GEOMORPHIC WETLANDS
SWAN COASTAL PLAIN DATASET
REQUEST FOR MODIFICATION

LOT 123 MORTIMER RD
CASUARINA

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From the detailed hydrological studies of the Swan Coastal Plain, it is well known that superficial and deeper artesian aquifer interactions influence local water tables, and that local soil conditions (particularly the occurrence of clay and silt particles in surface soil) can create "perched" water tables which lie above local superficial aquifers.

In summary the primary judgement of whether a wetland exists is determined by local groundwater levels, and secondarily by the nature of soils which are connective to a) capillary rise of underlying groundwater creating a saturated state, and b) conditions which create local perching. Accordingly, it is hydrological studies, augmented by soil physical structure which are the major determinants of the presence or absence of wetlands.

2.2. Vegetation and Soil Type

Hill et al (1996) notes the relatedness of vegetation and soil to wetland characteristics:

"Wetland terrains may be distinguished by the occurrence of water, or waterlogged soils, or vegetation typical of water conditions (eg. swamp trees, reed beds) or hydric soil (ie. formed in response prevailing water inundation or waterlogging, and including peats, peaty sands, carbonate muds, etc.)" (p. 32)

The Collins Dictionary defines "distinguished" as: 1. to make, show or recognise a different or differences (between or among): differentiate (between). 2. to be a distinctive feature of; characterise. 3. to make out, perceive. The word distinguish does not mean define, it means show or differentiate.

Semeniuk et al. (1990) proposed a classification of wetland vegetation which can be used to augment the basic geomorphic wetland types." (p. 42) (Hill et al, 1996)

The term "augment" clearly shows the authors do not mean that vegetation defines a wetland, but rather that it assists the classification of wetlands once they are so defined.

This is further elaborated in section 3.5 where the study details the importance of field verification of wetlands

> *"Wetland vegetation, which is a good indicator of hydro-period needed to be assessed in the field. In many instances aerial photographic work can only reveal a closed forest or a heath, without any indication as to whether water levels or hydro-period, and compositional differences between forest and heath types (eg. Melaleuca preissiana forest and Melaleuca rhaphiophylla forest). These differences in vegetation signal major differences in hydro-period features and cannot be ascertained from aerial photographs."* (*ibid*, p. 59)

Note the authors restate vegetation is an indicator, not a definition. The authors also chose to distinguish *M. preissiana* and *rhaphiophylla*, eruditely reflecting Marchant's observations that *M. rhaphiophylla* (Swamp paperbark) occurs in watercourses and permanent swamps, whereas *M. preissiana* (Moonah paperbark) borders watercourses and winter wet depressions.

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, although 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.

The point is raised here only to illustrate that should hydrological and soil examination provide equivocal or ambiguous results, vegetation may assist by augmenting the data. In this specific case *M. preissiana* would help define the boundary of a wetland as it occurs along boundaries.

Bioscience notes that DEC's Wetland Program Office has in the more recent past defined wetlands in terms of the presence of "obligate" wetland plants. This is not a term used in Western Australian botany and is not contained in the flora of the Perth Region, nor is it used in the Western Australian Herbarium. We note it is used in the United States Department of Agriculture, where they use the following definitions:

Indicator Code	Wetland Type	Comment
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
NA	No agreement	The regional panel was not able to reach a unanimous decision on this species.
NI	No indicator	Insufficient information was available to determine an indicator status.
NO	No occurrence	The species does not occur in that region.

We include this definition to address the status of vegetation across the site.

2.3. Groundwater Levels and Soil Type

Because groundwater is fundamentally important to areas outside environmental science, (e.g. scheme water supply, urban drainage and civil engineering) methods for measuring and monitoring groundwater are well established and an extensive dataset exists for the Swan Coastal Plain covering many decades of records.

Davidson (1995) describes at length the nature and dynamics of the superficial aquifers and notes that the watertable fluctuates seasonally about 1 m in the central sandy areas (Bassendean sands) with the maximum watertable elevation occurring during September/October.

