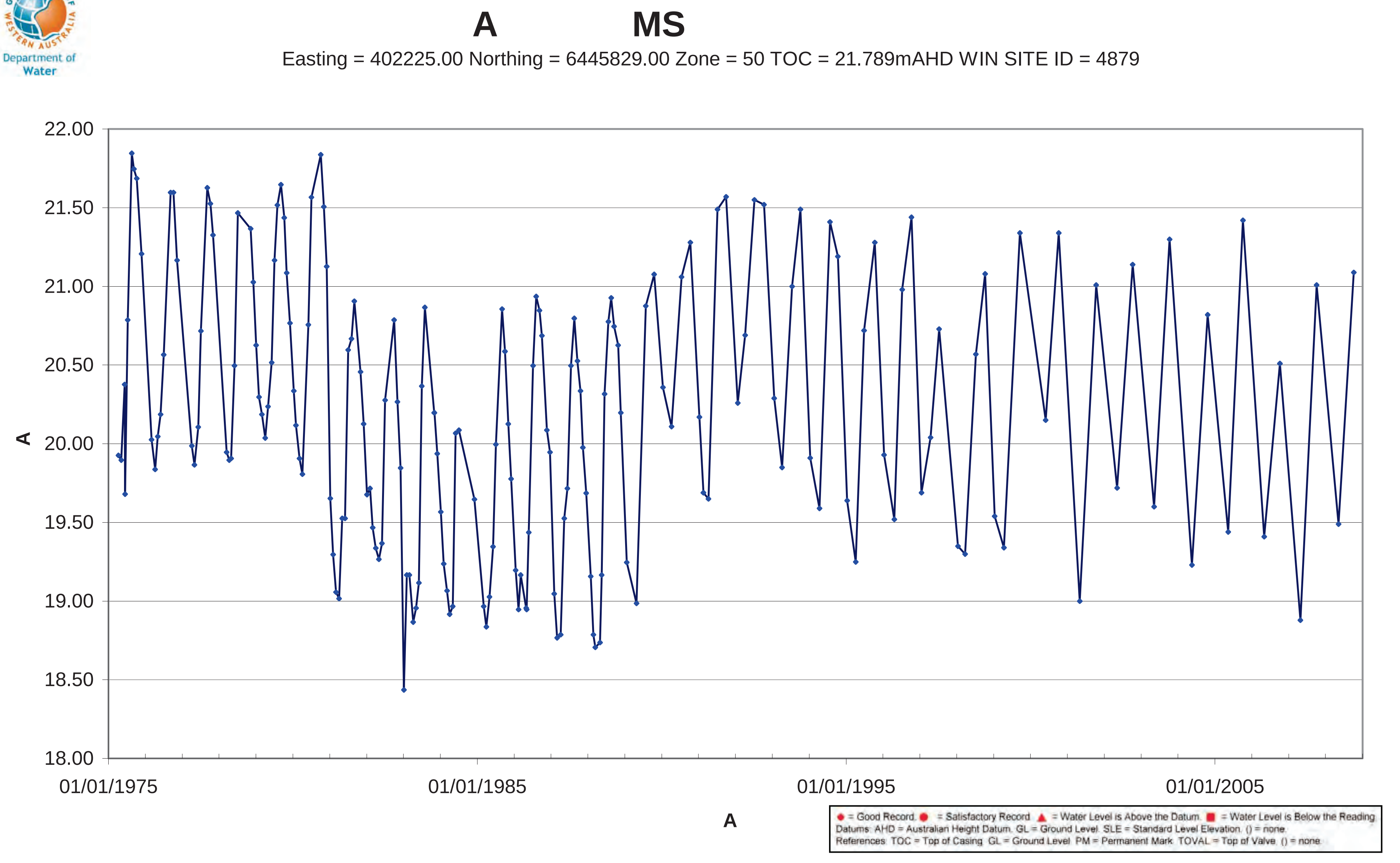


Figure 7b - Hydrograph of bore 4879 located 1.6 km due south of the site.

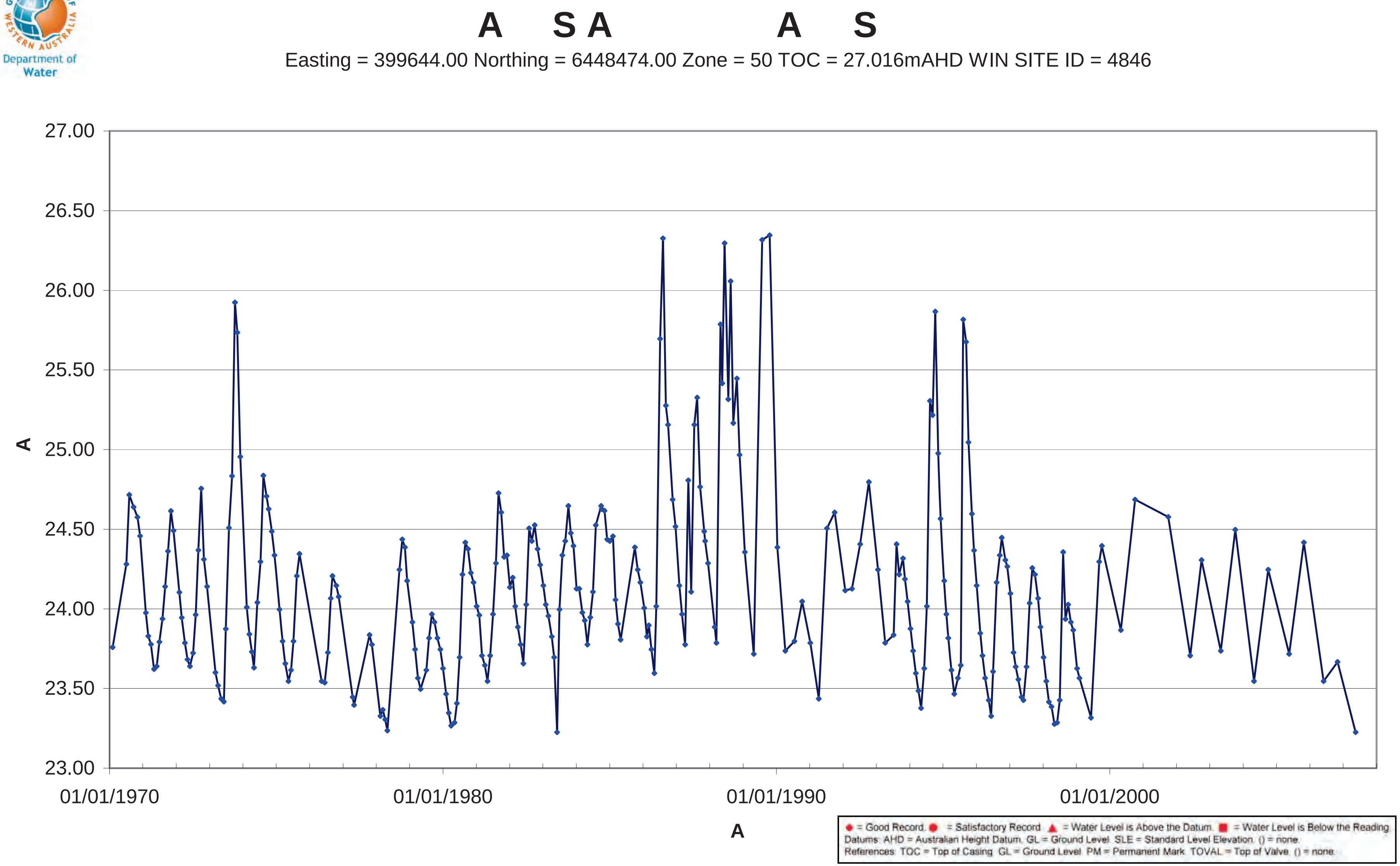


Figure 7c - Hydrograph of bore 4864 located 2.1 km due west of the site.

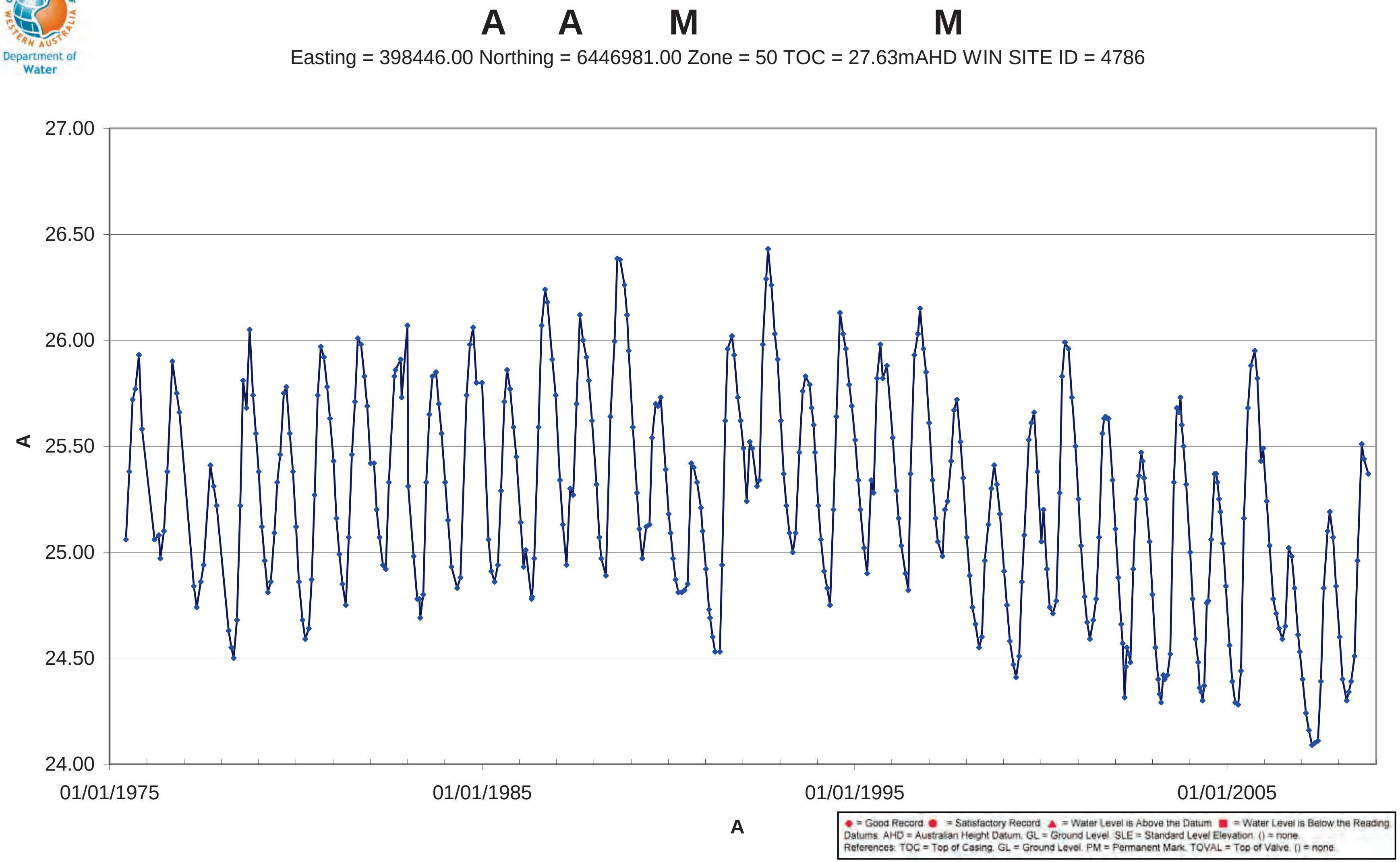


Figure 7d - Hydrograph of bore 4786 located 2.9 km northwest of the site.

r nd ater M delling

Water levels have been measured since the 30th October 2008, and most currently on the 7th July 2009. Details of the groundwater levels in meters AHD are contained in the piezometer logs in Appendix 3.

Despite insufficient data to accurately determine the yearly maximum groundwater level (i.e. as August and/or September measurements have not yet been collected), by referencing 30 years of nearby DoW monitoring bores records, and considering the fairly average rainfall year and timing in 2008, we can infer at the time recordings were made (30th October), groundwater levels would have been declining and be in the order of 0.25 – 0.5 m below maximum groundwater levels. Consequently, this estimation allowed the raw data from the DoW bores to be extensively interrogated and modelled.

This work included correlating groundwater levels and change rates with Bureau of Meteorology rainfall records, and projecting the maximum groundwater levels possible in extreme rainfall events and rainfall years. Trend analyses details are contained in Appendix 4 and 5, but in summary, groundwater levels have remained quite constant since records commenced, and annual/monthly maximum very closely follows the annual/monthly rainfall, thereby enabling confident projections of Annual Average Maximum Groundwater Levels (AAMGL) which is estimated to be 20.47mADH, in addition to estimating extreme groundwater levels such as a 1 in 10 and 1 in 100 year events (Figures 8, 9 and 10).

This estimate is in accord with work by JDA undertaken on the broader scale of the entire Southern River area.