Davidson (1995) also notes in reference to wetlands:

> *"Many of the swamps are perched above the water table and downward leakage of water is inhibited by peaty swamp deposits and in some areas, particularly south of Perth, by a ferruginous hardpan colloquially called 'coffee rock'."* (p. 11)

The term "hydritic soil" refers to chemical changes which occur when soils are permanently or intermittently waterlogged. Because void spaces between soil particles become filled with water, and because gas diffusion is much slower in liquid than in air, such soils become depleted of oxygen. As oxygen has a significant impact on redox potential, such soils become reducing, rather than oxidising. This means organic carbon accumulates and soil sulphur becomes reduced and immobilised as organic and free sulphides. Accordingly, hydritic soils progressively become darker due to accumulation of fine organic humus, and permeability becomes reduced.

Such soils on the Swan Coastal Plain also typically accumulate reduced sulphur and tend to become so-called "acid sulphate soil". Reduced sulfides also interact with free iron forming the ferricrete layer termed "coffee rock".

These characteristics of "swampiness" accurately reflect the extent and duration of inundation and waterlogging. The location of ferruginous layers is also an indicator of the Average Annual Minimum Groundwater Level.

Areas which have prolonged inundation also develop a characteristic sediment layer, with the specific composition of sediment determined by geomorphology and water chemistry during inundation. When sediments include durable materials such as invertebrate parts including shells, or diatom exoskeletons, they can become a very useful indicator of the geological history of inundation.

A further feature of inundated wetland soils relates to the progressive accumulation, under certain circumstances, of precipitated salts to form minerals such as gypsum (calcium sulphate) and limestone (calcium carbonate). These occasionally form where a wetland becomes an evaporitic basin, receiving inflow from surrounding creeks, then the water evaporates of summer months, leading to increases in dissolved salts above their solubility thresholds. In the Perth region, such depositional wetlands are common close to the coast, but occasionally inland wetlands (e.g. Forrestdale Lake) have such deposits.

As a result of many physical and chemical processes which occur in the presence of water, soils develop characters that can be identified for determination of wetland presence and boundaries. Wetland soils can thus be identified using soil morphological indicators such as:

- Accumulation of organic matter
- Sediment layer
- Gleyed soil colours
- Soil mottling
- Iron or manganese aggregations
- Oxidising root channels and soil pore linings
- Reducing of sulfur and carbon (ie Acid Sulfate Soils)
- Precipitated salts

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.

2.4. The Classification of Wetlands

When a site has been defined as a wetland, in order to classify that area in terms of appropriate management, an assessment is undertaken using the protocols described in EPA Bulletin 686 "*A Guide to Wetland Management in Perth and near Perth Swan*

Coastal Plain area". By using a structured assessment protocol which considers both natural and human use attributes, a wetland is classified into one of three management categories, Conservation Category (CCW), Resource Enhancement (REW), or Multiple Use (MUW). Management decisions in relation to appropriate land use can then be made.

The system of classification is currently under revision, and has been for quite some time. The protocol for proposing modifications to the Geomorphic Wetlands Swan Coastal Plains dataset (2007) states:

> *"DEC is currently preparing an evaluation method guideline to assign wetland management categories, which will consolidate and replace the evaluation method in Hill et al (1996a), V & C Semeniuk Research Group (1998), and the EPA Bulletin 686 A Guide to Wetland Management in the Perth and Near Perth Swan Coastal Plain Area (EPA 1993)"* (p. 1)

The wetlands re-assessment protocol provides very little by way of further guidance other than to the references previously used, however it requires a far greater amount of work to be undertaken, particularly in relation to definition of vegetation, where comprehensive vegetation surveys are required. The draft is paradoxical in that none of the cited references contained therein require such a detailed assessment of vegetation.

One important reference is Tiner (1999) *Wetland indicators, a guide to wetland identification, delineation, classification and mapping* which refers to wetlands in the US. Most importantly, whereas Hill et al (1996) refers in general terms to distance to watertables, Tiner is quite specific as to how far the watertable must rise and for what duration before an area is classified as a wetland. Tiner (1999) also modifies this definitional benchmark according to soil permeability such that the distance to groundwater is decreased for highly permeable soil, and increased for lower permeability soil.