A3 Figure 8 - AAMGL

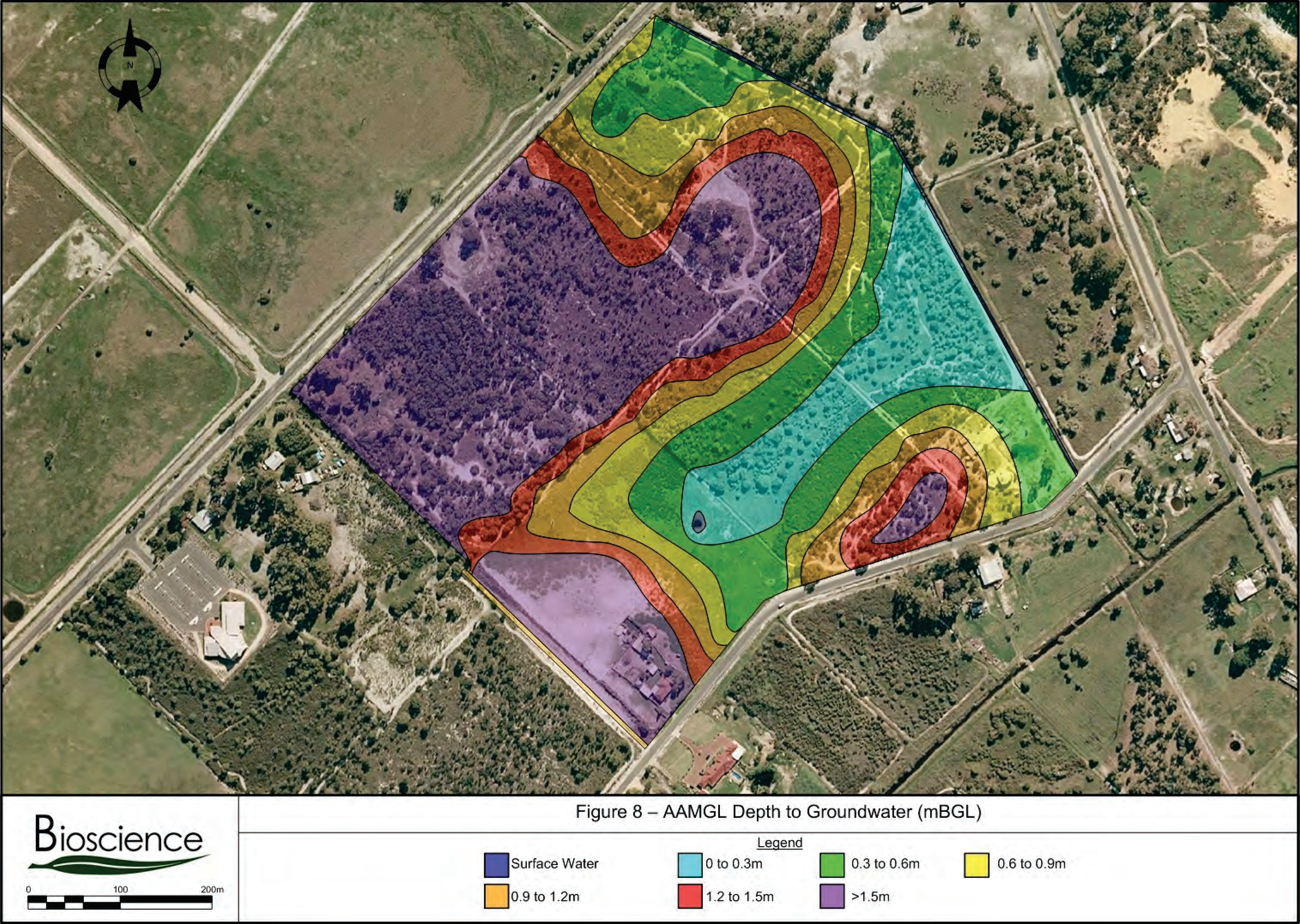


Figure 8 – AAMGL Depth to Groundwater (mBGL)

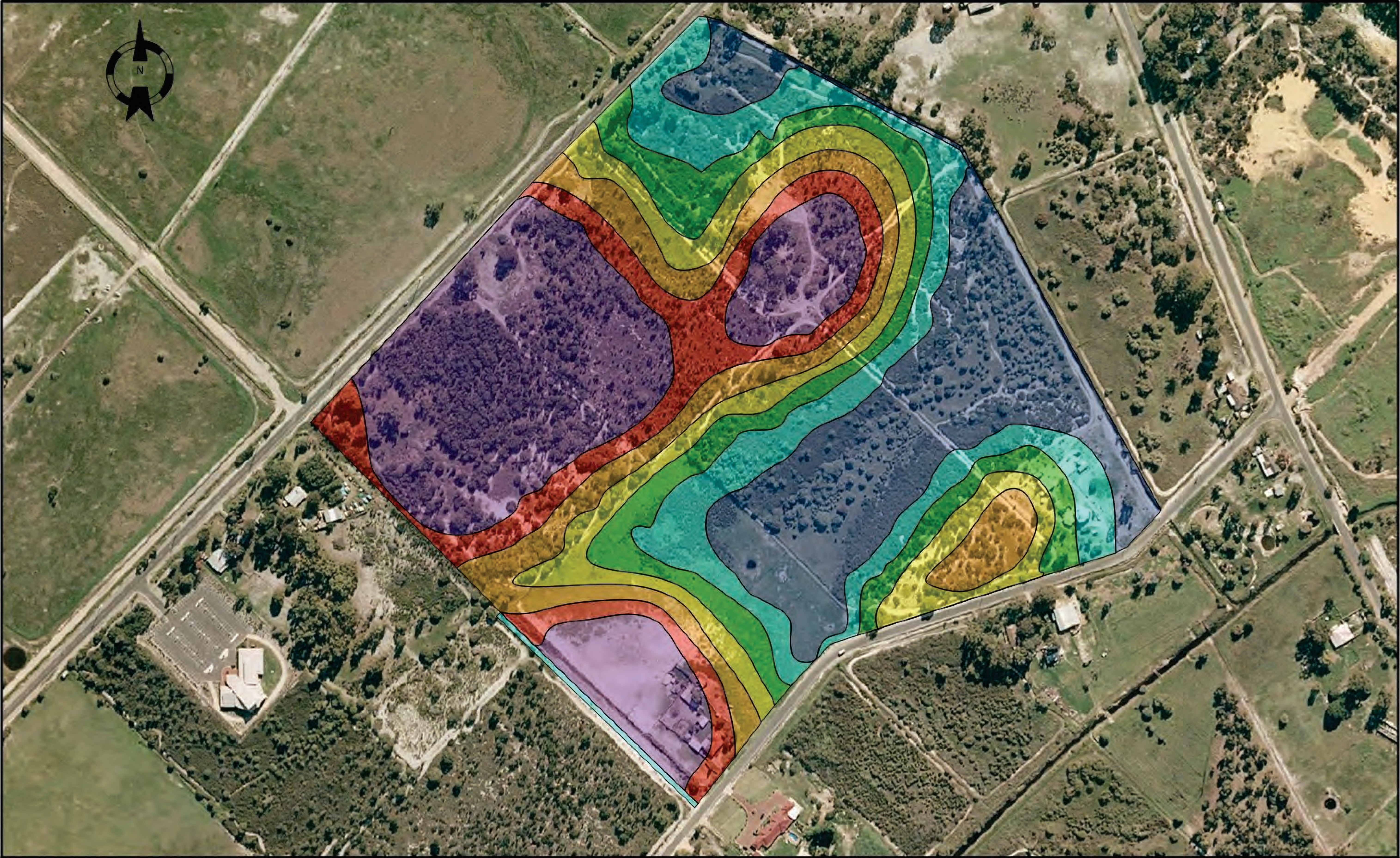
Bioscience

0 100 200m

Figure 9 – Depth to Groundwater in a 1 in 10 Year Maximum Groundwater Event (mBGL)

Legend

Surface Water
0 to 0.3m
0.3 to 0.6m
0.6 to 0.9m
0.9 to 1.2m
1.2 to 1.5m
>1.5m



Bioscience

0 100 200m

Figure 10 – Depth to Groundwater in a 1 in 100 Year Maximum Groundwater Event (mBGL)

Legend

Surface Water
0 to 0.3m
0.3 to 0.6m
0.6 to 0.9m
0.9 to 1.2m
1.2 to 1.5m
>1.5m

Arti i ial rainage

A Local Authority drain was dug along the south western boundary of lot 18 in the Landor St road reserve; however oddly it has not been constructed below AAMGL (i.e. 20.47m AHD) and it hasn't been maintained, thus currently it has a maximum depth of 21.07m AHD. Consequently, the actual effect of this drain is somewhat questionable; however Bioscience suspects it may still carry water but only during extreme rainfall events.

Directly north east of lots 20 and 22 is another Local Authority drain with an approximate depth of 19.6m ADH (Photograph 21 and 28). The purpose of this drain is to remove surface water from the surrounding area and direct it towards the Forrestdale drain, where it is redirected into the Southern River. A recent Urban Water Management Strategy report from the Southern River / Forrestdale / Brookdale / Wungong, Structure Plan titled "Impact of Existing Drains and Proposed Living Streams on Groundwater Table and Nutrient Export" (JDA, 2002) specifies the drawdown influence of drains of varying depths within this region. Their results can be used to estimate desirable drains depth and distances from significant environmental features such as CCWs to provide protection from groundwater lowering (Table 1). Consequently, it can be used in the reverse manner to deduce the impact a drain has on a wetland given its invert below AAMGL and distance are known.

Table 1 – Impact of Drain Invert on AAMGL Drawdown (JDA, 2002).

Drain Invert below AAMGL (m)	Drawdown of AAMGL at Varying Distance from Drain (m)			
	0m from Drain	100m from Drain	500m from Drain	1km from Drain
0.5	0.3	0.19	0.03	0.00
0.9	0.57	0.38	0.07	0.008
1.0	0.63	0.41	0.08	0.01
1.5	0.98	0.67	0.14	0.02

In relation to the site, the drain invert is approximately 0.9 m below AAMGL which is consistent with (JDA, 2002) findings of Local Authority drains within the area being 1m below AAMGL. Consequently, groundwater levels within 1km of this drain will decline logarithmically from between 0.57m to 0.008m (Figure 11), thus having a very significant impact on groundwater levels of the entire site. Several models were created to help visualise the extent this drain effects the site hydrology (Figures 12, 13, and 14).

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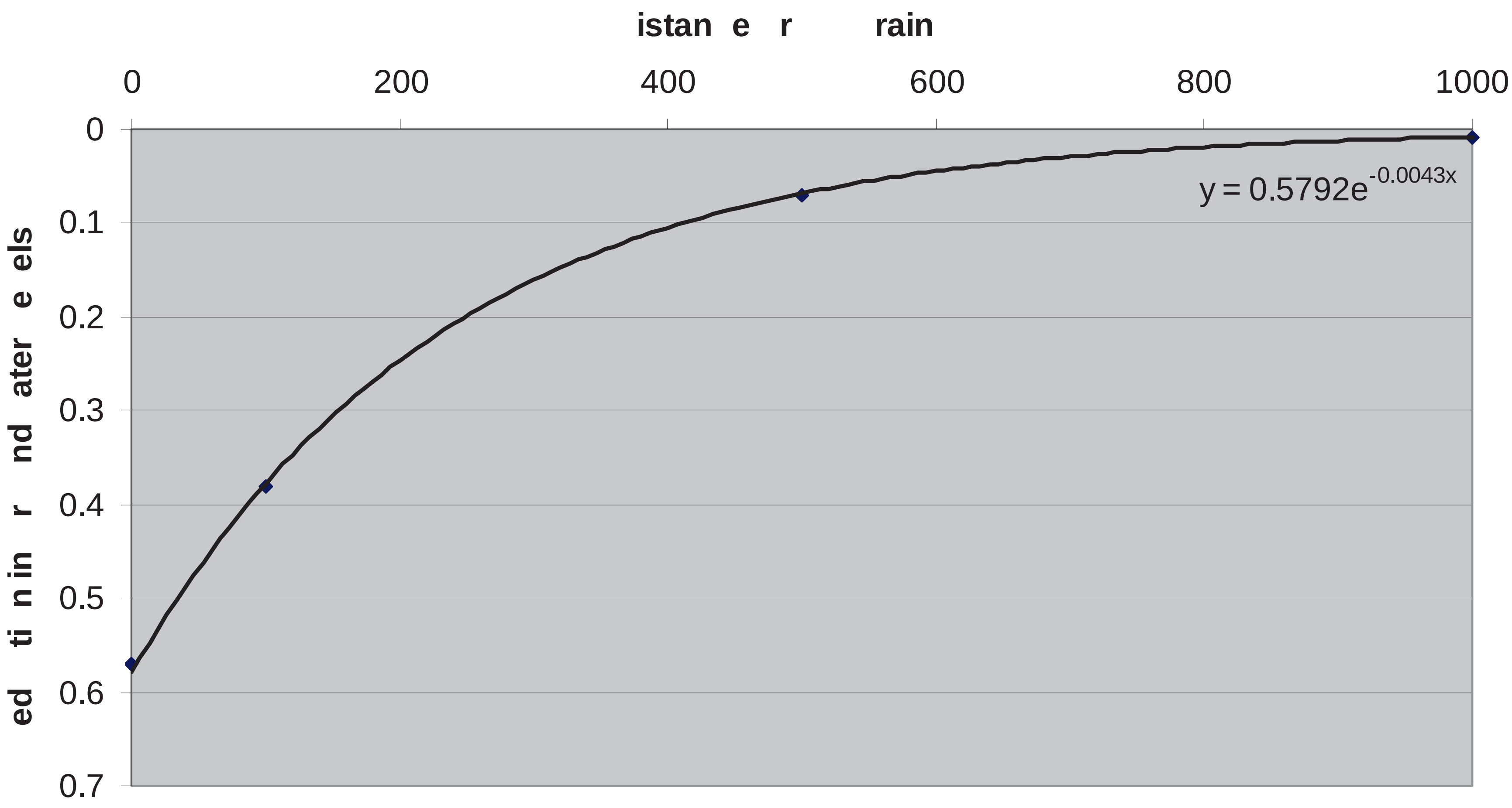
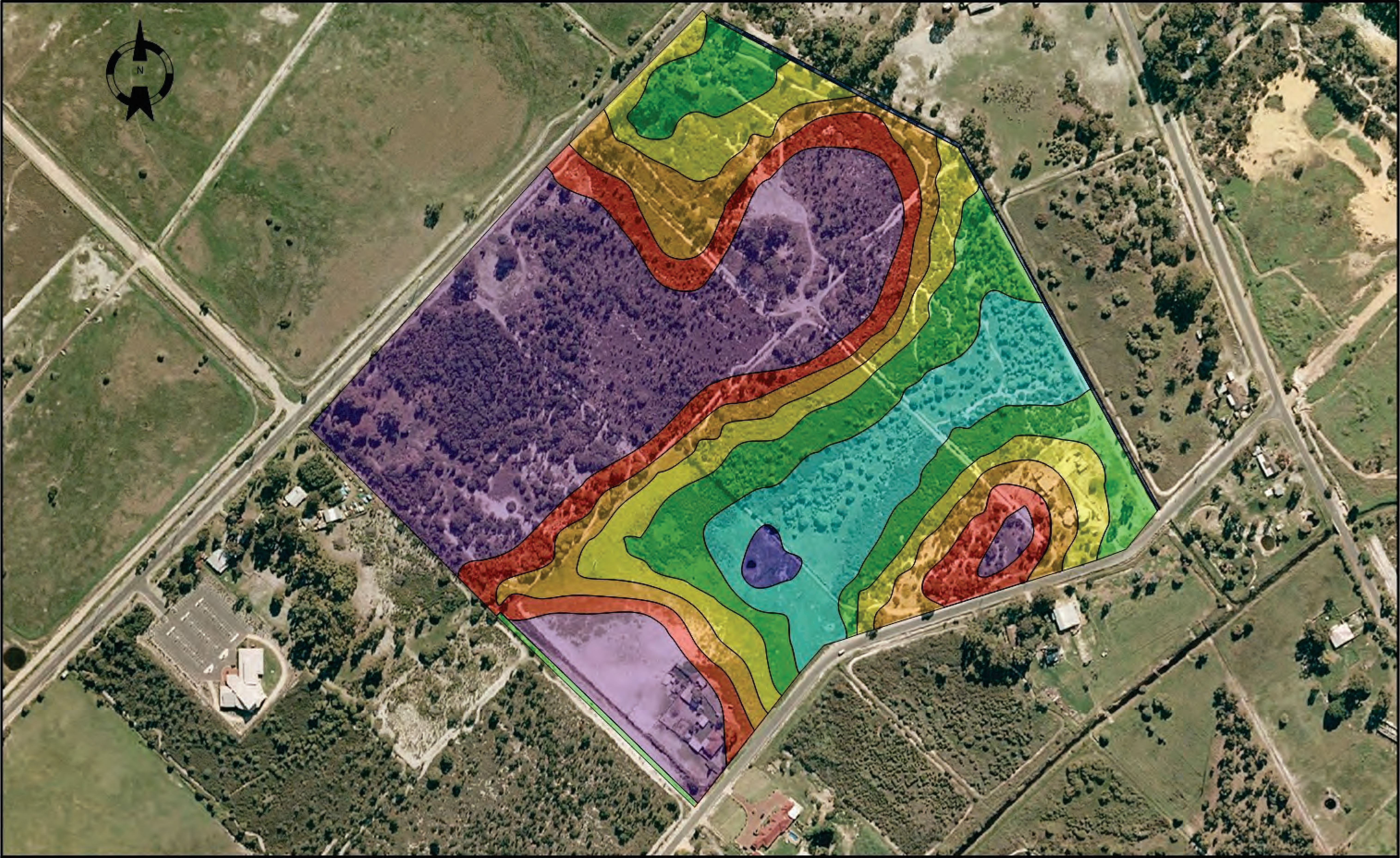