A further enhancement Tiner brings to wetland classification in WA is a careful and detailed description of hydritic soils (which although mentioned, are not defined by Hill et al).

2.5. Field Verification

Hill et al (1996) state at 3.12 that field verification is important for classifying wetlands for several reasons:

- Climatic variations influence wetlands, and field investigations are needed to determine such changes
- The maximum and minimum water levels in wetlands are required in order to apply geomorphic wetland classification
- Wetlands have to be classified according to the present water regime, as drainage modifies the wetness characteristics of the system.
- Wetlands in unusual or particular settings require field studies to clarify their attributes.
- As previously mentioned, vegetation can provide indicators of hydro period, and these cannot be ascertained from aerial photograph.

3. DESKTOP STUDY

3.1. Climate

The south west of Western Australia is characterised by a Mediterranean climate comprising hot dry summers and cool wet winters. According to the Bureau of Meteorology the average annual rainfall within the vicinity of the site is 827.7mm (Jandakot Aero No. 009172). The monthly distribution of rainfall (Figure 2) indicates approximately 85% of the rainfall occurs during the months of May to October. The potential annual evaporation of the area is 1800 mm, which is significantly more than annual precipitation (Davidson and Yu, 2006). The prevailing wind is from a south-westerly direction, however easterly winds common, particularly in the summer months.

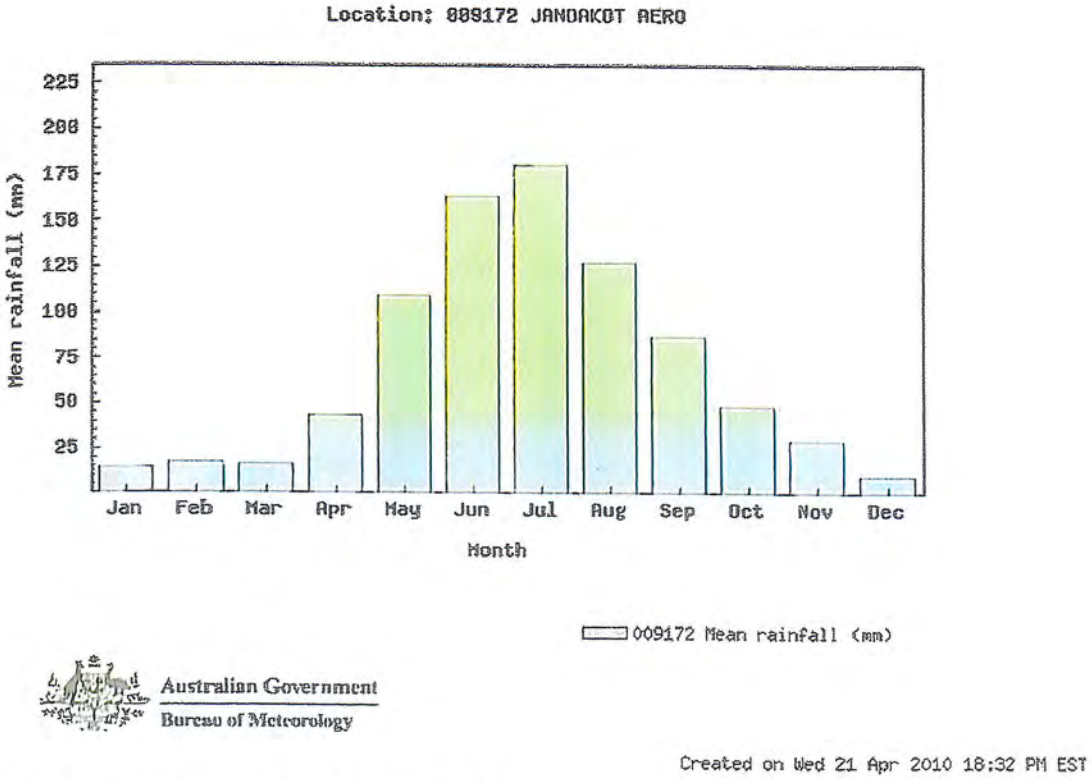
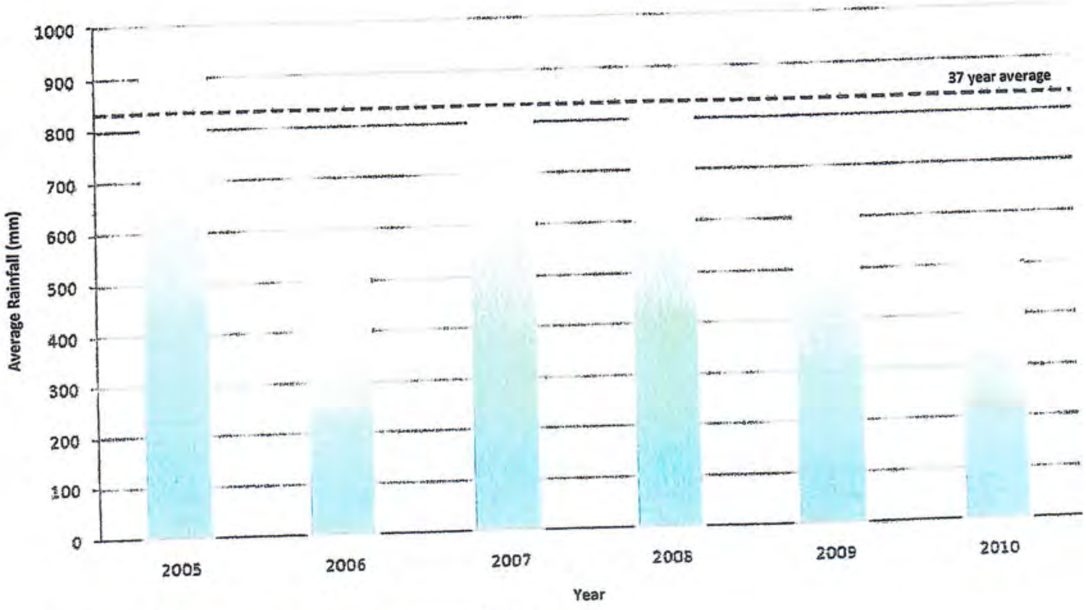


Figure 2: Average Annual Rainfall 1972-2010

The average rainfall over the 6 year study period for this report varied markedly, with some years receiving average or slightly above average rainfall and others with significantly less rainfall than the 37 year average, with 2006 and 2010 receiving nearly half the average amount. However, 2005 recieved 13% more rainfall than the average and 2008 received 5% more rainfall than the average (Figure 3).



Data from Bureau of Meteorology website www.bom.gov.au (Accessed 14/04/11)

Figure 3: Rainfall over the study period

3.1.1. Climate change

Australia is one of the driest continents in the world and the affects of climate change are no more obvious than in south-western Australia. Time series charts such as figure 4 illustrate an excessive decrease in annual rainfall over the past 100 years. Decreasing rainfall and increasing temperatures over south-western Australia has had grim consequences for the Swan Coastal Plain's diverse wetlands. These factors have left many wetlands dry due to decreased groundwater recharge and increased evaporation.

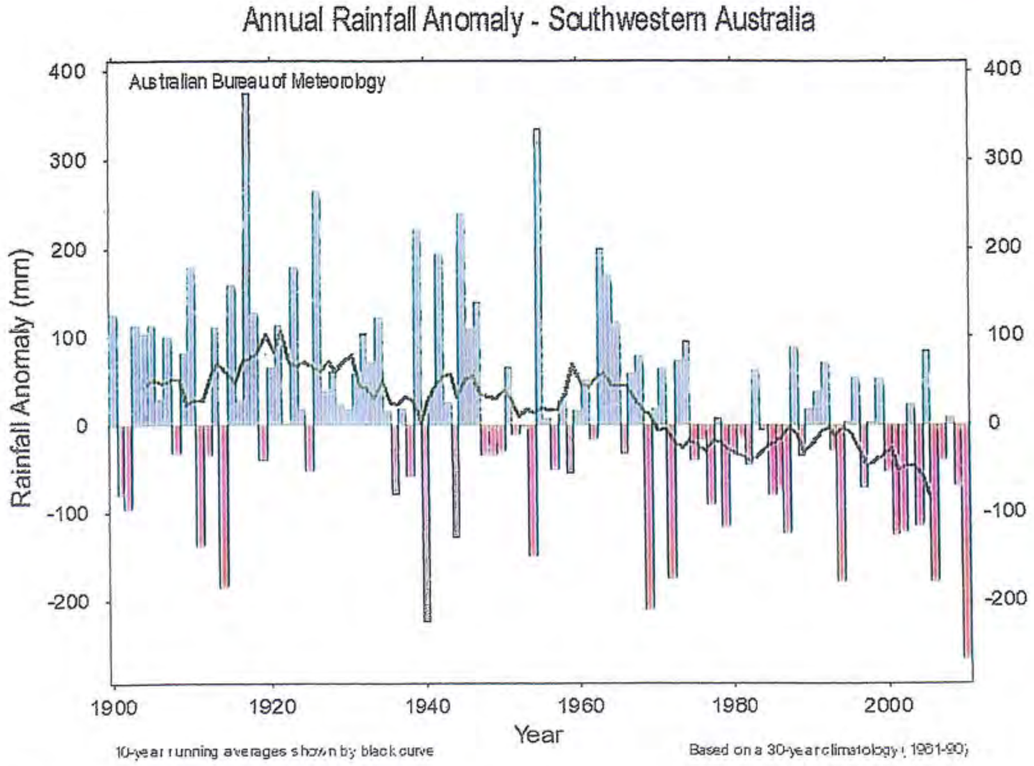


Figure 4: Annual rainfall anomaly for south-western Australia

Climate change predictions indicate that the current trend is likely to continue into the future as a result of human activity. Climate change projections to 2030 in Australia's south-west include an eight percent reduction in average rainfall compared to 1980-99 average rainfall data (DoW, 2009).

3.2. Geomorphic Dataset

The original wetland mapping for the Swan Coastal Plain is contained in Hill et al. (1996) Volume 2b. This was progressively transformed into a digital data set which is now contained within the Western Australian Land Information Service available through the internet (www.walis.wa.gov.au).

In 2002 part of the northern section of the property was classified as Conservation Category Wetland (CCW) under the Department of Environment's Wetland classification guidelines. Four other areas respectively classified as Resource Enhancement Wetlands (REW) also overlap the site (Figure 9).