Bioscience

Figure 12 – Influence of the Drain on the AAMGL Depth to Groundwater (mBGL)

Legend

Surface Water
0 to 0.3m
0.3 to 0.6m
0.6 to 0.9m
0.9 to 1.2m
1.2 to 1.5m
>1.5m



Bioscience

Figure13 – Influence of the Drain on a 1 in 10 Year Maximum Groundwater Event (mBGL)

Legend

Surface Water	0 to 0.3m	0.3 to 0.6m	0.6 to 0.9m
0.9 to 1.2m	1.2 to 1.5m	>1.5m	

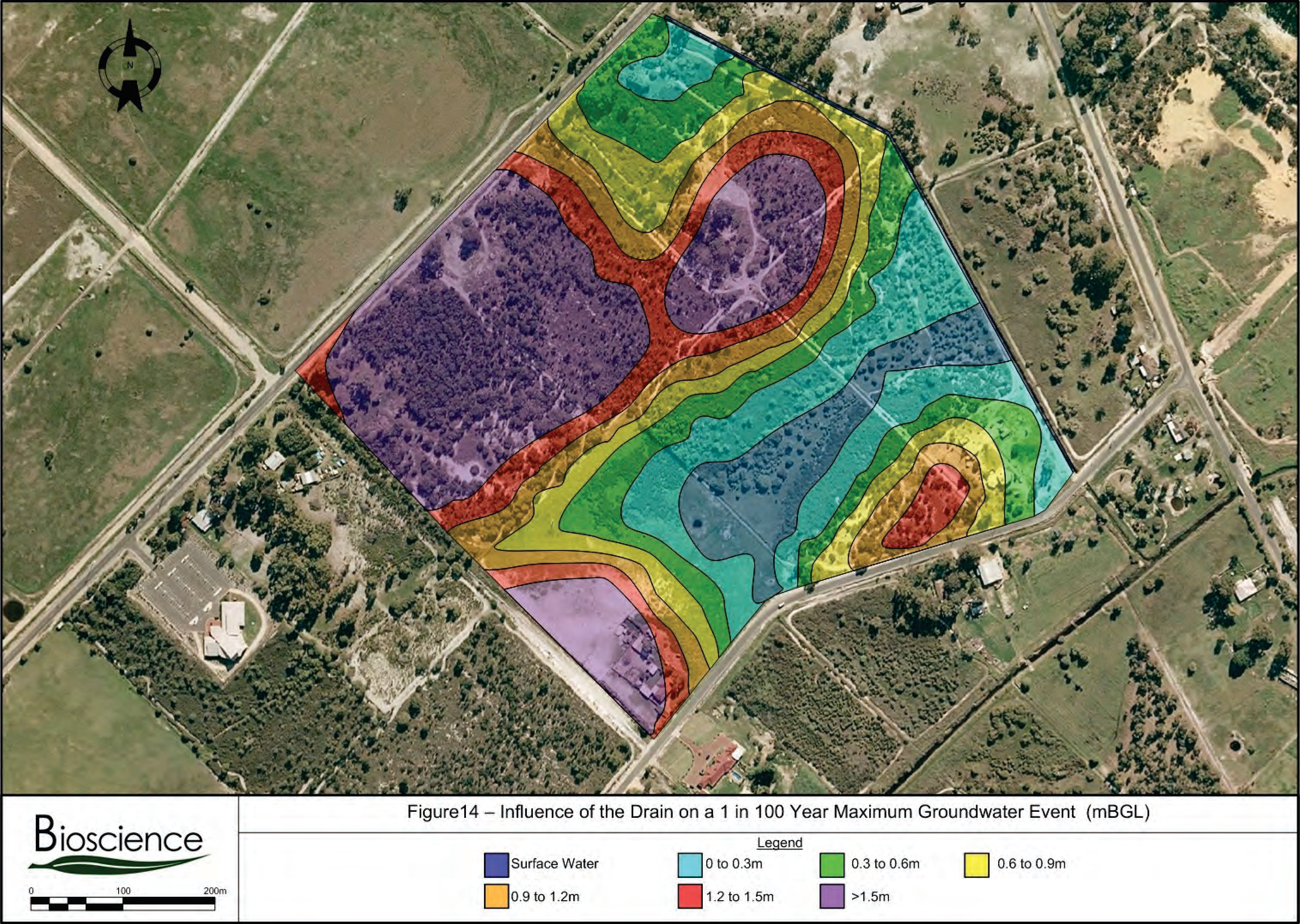


Figure14 – Influence of the Drain on a 1 in 100 Year Maximum Groundwater Event (mBGL)

Legend

Surface Water
0 to 0.3m
0.3 to 0.6m
0.6 to 0.9m
0.9 to 1.2m
1.2 to 1.5m
>1.5m

6.2. *Hydritic and Acid Sulfate Soils*

S il r iles and es ri ti ns

Details of soil profiles, descriptions and analytical results are contained in Appendix 1. With few exceptions, soils were found to be composed of medium textured, deep quartz sand of the Bassendean Dune system.

The exceptions were soils composed of fine textured, sandy clays to clayey sands and were located in lower lying area, that in the past were subjected to inundation. In some cases, under this layer of clayey sand soils become coarse, rounded quartz sand, which is suggestive of an ancient river bed

In 7 locations, during the installation of piezometers with the hand auger, an impassable layer was encountered. It is suspected that this layer is comprised of a typically 0.5 m depth of ferruginous induration or “coffee rock” material.

ed tential

The chemical properties of recovered soil were investigated in Bioscience’s soil laboratory. Redox potential was measured using an Ionode intermediate junction platinum redox electrode with an Ag/AgCl internal reference. The soil was measured soon after collection and the electrode was calibrated using freshly made ZoBell solution.

Of the 102 samples tested, only 20 displayed a redox potential indicative of hydritic soil (i.e. less than 300 mV) (see Appendix 1). Of these eleven, 13 were recorded from depths greater that 1.5m BGL. Of the remaining seven, one was located at DHW 13 (600 to 1600mm), one at DHW19 (1400 to 1800mm) and another at DHW23 (950 to 2200mm), whereas all the others were all located at DHW1 at various depths (samples 300 to 400mm, 400 to 700mm, 700 to 800mm, and 800 to 2500mm).

Those samples which showed even remote possibility of having hydritic characteristics (i.e. having a redox EC value of less than 300mV), were further examined (with the exception of DHW1 to 5 in which all samples underwent examination).

tal ar n and S l r

Carbon and sulfur were measured using a LECO CS200 induction furnace analyser. Soils were first dried at 100^0C then ground to a fine powder using a Retch reciprocating laboratory grinder. The LECO system was calibrated using LECO calibration standards appropriate for C in the range of 0 – 3% and S in the range of 0 – 0.1%.

Of the samples that underwent total carbon and sulphur analysis, total carbon ranged from 0.01% to 2.85%, whereas total sulfur ranged from <0.01% to 0.04%. Of importance to this report are the two samples that had sulphur levels above 0.03% (indicates a possibility of ASS), namely DHW1 2500 to 3200mm and DHW13 2400 – 2900mm which recorded levels of 0.03% and 0.04%, respectively.

S AS esting

Eleven soil samples were further examined (i.e. SPOCAS suite) for acid sulfate properties. Such data can provide insight into the geological history of inundation back from the beginning of the Holocene era to the present, rather than just the recent history. No single method, including SPOCAS, will provide all the answers to the complex chemistry involved in reactions of acid sulfate soils. However results from SPOCAS test procedures will provide guidance to identify potential ASS and the nature of cations contributing to total and potential acidity (Acid Sulfate Soils – Laboratory Methods Guideline, 2004). This in turn reveals whether freshwater or sea water inundation has occurred. Action criteria are defined and give advice when soils disturbed at a site will require ASS management. These action criteria are based on the sum of existing plus potential acidity (Table 2).

Table 2 – SPOCAS suite Action Criteria for ASS (Ahern et al, 1998).

Type of Material		Action Criteria, <1,000 tonnes		Action Criteria, >1,000 tonnes	
Texture	Approx Clay Content (%<0.002 mm)	Sulfur Trail S_{POS} %	Acid Trail TPA mole H^+/t	Sulfur Trail S_{POS} %	Acid Trail TPA mole H^+/t
Coarse e.g. sands	≤5	0.03	18	0.03	18
Medium e.g. loams/light clays	5 – 40	0.06	36	0.03	18
Fine clays/silts	≥40	0.1	62	0.03	18

Results (Table 3) indicate that none of the 11 samples tested exceeds the action criteria for both TPA and total Sulfur (Note, S_{POS} gives a measure of the maximum “oxidisable” sulphur present in a soil sample, where as total sulphur S_{TOTAL} (as measured in this report) gives a measure of total sulphur present with a soil sample, consequently S_{TOTAL} will always be equal to or greater than S_{POS}). Three of the 11 samples do exceed the Titratable Peroxide Acidity (TPA), however as they all possess S_{TOTAL} less than the action criteria (i.e. 0.03%) are considered to have an inconsequential ASS risk.

The magnesium to calcium acidity ratios of DHW 1 are somewhat higher than those of the deep soils at DHW9 and 15, suggesting DHW's accumulated acidity, although not at a threshold to make it acid sulfate, stems from freshwater inundation, whereas the deeper soils chemistry results from seawater inundation. The last time the Swan Coastal Plain was inundated is believed to be between 4900 and 5100 years ago (Gozzard 2007).

Table 3 - SPOCAS Results for selected samples.

Sample Name		DHW1 300-400	DHW1 400-700	DHW1 700-800	DHW1 800-1500	DHW1 3200	DHW9 3800-3900	DHW12 1700-2500	DHW13 600-1600	DHW13 1600-2400	DHW13 2400-2900	DHW15 1800-2200
pH (KCl)		8.96	8.52	6.86	6.46	6.60	5.42	6.57	6.46	6.71	5.99	5.57
TAA	mol H+/t	0.00	0.00	0.00	0.53	0.00	8.58	0.00	0.75	0.00	0.91	64.44
	%w/w S	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.10
	Mg	3.15	3.11	2.18	2.68	3.61	2.36	2.85	3.94	3.47	5.46	2.53
	Ca	0.46	0.53	0.28	0.32	0.57	0.25	0.64	0.81	0.87	0.85	0.48
pH (OX)		5.57	5.48	5.36	5.09	4.40	2.46	2.43	3.43	5.39	5.15	2.01
TPA	mol H+/t	0.00	0.00	0.00	0.00	0.00	81.77	44.20	0.00	0.00	0.00	55.58
	%w/w S	0.00	0.00	0.00	0.00	0.00	0.13	0.07	0.00	0.00	0.00	0.09
	Mg	3.48	3.70	2.00	2.92	6.34	2.76	1.78	3.73	2.95	4.72	3.60
	Ca	0.49	0.41	0.26	0.49	0.75	0.21	0.83	0.98	1.30	1.97	1.05
TSA	mol H+/t	0.00	0.00	0.00	-0.53	0.00	73.19	44.20	-0.75	0.00	-0.91	-8.86
	%w/w S	0.00	0.00	0.00	0.00	0.00	0.12	0.07	0.00	0.00	0.00	-0.01
	Mg	0.32	0.59	-0.17	0.24	2.73	0.41	-1.06	-0.20	-0.51	-0.74	1.07
	Ca	0.03	-0.12	-0.02	0.17	0.18	-0.04	0.19	0.17	0.42	1.11	0.57
Sulfate	S (Total)	0.01	0.00	0.01	0.01	0.03	0.01	0.02	0.01	0.01	0.04	0.18
Carbon	C (Total)	0.12	0.15	0.51	0.04	0.05	0.68	0.50	0.03	0.01	0.04	2.85

Sedi ent l g

Soils were also examined microscopically for evidence of wetland sediments, particularly referring to the prior work on sedimentology of wetlands by Seminiuk and Seminiuk (2006 and 2004). In these articles, wetland sediments are described as the primary accumulates within a wetland basin, and not physical, chemical or biogenic alteration products of pre-existing material, and if soils are developed on them, the wetland soils will be near-surface alteration of those primary materials.