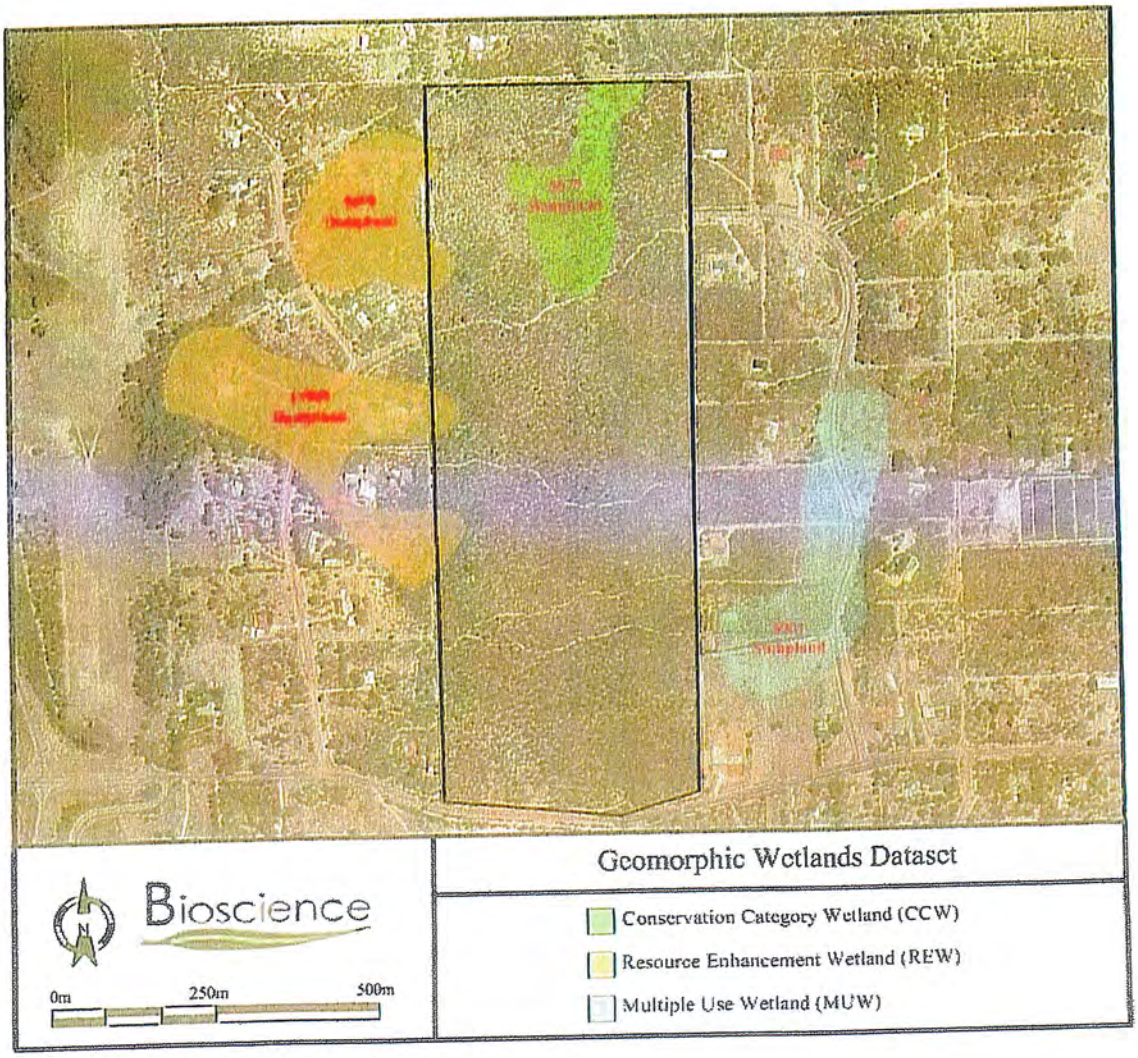


Figure 5: Geomorphic Wetlands Dataset Map

3.3. Topography

The area is undulating and according to the WA Atlas, elevation ranges from 38m AHD in the south eastern corner to 16m AHD in the demarked northern wetland areas and areas along the western boundary. The average height for the area is between 24 to 30m AHD with a general slope from south-east to north-west (Figure 6 contours from WA Atlas).

Bioscience formed the view these elevations were not consistent with other data, so the height was determined in the field using base-corrected differential GPS which is standard surveying equipment and accurate to 2 mm AHD. This work showed the northern demarked wetland had a minimum elevation of 17.605 m AHD and an average of 18.12 m across the relatively flat area. This was subsequently confirmed by the Water

Corporation survey of local drains undertaken in 2009 as part of the Peel Main Drain study for the Department of Water. That study found the wetland area had elevations of 18.40 m at the northern boundary and 18.2 m near the middle of the demarked wetland.