Only one type of sediment associated with the presence of a wetland as per Seminiuk and Seminiuk (2004) i.e “carbonate mud” was present within the property at several piezometer locations. Specifically, DHW1 at 2500 to 3200mm, DHW13 at 1600 to 2400mm, DHW20 at 1800 to 2500mm, DHW21 at 2500 to 3000mm, DHW23 at 2200 to 3000mm, DHW24 at 1000 to 1700mm and DHW25 at 2600 to 4400mm. This carbonate mud was formed via intrabasinal accumulative deposits, of carbonate sand (i.e. Bassendean quartz sands).

6.3. Wetland Vegetation

Ma ing

The vegetation broadly fits within the community types described in Gibson et al 1994 as type 23a, Central *Banksia attenuata – B. menziesii* woodlands, type 4 *Melaleuca preissiana* damplands and type 5 mixed shrub damplands. There is evidence that much of the land has been previously cleared for grazing, and more recently it has been disturbed through the dumping of domestic and building rubbish.

The current community types are defined by the accompanying map. The following are the community descriptions according to each numbered area on the map (Figure 15).

<u>Vegetation Community 1a</u>: Tall open shrubland/low open woodland of *Adenanthos cygnorum*, *Kunzea glabrescens*, and *Daviesia divaricata* with a few *Macrozamia riedlei* and *Allocasuarina fraseriana* and occasional *Podotheca gnaphalioides*. No other native taxa were found. The understorey is almost completely weeds with velt grass, pigface and *Briza major*.

<u>Vegetation Community 1b</u>: Very similar to area 1 with the exception that *Macrozamia riedlei* and *Allocasuarina fraseriana* were not present, A single specimen of *Desmocladus flexuosus* and of *Regelia ciliata* were found however the soil was for the most part bare earth rather than weeds.

<u>Vegetation Community 2a</u>: Low closed woodland of *Banksia menziesii* and *Eucalyptus todtiana* over shrubland of *Kunzea glabrescens*, *Acacia pulchella*, *Adenanthos cygnorum*, *Hibbertia subvaginata* and the herbs *Anagozanthus manglesi*, and *Laxmannia squarrosa*. The understorey is almost completely weeds with velt grass, pigface and *Briza major*.

<u>Vegetation Community 2b</u>: Originally similar to 2a, however has undergone extensive clearing.

<u>Vegetation Community 3</u>: Woodland of *Eucalyptus todtiana* and *E. decipiens* with single specimens of *Xanthorrhoea preissii*, *Patersonia occidentalis*, *Acacia pulchella*, *Nuytsia*

floribunda. The understorey is exclusively weeds including velt grass, pigface, erum lilly, watsonia gladiolus lovegrass and serradella.

Vegetation Community 4: Cleared and degraded, with only native present being isolated *Lepidospernum longitudinale* over pasture weeds including fescue, perennial ryegrass, brome grass, Avena sativa, dock.

Vegetation Community 5a: Closed shrubland of *Regelia ciliata*, *Pericalymma ellipticum*, *Astartea affinis, Phlebocarya cilliata*, and *Juncus subsecundus* and *Schoenus sp*.on edges. Weeds include Gladiolus, *Avena sativa, Briza major*.

Vegetation Community 5b: Very similar to 5a but with *Melaleuca priessiana*.

Vegetation Community 5c: Very similar to Area 5a, however with lower diversity and greater invasion of weeds cover than 5a.

Vegetation Community 5d: Almost identical to 5b, however has greater disturbance and weeds.

Vegetation Community 5e: Almost identical to 5a, however has greater disturbance and weeds

Vegetation Community 5f: Superficially similar to area 5a, but evidence of previous clearing, resulting in essentially a dense monoculture of *Regelea ciliatea*, with occasional *Melaleuca tymoides*, *Xanthorrhoea preissii* and *Juncus* sp.

Vegetation Community 5g: Similar unit to vegetation community 5a, but with *Boisseae sp, Pericalymma elipticum* and some small *Melaleuca priessiana* and *Nyutsia floribunda.* Degraded by previous clearing and by extensive weed invasion.

Vegetation Community 5h: Very similar to Area 5a, however with scattered low trees of *Melaleuca priessiana Allocasuarina fraseriana*, *Xanthorrhoea preissii* and *Bossiaea* sp.

Vegetation Community 5i: Very similar to 5b but with an invasion of a Non-endemic eucalypts species.

Vegetation Community 6a: Low woodland to low open woodland of *Melaleuca raphiophilla* as the only native present over weeds including cooch, serradella, fescue, dandelion, dock.

Vegetation Community 6b: Low closed woodland of *Melaleuca raphiophylla* over weeds – cooch, wild oats, lovegrass, and nightshade.

Vegetation Community 6c: Very similar to 5b but with greater weed invasion and disturbance.

Vegetation Community 7: Previously cleared, mono culture of *Kunzea glabrescens*.

Vegetation Community 8: Open woodland of *Melaleuca priessiana, Kunzea glabrescens, Nuytsia floribunda* over Shrubland of *Regelia ciliata, Pericalymma ellipticum, Hypocalymma augustifolium, Astartea affinis, Pattersonia occidentalis.* Weeds include erum lily, fescue, dandelion, Briza major.

Vegetation Community 9a: Transition zone between 5a and 10a. Contains all of 5, but this gradually diminishes northward and is progressively replaced by *Eucalyptus.todtiana, Allocasuarina. fraseriana, Xanthorrhoea preissii, Banksia menziesii, Melaleuca thymoides.* Weeds generally less but include velt grass, gladiolus, Briza Major.

Vegetation Community 9b: Very similar to 9a, however has greater disturbance and lower diversity.

Vegetation Community 10a: Low woodland of B*anksia menziesii, B.attanuata, B.ilicifolia, Eucalyptus todtiana. Allocasuarina fraseriana, Nuytsia floribunda,* over herbland of *Conostylus aculeate, Patersonia occidentalis.* Weeds include Velt grass, Briza major, Gladeolus.

Vegetation Community 10b: Originally same as 10a but trees cleared and only contains short *Adenanthos cygnorum* and *Banksia menziesii.*

Vegetation Community 10c: Similar to area 10a, but with no *Allocasuarina*, Understorey also contains *Pimelea rosea*, *Petrophile axillaris*. Weeds include velt grass, gladiolus, *Briza major* but generally in better condition than surrounds.

Vegetation Community 10d: Low open woodland of B*anksia menziesii*, *B.attanuata*, *B.ilicifolia, Eucalyptus todtiana. Allocasuarina fraseriana, Nuytsia floribunda,* over herbland of *Conostylus aculeate, Patersonia occidentalis.* Some cleared areas regenerated to *Kunzea glabrescens* and *Adenanthos cygnorum.* Weeds include Velt grass, Briza major, Gladeolus.

Vegetation Community 10e: Originally similar to area 10a however cleared and severely disturbed and/or extensive evidence of Banksia death due to *Phytophthora*. Very weedy and degraded.

Vegetation Community 11: Open woodland of *Allocasuarina fraseriana* over shrubland of *Acacia pulchella, Xanthorrhoea preissii, Conostylus aculeate.* Minor weeds of Briza major, velt grass.

Vegetation Community 12: Woodland of *Eucalyptus todtiana* and *Melaleuca priessiana* over *Patersonia occidentalis* and dense weeds including velt grass, pigface and Briza major

Vegetation Community 13: Previously parkland cleared with, understorey regeneration of *Kunzea glabrescens*, otherwise weeds.

Vegetation Community 14: Non-endemic eucalypts over weeds.

Vegetation Community 15: Previously cleared low closed shrubland of *Astaria affinis* with occasional *Regelia ciliata* with understorey of *Patersonia occidentalis*. Understorey mostly weeds including dandelion, serradella.

nditi n ating

In Western Australia, particularly on the Swan Coastal Plain, vegetation condition reporting has become an important tool for judging the relative conservation value of bushland, particularly for areas being considered for either conservation or clearing to urbanization. The rationale is that biodiversity conservation is much harder in severely degraded bushland, but more easily and cost effectively implemented for bushland in good condition.

The first published condition rating method was by Trudgen in the early 1990's, who broke condition into 6 groupings, ranging from excellent to completely degraded, with intermediate grading of very good, good, poor and very poor.

Later Keighery, acknowledging Trudgen, modified the names and descriptions of the various divisions. This was adopted in the Bush Forever publications, and since 2000 has been widely cited. The two systems are summarised in the Table 4.

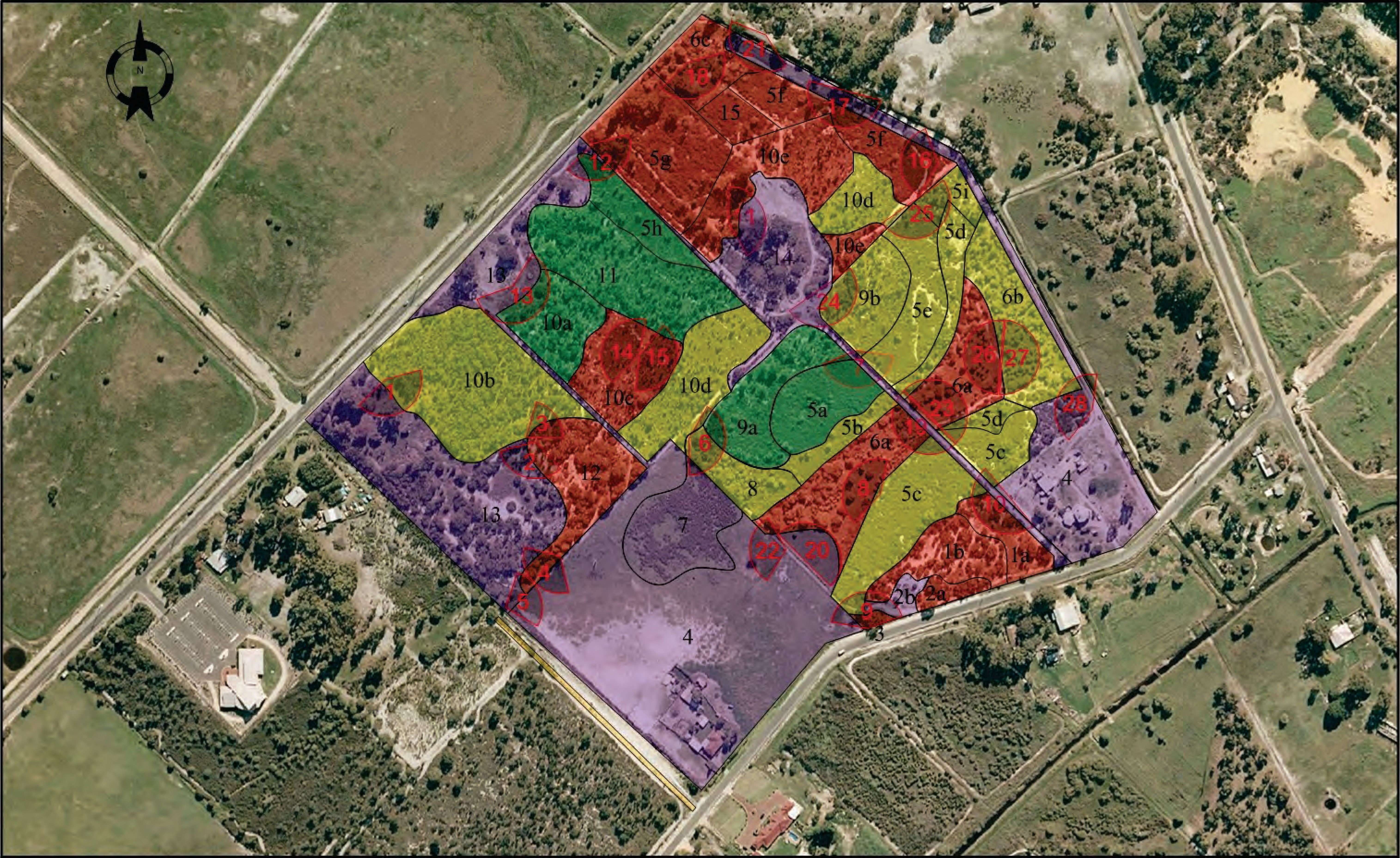


Figure 15 – Vegetation Community Type and Condition, and Photograph Location with Field of Vew

Bioscience

0 100 200m

Legend

Pristine
Excellent
Very Good
Good
Degraded
Completely Degraded
1 Vegetation Community Type
1 Photo Location

Table 4 – Comparison between Trudgen and Keighery Vegetation scoring methods.

Trudgen	Description	**Keighery**	Description
Excellent	The vegetation is pristine or nearly so, with no obvious signs of damage caused by the activities of European man.	Pristine	Pristine or nearly so, no obvious signs of disturbance.
Very Good	Some relatively slight signs of damage caused by the activities of European man. E.g. some signs of damage to tree trunks caused by repeated fire and the presence of some relatively non-aggressive weeds such as *Ursinia anthemoides* or *Briza sp.* or occasional vehicle tracks.	Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive.
Good	More obvious signs of damage caused by the activities of European man, including some obvious impact on the vegetation structure such as caused by low levels of grazing or by selective logging. Weeds as above, possibly some more aggressive ones.	Very Good	Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.
Poor	Still retains basic vegetation structure or ability to regenerate it after very obvious impacts of activities of European man such as grazing or partial clearing (chaining) or very frequent fires. Weeds as above plus some more aggressive ones such as *Ehrharta* spp.	Good	Vegetation structure significantly altered by very obvious signs of multiple disturbance. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
Very Poor	Severely impacted by grazing, fire clearing or a combination of these activities. Scope for some regeneration but, not to a state approaching good condition without intensive management. Usually a number of weed species including aggressive species.	Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds at high density, partial clearing, dieback and grazing.
Completely degraded	Areas that are completely or almost completely without native species in the structure of their vegetation. I.e. areas that are cleared or “parkland cleared” with their flora comprising weed or crop species with isolated native tress or shrubs.	Completely degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as ‘parkland cleared’ with the flora comprising weed or crop species with isolated native trees or shrubs.

In providing data-based advice to clients, Bioscience has had difficulty in using the condition rating system because its terms are somewhat subjective, and the rating is based on the experience, preference and proclivity of the observer rather than objective measurement. Accordingly we have sought to rate vegetation condition objectively, using the same criteria adopted by Trudgen and by Keighery.

The factors they mention which impact on condition are physical disturbance, pests and disease and weed invasion. Collectively these reduce “naturalness”, reduce native biodiversity and promote the “unnatural selection” of hardy and robust taxa over more delicate and sensitive species.

Physical disturbances in Perth’s bushland range from gross disturbance such as logging for timber (mostly of Jarrah), grazing, clearing for farming, filling, domestic gardening, digging of soaks and drains and for sand, and the dumping of rubbish. Sometimes past clearing is obscured by regrowth, however in the Bassendean sands areas, there is typically a dominance of pioneering species such as *Kunzea globorescens* or *Adenanthos obovatus* at levels of dominance not seen in undisturbed land. Grazing, depending on the livestock, typically selectively reduces the middle storey and succulent natives, leaving tuberous or spikey species.

The major disease is die-back, caused by *Phytophthora cinnamomi*. This fungus kills a wide range of native flora with about 50% of the Swan Coastal Plain flora susceptible. Devastation is worst in the jarrah forest flora of the Darling Scarp, however there are serious impacts in the Eucalyptus and Banksia woodlands of the Swan Coastal Plain. The parasite is best suited to wet, but not anaerobic soils which are somewhat acidic. Accordingly, disease impact is least on the waterlogged anaerobic soils of wetlands, and the neutral to alkaline Quindalup and Spearwood sands whereas impacts are greatest on the acidic Bassendean sand dunes rather than depressions.

Pests are most commonly rabbits which are selective feeders on more succulent plants, and can create substantial ground disturbance by building substantial burrows.

Weeds are plants which are not native to the area (being introduced from overseas or from other Australian botanic provenances), and by virtue of their biology and/or the absence of natural controls, are well adapted to local conditions and thrive at the expense of native flora. Impacts on native flora can be either because of the very robust and aggressive growth rate choking other plants, or by active inhibition of competing plants (allelopathy).

The vegetation condition rating system developed by Bioscience seeks to quantify the three factors described above, then to determine the cumulative impact of loss of biodiversity by comparison of the site at issue to similar vegetation units floristic diversity as described in Gibson et al. Each of the three factors are rated (using hedonic scoring of the separate component) as integer values from 0 to 5.

The loss of biodiversity is rated as 0 to 10 based on decline scored in deciles when species richness of a vegetation unit is compared average values reported in Gibson et al. The four values are summed to arrive at a value between 0 and 25. The summed score is then related to the rating system of Trudgen or Keighery as per table 5.

Table 5 – Bioscience vs Trudgen and Keighery Condition Rating.

Trudgen	**Keighery**	**Bioscience Score**
Excellent	Pristine	0 - 4
Very Good	Excellent	5 – 8
Good	Very Good	9-13
Poor	Good	14 -17
Very Poor	Degraded	18-21
Completely degraded	Completely degraded	22 - 25

The advantage of this approach is it is objective, in that a field biologist with the ability to recognise plant taxa and disturbances to geomorphology, can undertake quantitative analyses, and with the resources to reference just a few major publications will arrive at the same score irrespective of their personal preferences.

In a more pragmatic sense, the scoring system provides to those charged with rehabilitation and maintenance tasks, a scored set of priority issues to conserve native flora diversity and highlights factors causing detriment of vegetation values upon which to target remediation and management strategies. The conditions of the sectors defined in the vegetation map are colour coded as described on the map (Figure 15). The basis of scoring is defined in Appendix 6.

al and egi nal Signi i an e

The site is located within approximately 2 km of seven Bush Forever Sites 125, 413, 340, 465, 255, 464, and 246 which have a total area of 293.88 ha (Figure 16). At the regional scale, the vegetation complex of the area is a combination of Bassendean Dunes/Pinjarra Plain Southern River Complex. Only 17% of this complex remains. Some 1775 ha are protected as Parks and Recreation under the MRS, Department of Conservation and Land Management (CALM) managed lands and Crown Reserves with a Conservation Purpose. This, together with the 1372 ha under Bush Forever, protects 10% of the Southern River complex.

The Bush Forever Site No. 125 is part of a regionally significant fragmented bushland/wetland linkage. Whilst limited survey of the Bush Forever site has been undertaken, more than 80% of the vegetation condition is excellent (with some areas considered pristine) and the remaining ranked as very good to good. In contrast the subject site is regarded to be good to completely degraded, despite having some vegetation in very good condition. In addition, no significant flora including two DRF orchid species (*Diuris purdiei* and *Caladenia hueglii*) known to reside in Bush Forever Site No. 125, were found on the site. Consequently, the significance of this site, in terms of conservation value is relatively low. Despite this, an area within the site that has been classified as being in very good condition will be protected and conserved as part of the façade of the proposed development.

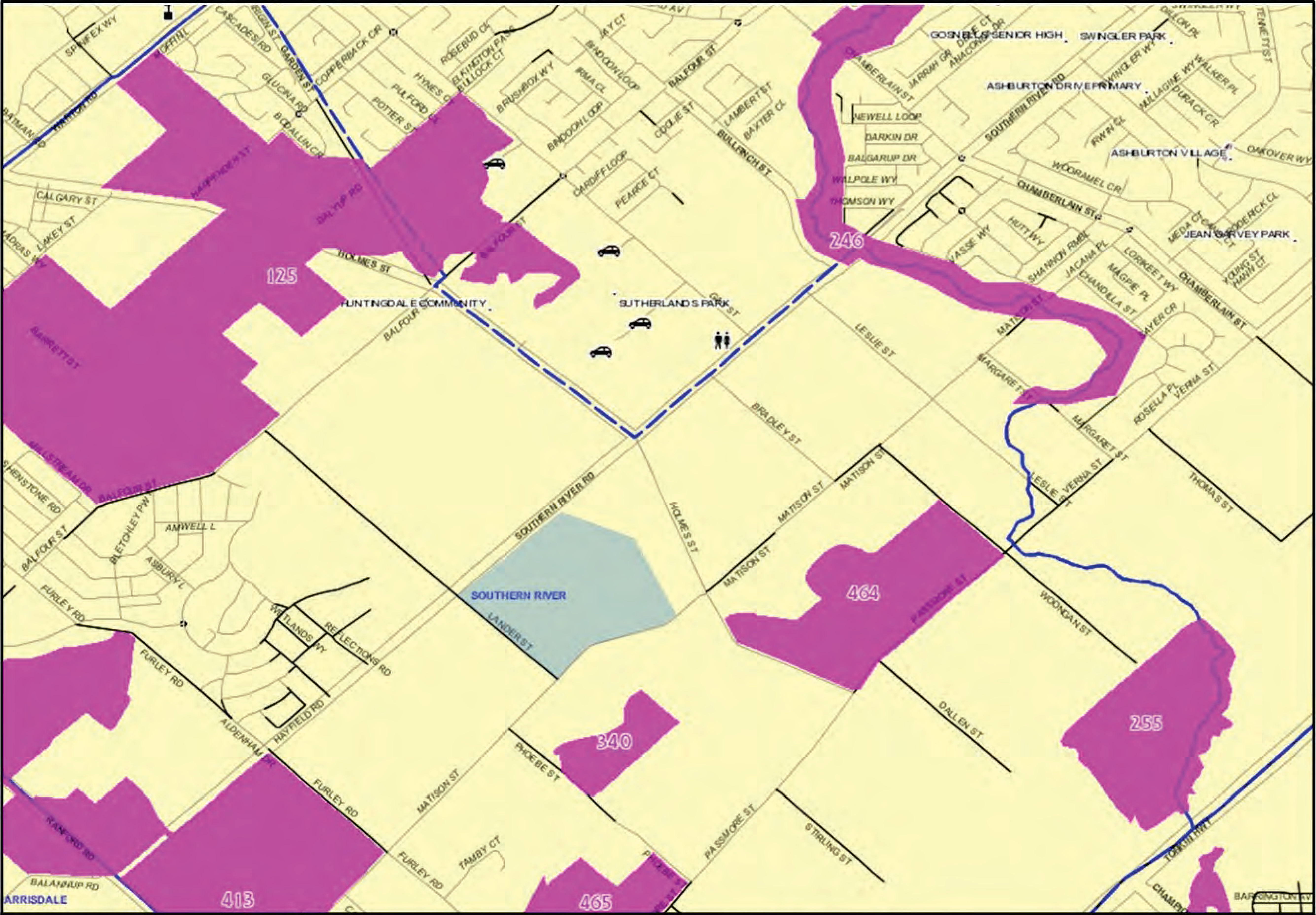


Figure 16 – Bush Forever Sites

Legend

Site Location

Bush Forever Sites

Bioscience

0 250 500m

7. n l si ns

7.1. Hydrology

We conclude the AAMGL for the site is 20.47mAHD and the seasonal groundwater range likely to be 1.4 m for most years. Ongoing monitoring will progressively eliminate the uncertainty of these estimations. Based on these estimations and using HydrogeoAnalyst, we were able to create several groundwater models.

Figure 8 illustrates depth to groundwater at AAMGL and Figures 9 and 10 illustrate 1 in 10 and 1 in 100 year groundwater events based on surface contours. These models do not include the influence of drains, thus project the earlier hydrological regime. They indicate that a significant proportion of Lots 18, 19 and 20 formerly became inundated; however only the 1 in 100 year model suggest the northern part of Lots 22 became inundated. Consequently, there appears to have been at once, two wetland-like areas located within the site; however these models do not integrate the influence of the Local Authority drain to the north east of lots 20 and 22.

According to the JDA (2002) study of this area, for ever kilometre of drain with an invert depth of 0.9m, 42700m^3 of water is exported. Considering the length of the drain on the north eastern boundary of Lot 22 is approximately 254m, and on the adjacent property Lot 20 is 357m, this drain will have a significant lowering of groundwater levels to both wetland-like areas. Groundwater levels within 1km of this drain will decline logarithmically from between 0.57m to 0.008m (JDA, 2002) (Figure 11). Three groundwater models (Figures 12, 13 and 14) were created to illustrate the significant impact of this drain exerts on groundwater levels, thereby illustrating the current groundwater setting.

Figure 12 illustrates the influence of the drain on depth to groundwater, given that groundwater levels are at AAMGL. Like Figure 8, Figure 12 indicates that only a small area of lot 18 becomes inundated, however small area of land on lot 18 has groundwater levels between 0 to 0.30 mBGL, whereas a significant part of lots 18, 19 and 20 remains between 0.3 to 0.6 mBGL. Also the groundwater levels on the northern part of Lots 22 and 21 have decreased from 0.3 to 0.6 mBGL to 0.6 to 0.9 mBGL.

Figures 13 and 14, illustrate the influence of the drain on extreme 1 in 10 and 1 in 100 year groundwater events. In a 1 in 10 year event there is a relatively small area of inundation on Lot 18, whereas a significant area of Lots 18, 19 and 20 becomes inundated in a 1 in 100 year event. Even in a 1 in 100 year event, the wetland-like area to the north of Lots 21 and 22 doesn't become inundated.

We can thus conclude that using hydrological estimation and modelling, in the past two independent wetlands existed on the site. The first running through centre of Lots 18, 19 and 20 in a southwest to northeast direction and the second towards the northern part of Lot 22. However, due to the construction of the Local Authority Drain, groundwater levels of the wetland located on the northern part of Lot 22 have decrease from between 0.57 to 0.29m, thus it no longer has hydrology characteristics of a wetland. Despite reduced groundwater levels from between 0.57 and 0.06m, a proportion of the wetland on Lots 18, 19 and 20 is still considered to have a hydrology consistent with that of a wetland.

7.2. Hydritic Soils

The conclusions we draw from the examination of soils is that no samples display any evidence of actual or potential ASS and only eleven samples display any evidence of hydritic characteristics, namely DHW1, DHW13, and DHW19 to DHW25. All soil samples showed a reduced redox potential (i.e. below 300mV), only modest accumulation of organic carbon and are alkaline on the surface, graduating to acidic at depth. All the other soils show that throughout the entire depth which is important for plant growth, soils are uniform Bassendean sands which have high redox potential, and levels of carbon and sulfur which are typical of upland soils. Based on sedimentology, DHW1 and DHW19 to DHW25 show clear wetland characteristic. The results from chemical and stratigraphic studies of soil are entirely consistent with the conclusions based on hydrology.

7.3. Wetland Vegetation

The only areas which have vegetation which is unequivocally wetland specific are vegetation community 6a, 6b and 6c as they contain almost entirely the swamp paperbark *Melaleuca raphiophylla*. The understorey of vegetation community 6a and 6b have been previously cleared and used for summer grazing, so the vegetation was in a degraded and good condition, respectively (Photo 8, 19, 23, 26, and 27 see Figure 15 for photo location). Despite no recent signs in inundation, vegetation community 6c (Photo 18) has mature *Melaleuca preissiana* present, however is also classified as degraded due to significant disturbances. Immediately northwest of vegetation community 6c a 2m deep drain (0.9m below AAMGL) has been constructed. This drain has altered hydraulic gradients resulting in the reduction of groundwater, and whilst still maintaining *Melaleuca raphiophylla* in this region, they appear to be water stressed and in decline.

Moving upland from these wetland vegetation areas, it can be concluded that vegetation transforms from only possessing wetland species such as *Melaleuca raphiophylla* to having wetland indicator species such as *Melaleuca preissiana*, *Pericalymma ellipticum*, *Kunzea* *glabrescens* and *Atsartea affinis*, but it also contained non-wetland species such as *Nuytsia floribunda*, *Eucalyptus todtiana* and *Eucalyptus decipiens*. The vegetation surrounding these areas is thus best described as transitional between typical wetland vegetation and typical upland vegetation of the Southern River area.

7.4. Proposed Wetland Dataset Modification

etland Area Ma ing

In consideration of hydrology, hydritic soils and wetland vegetation, we conclude that in the past the site had two wetlands, one on the northern part of Lot 22 and the other running in a southwest to northeast direction on Lots 18, 19 and 20. However, since the construction of the Local Authority drain with an invert some 0.9m below AAMGL, the hydrology within the area has changed significantly.

The result of which is that the northern part of Lots 21 and 22 no longer become inundated (i.e. at most for a short time during 1 in 100 year recurrence interval) and indeed they may never become inundated. Despite the vegetation surrounding this area still contains species which are characteristic of a wetland, this vegetation is in a very degraded condition due to past land use. Consequently Bioscience believes this area no longer has substantial wetland values and/or attributes.

The wetland on Lots 18, 19 and 20 has also been affected by this drain, however to a lesser extent. We conclude that only a small area on Lot 18 continues to become inundated from year to year and also in 1 in 10 year maximum groundwater event (Figure 12 and 13), whereas areas of lots 18, 19, and 20 only become inundated in above average years such as a 1 in 100 year events (Figure 14).

The effect of the drain has reduced the size of this wetland and the duration of inundation. The precise setting of wetland boundaries is equivocal at best. Using vegetation as the sole criterion, the majority of Lot 19 and 20 and the northern part of lots 21 and 22 might be considered a wetland as the species present are characteristic of wetlands and wetland fringes; however this is inappropriate as this vegetation is clearly transitional. Based on sedimentology and soil chemistry (redox), DHW1 and DHW19 to DHW25 show clear wetland characteristic suggests that the boundary would be that area marked as vegetation group 6 in the vegetation mapping (Figure 15), however again this is clearly inappropriate and this does not take into account recent changes to hydrology.

We propose that the wetland be classified by the presence of water, specifically, where the soil becomes inundated or waterlogged, either permanently or seasonally. There is graphical guidance in Chapter 2 of Volume 2a of Hill *et al* (1996) which suggests a wetland boundary is where capillary water rises to the surface during an extreme seasonal groundwater rise. This is also consistent with Tiner (1999). Consequently, we propose that the wetland boundary be where capillary water rises to within 0.3m of the surface during an extreme 1 in 10 year maximum groundwater event (Figure 12 and 17).

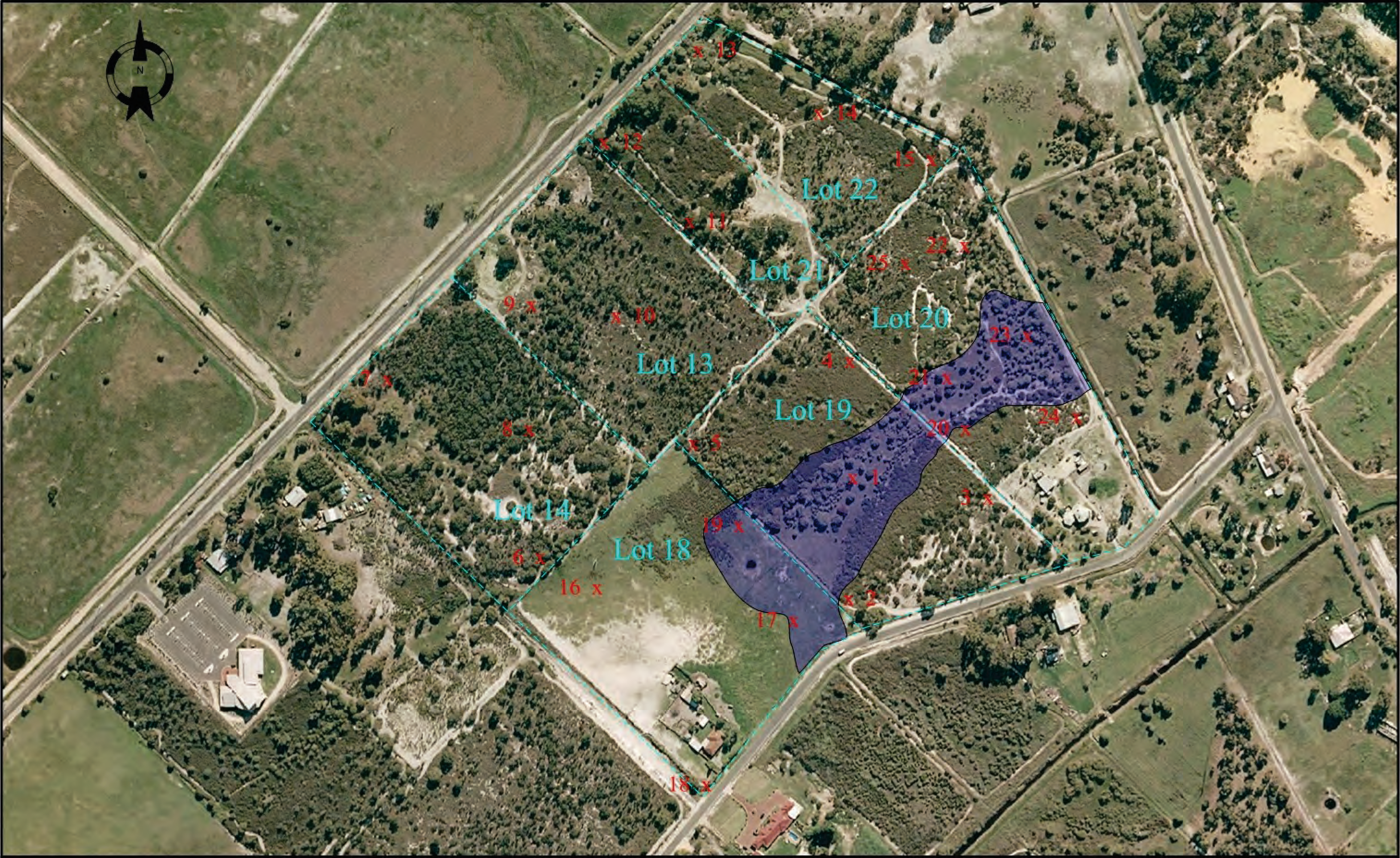
etland e lassi i ati n

According to JDA (2002) the long period of settlement and agriculture activity of the southern river area has substantially altered the natural vegetation, groundwater and surface drainage so that most of the wetlands are degraded to varying degrees.

This is essentially true for this site, despite five of the 32 vegetation communities having a condition rating of very good, these areas were either in upland areas (i.e. vegetation communities 10a and 11) or in wetland to upland transitional areas (i.e. vegetation communities 5a, 5h and 9). Based on hydrology, these areas are not within the functional area of the wetland. The vegetation communities that are within the functional area of the wetland (i.e. vegetation communities 4, 5b, 5c, 5d, 6a, 6b and 7) are good to completely degraded in condition.

Bioscience believes that inaccuracy in defining the wetland boundary has resulted in the wetland being categorised as a Resource Enhancement Wetland. This assessment was likely based on the condition of vegetation as the sole criterion for this management category.

Using the criteria of Bulletin 686, the wetland area defined previously, in our judgment should be a Multiple Use Wetland as the wetland functions, values and attributes have been seriously degraded such that they no longer serve any substantial ecological role.



Bioscience

0 100 200m

Figure 17 – Proposed Wetland Boundaries and Classification

Legend

Multiple Use Wetland
Lot Boundaries
x Piezometer Location

Report prepared and written by:

Peter Keating B.Sc (Hons) Ph.D.
Managing Director

&

Andrew Jackson B.Sc (Hons)
Environmental Scientist

e eren es

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A endi lletin es lts

Area 1A) **Part IIB – Natural Attributes**

i)	No	1
ii)	Yes	0
iii)	No	1
iv)	Large paperbarks in dense clumps	1
	Scattered “clumps” of rushes and sedges	1
	Flooded grassland in winter/spring	1
v)	Yes	0
vi)	>40%	1
vii)	<10ha	1
TOTAL		7

Part III – Human Use

i)	Little noise	2
	Few visitors	1
ii)	None	0
iii)	Other	1
iv)	No groups	0
v)	None	0
vi)	None	0
vii)	Proposed urban/housing use	1
TOTAL		5

Area 1B) **Part IIB – Natural Attributes**

i)	No	1
ii)	Yes	0
iii)	No	1
iv)	Large paperbarks in dense clumps	1
	Low thickets	1
	Scattered “clumps” of rushes and sedges	1
	Flooded grassland in winter/spring	1
	Fringing woodland and heath	1
v)	Yes	0
vi)	21-30%	3
vii)	<10ha	1
TOTAL		11

Part III –Human Use

i)	Little noise	2
	Few visitors	1
ii)	None	0
iii)	Other	1
iv)	No groups	0
v)	None	0
vi)	None	0
vii)	Proposed urban/housing use	1
TOTAL		5

Part IV – Supplementary Questions

i)	No
ii)	No?
iii)	No

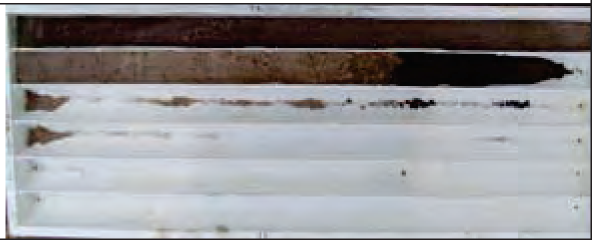
Area 2) Part IIB – Natural attributes

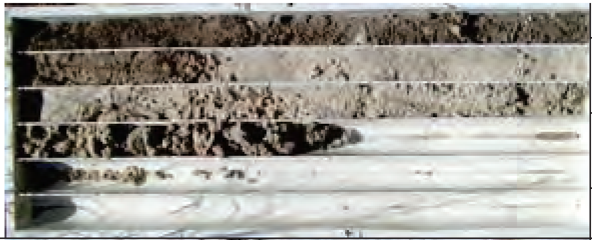
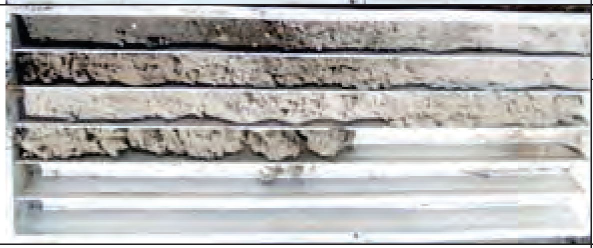
i)	No	1
ii)	Yes	0
iii)	No	1
iv)	Large paperbarks in dense clumps	1
	Fringing woodland and heath	1
v)	Yes	0
vi)	31-40%	2
vii)	<10ha	1
TOTAL		7

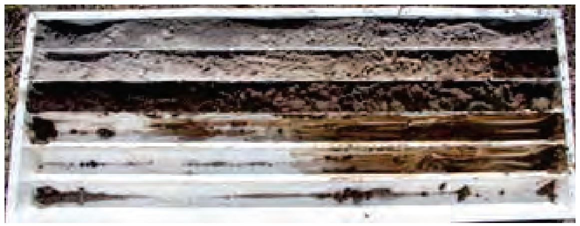
Part III –Human Use

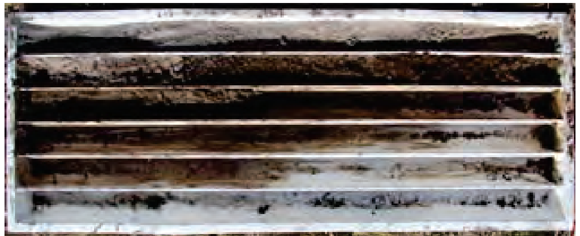
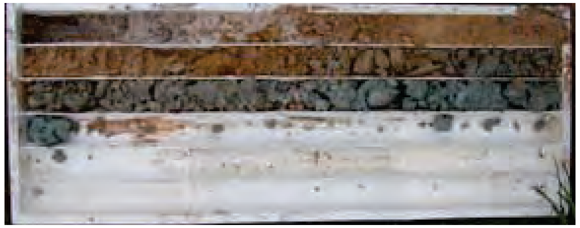
i)	Few visitors	1
ii)	None	0
iii)	Other	1
iv)	No groups	0
v)	None	0
vi)	None	0
vii)	Proposed urban/housing use	1
TOTAL		3

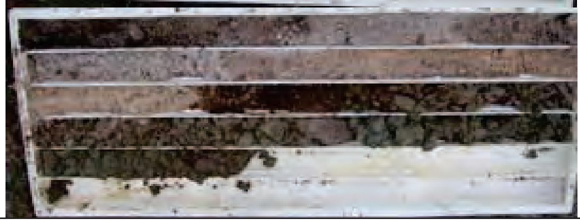
A endi S il r ile e i al Anal sis and es ri ti n

Bore ID	Soil Profile Photo	Soil Depth (mm)		Redox Potential (mV)	Carbon (%)	Sulphur (%)	Soil Description
DHW1	No Photo Taken.	0	150	454	1.22	0.01	Light grey, medium textured, Bassendean quarts sand, with organic material.
		150	300	348	0.59	0.00	White to cream, medium textured, Bassendean quarts sand.
		300	400	206	0.12	0.01	Medium texture Bassendean quarts sand
		400	700	183	0.15	0.00	Light brown, medium textured, Bassendean quarts sand.
		700	800	227	0.51	0.01	White to cream, medium to fine textured, Bassendean quarts sand with ferrunginous induration “coffee rock”.
		800	2500	233	0.04	0.01	White to cream, coarse to medium textured, rounded, Bassendean quarts clayey sand.
		2500	3200	131	0.05	0.03	Light grey to grey, fine textured Bassendean quarts clay.
DHW2	No Photo Taken.	0	250	457	0.57	0.01	Light grey, medium textured, Bassendean quarts sand, with organic material.
		250	600	470	0.09	0.00	Light grey, medium textured, Bassendean quarts sand.
		600	1500	464	0.05	0.01	Light grey to white, medium textured, Bassendean quarts sand over an impassable ferrunginous induration “coffee rock”.
DHW3	No Photo Taken.	0	200	469	1.65	0.01	Dark grey, medium textured, Bassendean quarts sand, with organic material.
		200	400	478	0.94	0.01	Grey, medium textured, Bassendean quarts sand.
		400	2000	469	0.04	0.00	White, medium textured, Bassendean quarts sand.
DHW4	No Photo Taken.	0	300	469	1.63	0.01	Grey, medium textured, Bassendean quarts sand, with organic material.
		300	600	478	0.16	0.01	Light grey, medium textured, Bassendean quarts sand, with organic material.
		600	1500	487	0.14	0.00	Light grey to white, medium textured, Bassendean quarts sand over an impassable ferrunginous induration “coffee rock”.
DHW5	No Photo Taken.	0	300	462	1.32	0.01	Grey, medium textured, Bassendean quarts sand, with organic material.
		300	700	484	0.30	0.01	Light grey, medium textured, Bassendean quarts sand.
		700	1500	422	0.16	0.00	Light brown, medium textured, Bassendean quarts sand over an impassable ferrunginous induration “coffee rock”.
DHW6		0	1000	328	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		1000	1600	424	-	-	Light brown to cream, medium to fine textured, Bassendean quarts sand.
		1600	1800	311	-	-	Brown, medium to fine textured, Bassendean quarts sand.
		1800	1900	306	-	-	Dark drown to black, medium to fine textured, Bassendean quarts sand over an impassable ferrunginous induration “coffee rock”.

DHW7		0	400	402	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		400	1200	421	-	-	Grey to light grey, medium textured, Bassendean quarts sand.
		1200	2800	385	-	-	White to cream, medium to fine textured, Bassendean quarts sand.
		2800	3500	338	-	-	White to light grey, medium to fine textured, Bassendean quarts sand.
DHW8		0	800	439	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		800	1200	477	-	-	Grey to light grey, medium to fine textured, Bassendean quarts sand.
		1200	3900	438	-	-	White/cream to light grey, medium to fine textured, Bassendean quarts sand.
DHW9		0	700	318	-	-	Grey, medium textured, Bassendean quarts sand, with organic material.
		700	3800	413	-	-	White to light grey, medium to fine textured, Bassendean quarts sand.
		3800	3900	249	0.68	0.01	Brown, medium textured, Bassendean quarts sand over an impassable ferrunginous induration “coffee rock” layer.
DHW10		0	450	386	-	-	Grey to light grey, medium textured, Bassendean quarts sand, with organic material.
		450	3500	475	-	-	White, medium textured, Bassendean quarts sand.
DHW11		0	600	471	-	-	Grey to light grey, medium textured, Bassendean quarts sand, with organic material.
		600	1700	506	-	-	White to cream, medium to fine textured, Bassendean quarts sand.
		1700	2600	322	-	-	Light brown, medium textured, Bassendean quarts sand.

DHW12		0	300	338	-	-	Dark grey to black, medium textured, Bassendean quarts sand, with organic material.
		300	900	413	-	-	Grey, medium textured, Bassendean quarts sand.
		900	1700	447	-	-	Light grey to white, medium textured, Bassendean quarts sand.
		1700	2500	298	0.50	0.02	Light brown, medium textured, Bassendean quarts sand over an impassable ferruginous induration “coffee rock”.
DHW13		0	100	403	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		100	600	320			White to pink, medium to fine textured, Bassendean quarts sand.
		600	1600	236	0.03	0.01	Light brown to cream, medium to fine textured Bassendean quarts Clayey Sand.
		1600	2400	196	0.01	0.01	Light grey to grey, fine textured Bassendean quarts clay.
		2400	2900	54	0.04	0.04	Grey to white, Coarse to fine textured, rounded, Bassendean quarts clayey sand.
DHW14		0	400	417	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		400	2100	397	-	-	White medium textured, Bassendean quarts sand
		2100	2500	361	-	-	Brown, medium textured, Bassendean quarts sand.
DHW15		0	300	419	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		300	850	434	-	-	Light grey, medium textured, Bassendean quarts sand.
		850	1800	429	-	-	White, medium textured, Bassendean quarts sand.
		1800	2200	294	2.85	0.18	Dark drown to black, medium to fine textured, Bassendean quarts sand over an impassable ferruginous induration “coffee rock” layer.
DHW16		0	200	401	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		200	1000	463	-	-	Grey to light grey, medium textured, Bassendean quarts sand.
		1000	1800	453	-	-	Light grey to white, medium textured, Bassendean quarts sand
		1800	2300	478	-	-	Brown, medium textured, Bassendean quarts sand.
		2300	3000	351	-	-	Light brown medium textured, Bassendean quarts sand

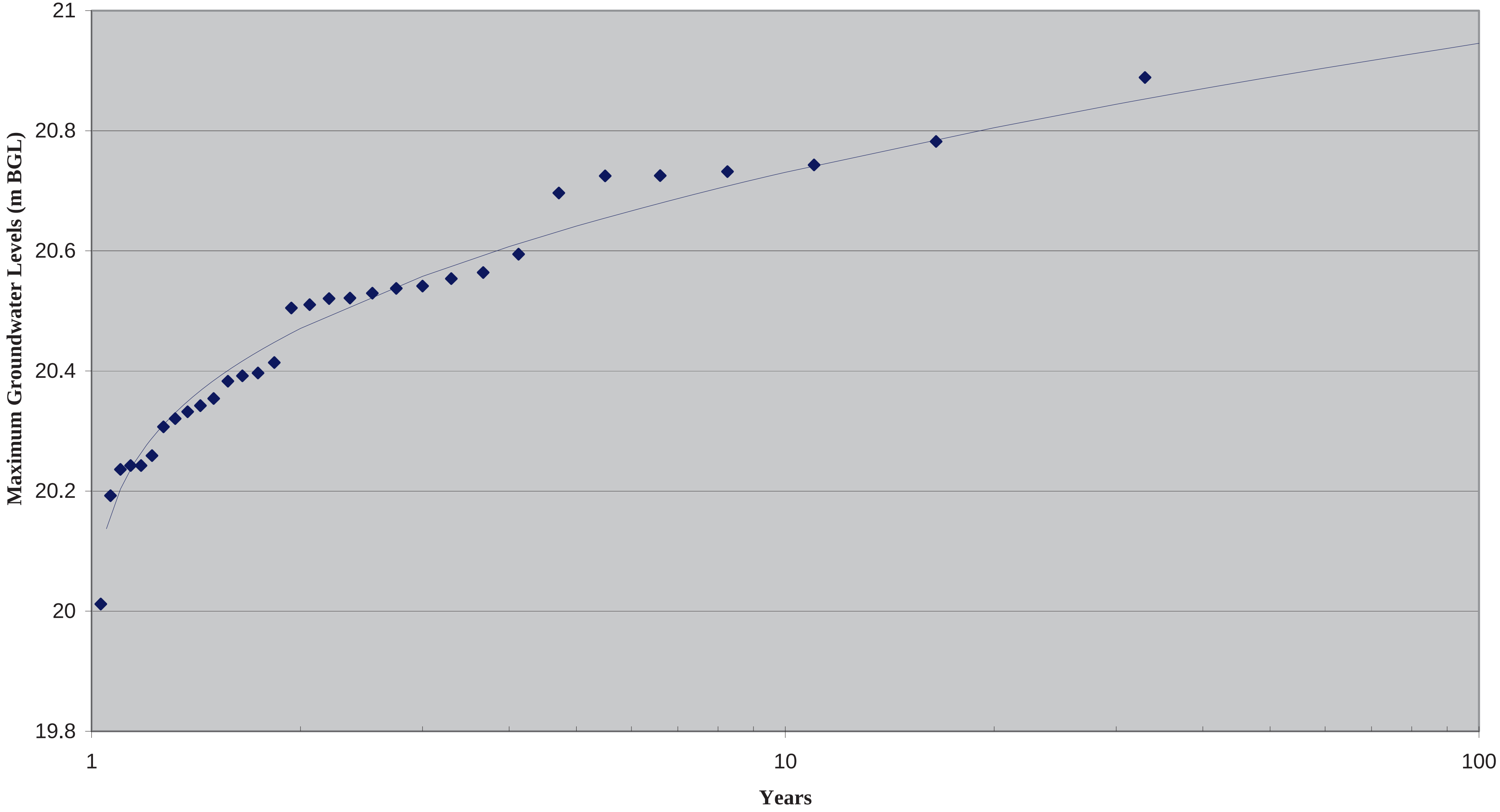
DHW17		0	250	415	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		250	1300	469	-	-	Grey to light grey, medium textured, Bassendean quarts sand.
		1300	1900	496	-	-	Brown, medium textured, Bassendean quarts sand.
		1900	2500	319	-	-	Light brown medium textured, Bassendean quarts sand
DHW18		0	200	468	-	-	Light grey medium textured, Bassendean quarts sand
		200	2500	515	-	-	Light grey to white medium textured, Bassendean quarts sand
		2500	3000	468	-	-	Light brown medium textured, Bassendean quarts sand
DHW19		0	400	452	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		400	600	377	-	-	Light grey to cream medium textured, Bassendean quarts sand
		600	1100	352	-	-	Light brown to cream medium textured, Bassendean quarts clayey sand
		1100	1400	348	-	-	Orange medium textured, Bassendean quarts clayey sand
		1400	1800	294	-	-	Light brown to cream medium to fine textured, Bassendean quarts sand
		1800	2500	187	-	-	Grey to green fine textured Bassendean quarts sandy clay
		2500	2600	495	-	-	Light grey to white medium textured, Bassendean quarts sand
DHW20		0	200	461	-	-	Dark grey to grey, medium textured, Bassendean quarts sand, with organic material.
		200	500	365	-	-	Light grey to cream medium textured, Bassendean quarts sand
		500	1800	324	-	-	Brown to orange fine to medium textured, Bassendean quarts sand
		1800	3100	247	-	-	Grey to green fine textured Bassendean quarts sandy clay
DHW21		0	200	479	-	-	Black to dark grey, medium textured, Bassendean quarts sand, with organic material.
		200	400	435	-	-	Light grey to cream medium textured, Bassendean quarts sand
		400	1000	350	-	-	Brown to cream medium textured, Bassendean quarts sand
		1000	1500	316	-	-	Orange medium textured, Bassendean quarts clayey sand with ferrunginous induration or “coffee rock” layer
		1500	2500	299	-	-	Grey to cream fine textured Bassendean quarts sandy clay
		2500	3000	274	-	-	Grey to green fine textured Bassendean quarts sandy clay

DHW22		0	250	497	-	-	Black to dark grey, medium textured, Bassendean quarts sand, with organic material.
		250	1600	512	-	-	Light grey to cream medium textured, Bassendean quarts sand
		1600	2600	507	-	-	Brown medium textured, Bassendean quarts sand
DHW23		0	150	484	-	-	Black to dark grey, medium textured, Bassendean quarts sand, with organic material.
		150	500	478	-	-	Light grey to cream medium textured, Bassendean quarts sand
		500	950	316	-	-	Brown to cream medium textured, Bassendean quarts sand
		950	2200	274	-	-	Cream to orange fine textured Bassendean quarts sandy with ferrunginous induration or "coffee rock" material
		2200	3000	196	-	-	Grey to green fine textured Bassendean quarts sandy clay
DHW24		0	100	463	-	-	Black to dark grey, medium textured, Bassendean quarts sand, with organic material.
		100	600	421	-	-	Light grey to cream medium textured, Bassendean quarts sand
		600	800	381	-	-	Brown medium textured, Bassendean quarts sand
		800	1000	365	-	-	Light grey to cream medium textured, Bassendean quarts sand
		1000	1500	307	-	-	Cream to light brown fine textured Bassendean quarts sandy clay
		1500	1700	298	-	-	Cream fine textured Bassendean quarts sandy clay
DHW25		0	300	483	-	-	Black to dark grey, medium textured, Bassendean quarts sand, with organic material.
		300	1300	521	-	-	Light grey medium textured, Bassendean quarts sand
		1300	2250	498	-	-	Cream medium textured, Bassendean quarts sand
		2250	2600	379	-	-	Brown medium textured, Bassendean quarts sand
		2600	4400	267	-	-	Grey to green fine textured Bassendean quarts sandy clay

A endi re r nd ater rend Anal sis

Year			1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Ave	SD
4786	Trend Analysis	Max	25.9	25.9	25.4	26.1	25.8	26.0	26.0	26.1	25.9	26.1	25.9	26.2	26.1	26.4	25.7	25.4	26.0	26.4	25.8	26.1	26.0	26.2	25.7	25.4	25.7	26.0	25.6	25.5	25.7	25.4	26.0	25.2	25.86	0.30
		Min	25.1	25.0	24.7	24.5	24.8	24.6	24.8	24.9	24.7	24.8	24.9	24.8	24.9	24.9	25.0	24.8	24.5	25.2	25.0	24.8	24.9	24.8	25.0	24.6	24.4	24.7	24.6	24.3	24.3	24.3	24.3	24.5	24.73	0.25
		Var	0.9	0.9	0.7	1.6	1.0	1.4	1.3	1.2	1.2	1.2	1.0	1.5	1.2	1.5	0.8	0.6	1.5	1.2	0.8	1.4	1.1	1.3	0.7	0.9	1.3	1.3	1.1	1.2	1.4	1.1	1.7	0.7	1.13	0.28
	Extropalated DoW Data (1:0.799 ratio to Site)	Max	20.7	20.7	20.3	20.8	20.6	20.8	20.8	20.8	20.7	20.8	20.7	21.0	20.9	21.1	20.6	20.3	20.8	21.1	20.6	20.9	20.8	20.9	20.6	20.3	20.5	20.8	20.5	20.4	20.6	20.3	20.7	20.2	20.66	0.24
		Min	20.0	20.0	19.8	19.6	19.8	19.6	19.8	19.9	19.7	19.8	19.9	19.8	19.9	19.9	20.0	19.8	19.6	20.2	20.0	19.8	19.9	19.8	20.0	19.6	19.5	19.7	19.6	19.4	19.4	19.4	19.4	19.6	19.76	0.20
4879	Trend Analysis	Max	21.8	21.6	21.6	21.5	21.6	21.8	20.9	20.8	20.9	20.1	20.9	20.9	20.8	20.9	21.1	21.3	21.6	21.5	21.5	21.4	21.3	21.4	20.7	21.1	21.3	21.3	21.0	21.1	21.3	20.8	21.4	20.5	21.19	0.40
		Min	19.7	19.8	19.9	19.9	20.0	19.8	19.0	19.3	18.4	18.9	18.8	18.9	18.8	18.7	19.0	20.1	19.6	20.3	19.8	19.6	19.2	19.5	19.7	19.3	19.3	20.1	19.0	19.7	19.6	19.2	19.4	19.4	19.44	0.47
		Var	2.2	1.8	1.8	1.6	1.6	2.0	1.9	1.5	2.4	1.2	2.0	2.0	2.0	2.2	2.1	1.2	1.9	1.3	1.6	1.8	2.0	1.9	1.0	1.8	2.0	1.2	2.0	1.4	1.7	1.6	2.0	1.1	1.75	0.36
	Extropalated DoW Data (1:1.081ratio to Site)	Max	21.0	20.8	20.8	20.6	20.8	21.0	20.1	20.0	20.1	19.3	20.0	20.1	20.0	20.1	20.3	20.5	20.7	20.7	20.7	20.6	20.5	20.6	19.9	20.3	20.5	20.5	20.2	20.3	20.5	20.0	20.6	19.7	20.36	0.38
		Min	18.9	19.1	19.1	19.1	19.3	19.0	18.3	18.5	17.7	18.2	18.1	18.2	18.0	18.0	18.3	19.3	18.9	19.5	19.1	18.8	18.5	18.8	18.9	18.6	18.6	19.4	18.3	19.0	18.8	18.5	18.7	18.7	18.69	0.45
4880	Trend Analysis	Max	18.9	18.6	18.4	19.2	18.7	18.9	18.8	18.6	18.9	19.0	18.8	19.0	18.8	18.9	18.5	18.7	19.1	19.3	18.9	19.3	18.8	19.0	18.7	18.6	19.0	18.9	18.9	18.9	19.0	18.8	18.8	18.6	18.85	0.21
		Min	17.5	17.3	16.8	16.6	17.4	16.6	16.7	16.7	16.8	17.1	17.4	17.3	16.9	16.8	17.0	17.8	17.0	17.8	17.8	17.4	17.4	18.2	18.2	17.7	17.8	18.1	18.2	18.4	18.1	18.4	18.7	18.3	17.50	0.61
		Var	1.4	1.3	1.7	2.5	1.3	2.3	2.1	1.9	2.1	2.0	1.4	1.7	1.9	2.0	1.4	0.9	2.1	1.4	1.1	1.9	1.4	0.9	0.6	0.9	1.1	0.8	0.7	0.4	0.9	0.4	0.1	0.4	1.35	0.63
	Extropalated DoW Data (1:0.961ratio to Site)	Max	20.5	20.1	19.9	20.7	20.2	20.5	20.4	20.1	20.5	20.6	20.3	20.5	20.3	20.4	20.0	20.2	20.7	20.8	20.5	20.9	20.3	20.6	20.3	20.1	20.5	20.4	20.5	20.4	20.5	20.3	20.3	20.2	20.39	0.23
		Min	19.0	18.7	18.1	18.0	18.8	18.0	18.1	18.0	18.2	18.4	18.9	18.7	18.2	18.2	18.4	19.3	18.4	19.3	19.3	18.8	18.8	19.6	19.6	19.1	19.3	19.5	19.7	19.9	19.6	19.9	20.2	19.8	18.93	0.66
Mean Extropalated DoW Data		Max	20.7	20.5	20.3	20.7	20.5	20.7	20.4	20.3	20.4	20.2	20.3	20.5	20.4	20.5	20.3	20.3	20.7	20.9	20.6	20.8	20.5	20.7	20.2	20.2	20.5	20.6	20.4	20.4	20.5	20.2	20.6	20.0	20.47	0.20
		Min	19.3	19.2	19.0	18.9	19.3	18.9	18.7	18.8	18.5	18.8	18.9	18.9	18.7	18.7	18.9	19.5	19.0	19.6	19.4	19.2	19.1	19.4	19.5	19.1	19.1	19.5	19.2	19.4	19.3	19.3	19.4	19.3	19.12	0.29
		Var	1.4	1.3	1.3	1.8	1.3	1.9	1.7	1.5	1.9	1.4	1.4	1.6	1.7	1.8	1.4	0.9	1.8	1.2	1.2	1.6	1.5	1.3	0.7	1.1	1.4	1.0	1.2	0.9	1.2	0.9	1.1	0.7	1.35	0.33

A endi in ear r nd ater e rren e nter al



A endi ie eter r nd ater gs

DHW1	20.48	20.524	#N/A	18.49	18.377	18.34	18.985
DHW2	20.369	20.45	19.167	19.017	#N/A	#N/A	19.577
DHW3	19.835	19.813	19.856	19.708	19.656	19.634	20.112
DHW4	20.381	20.405	19.39	#N/A	#N/A	#N/A	19.673
DHW5	20.294	20.33	19.513	19.296	19.092	19.074	19.774
DHW6	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
DHW7	#N/A	#N/A	#N/A	20.062	19.914	19.828	20.148
DHW8	#N/A	#N/A	#N/A	19.925	19.783	19.696	20.014
DHW9	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	20.017
DHW10	#N/A	#N/A	#N/A	19.742	19.6	19.52	19.981
DHW11	#N/A	#N/A	#N/A	#N/A	19.303	19.292	19.8
DHW12	#N/A	#N/A	#N/A	19.424	19.31	18.921	19.949
DHW13	#N/A	#N/A	#N/A	18.82	18.729	18.934	19.79
DHW14	#N/A	#N/A	#N/A	19.2	#N/A	#N/A	19.502
DHW15	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
DHW16	#N/A	#N/A	#N/A	#N/A	#N/A	19.99	20.623
DHW17	#N/A	#N/A	#N/A	#N/A	#N/A	18.904	19.775
DHW18	#N/A	#N/A	#N/A	#N/A	#N/A	20.072	20.527
DHW19	#N/A	#N/A	#N/A	#N/A	#N/A	18.467	19.751
DHW20	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	19.084
DHW21	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	19.051
DHW22	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	18.999
DHW23	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	19.298
DHW24	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	19.749
DHW25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	19.13

Note: #N/A indicated no water level was recorded, either due the piezometer being dry or not having been installed. Water levels in meters AHD.

A endi egetati n nditi n ating

Area ID	Disturbance				Weeds			Pest/Disease	Biodiversity		Total	Rating (Keighery)
	Rubbish	Clearing	Fill/Dig	Score	% Cover	Aggressiveness	Score	Score	% loss	Score		
1a	0	2	1	3	85	3	4	3	90	9	19	Degraded
1b	1	3	1	4	50	2	3	3	90	9	19	Degraded
2a	1	2	1	3	70	3	4	2	80	8	17	Degraded
2a	1	4	1	5	90	3	5	2	100	10	22	Completely Degraded
3	1	2	2	4	85	3	5	1	80	8	18	Degraded
4	0	5	3	5	100	4	5	3	100	10	23	Completely Degraded
5a	0	0	1	1	15	2	1	3	40	4	9	Very Good
5b	0	3	0	3	35	3	1	3	50	5	14	Good
5c	1	1	0	2	35	3	3	3	60	6	14	Good
5d	2	1	2	5	30	2	2	3	50	5	15	Good
5e	2	1	2	5	35	2	2	3	40	4	14	Good
5f	0	3	1	3	30	2	4	2	90	9	18	Degraded
5g	2	4	2	4	70	3	4	2	90	9	19	Degraded
5h	0	2	1	2	10	2	2	2	30	3	9	Very Good
5i	0	0	2	2	70	3	4	3	50	5	14	Good
6a	0	4	2	5	95	3	5	2	90	9	21	Degraded
6b	0	0	2	2	60	3	3	1	80	8	14	Good
6c	4	0	2	5	75	3	4	1	80	8	18	Degraded
7	0	5	1	5	70	3	4	2	100	10	21	Completely Degraded
8	1	2	2	3	40	2	3	2	60	6	14	Good
9a	2	1	1	4	30	2	2	1	30	3	10	Very Good
9b	2	2	2	5	40	2	3	2	50	5	15	Good
10a	2	0	1	3	10	2	2	1	30	3	9	Very Good
10b	4	3	0	5	20	2	3	1	50	5	14	Good
10c	4	4	1	5	45	3	4	2	70	7	18	Degraded
10d	5	3	0	5	35	3	3	3	50	6	17	Good
10e	5	4	0	5	45	3	4	4	70	7	20	Degraded
11	0	2	1	2	10	2	2	2	30	3	9	Very Good
12	3	3	3	5	85	3	4	3	80	8	20	Degraded
13	3	4	3	5	90	3	5	3	90	9	22	Completely Degraded
14	3	4	2	5	90	3	5	2	100	10	22	Completely Degraded
15	3	4	1	5	70	3	4	2	90	9	20	Degraded

Site t gra s

Photograph 1 – Taken on 09/04/09

Photograph 2 – Taken on 09/04/09

Photograph 3 – Taken on 09/04/09

Photograph 4 – Taken on 09/04/09

Photograph 5 – Taken on 09/04/09

Photograph 6 – Taken on 09/04/09

Photograph 7 – Taken on 09/04/09

Photograph 8 – Taken on 09/04/09

Photograph 9 – Taken on 09/04/09

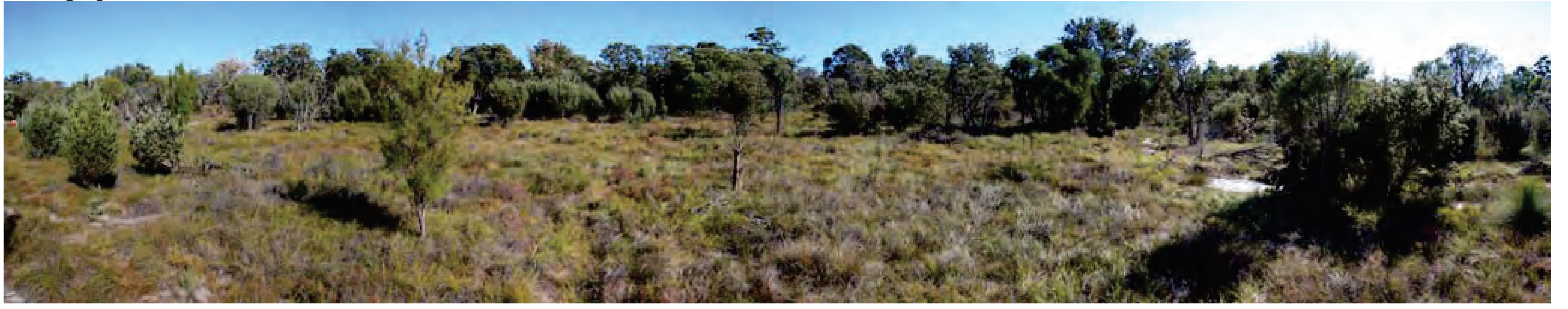
Photograph 10 – Taken on 09/04/09

Photograph 11 – Taken on 09/04/09

Photograph 12 – Taken on 09/04/09

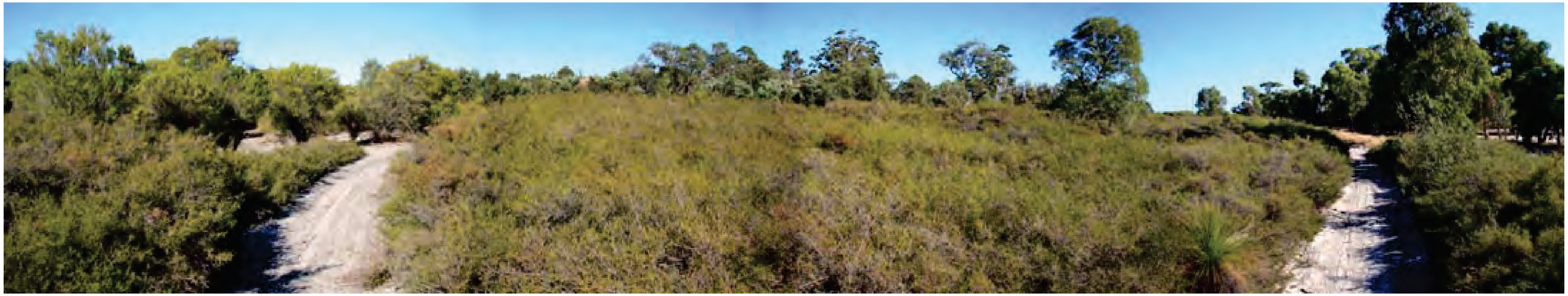
Photograph 13 – Taken on 09/04/09

Photograph 14 – Taken on 09/04/09



Photograph 15 – Taken on 09/04/09

Photograph 16 – Taken on 09/04/09



Photograph 17 – Taken on 09/04/09

Photograph 18 – Taken on 09/04/09

Photograph 19 – Taken on 21/05/09

Photograph 20 – Taken on 21/05/09

Photograph 21 – Taken on 21/05/09

Photograph 22 – Taken on 27/07/09

Photograph 23 – Taken on 27/07/09

Photograph 24 – Taken on 27/07/09

Photograph 25 – Taken on 27/07/09

Photograph 26 – Taken on 27/07/09

Photograph 27 – Taken on 27/07/09

Photograph 28 – Taken on 27/07/09