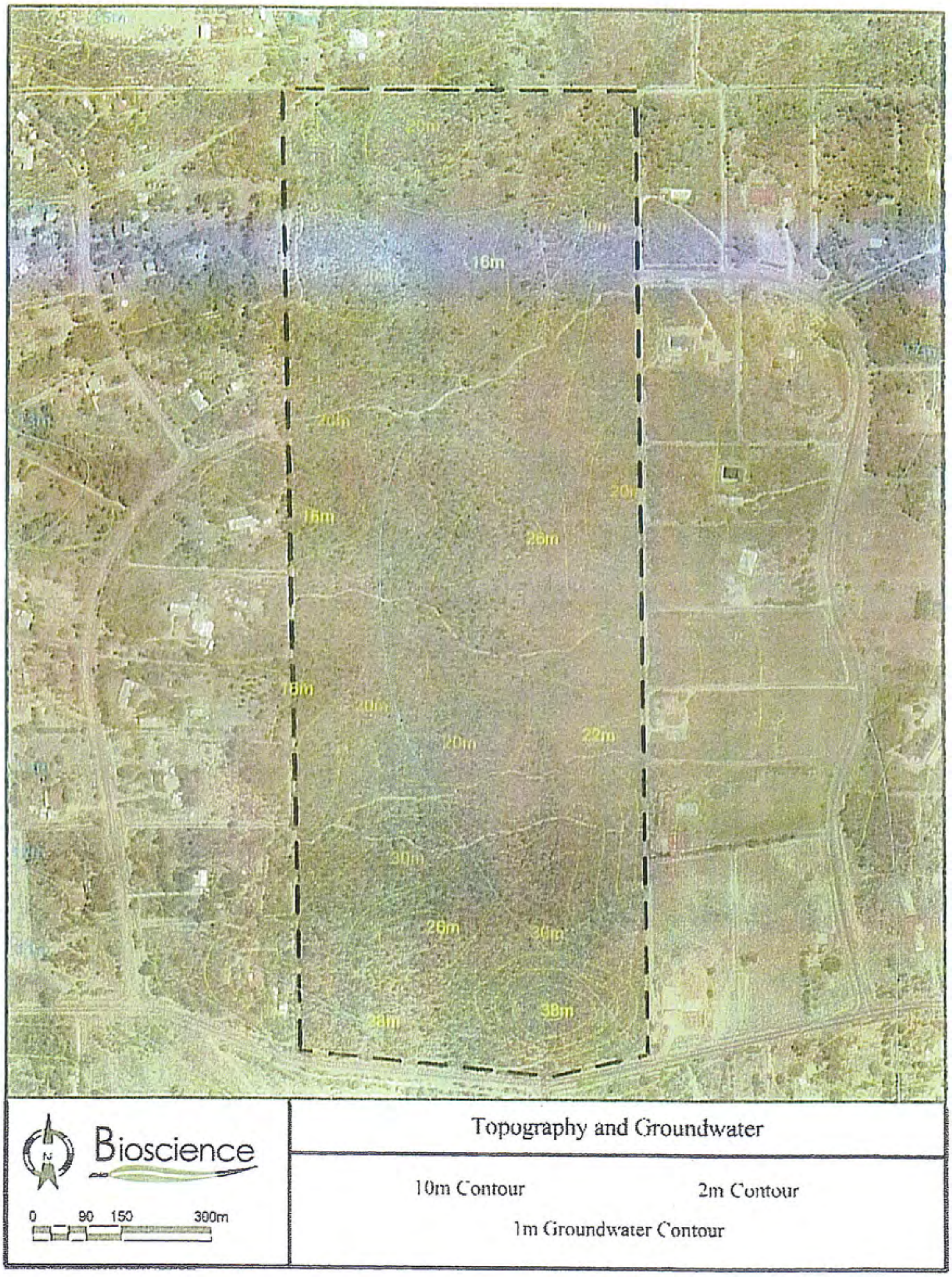


Figure 6: Topography and groundwater contours

3.4. Site Geology and Geomorphology

The subject site is located on the Swan Coastal Plain within the Bassendean dune system, an area characterised by low dunes of siliceous sand interspersed with poorly drained areas or wetlands. Soils tend to be a deep bleached grey colour sometimes with a pale yellow B horizon or a weak iron-organic hardpan at depths generally greater than 2 m.

Underlying the Bassendean formation is the Guildford formation. The soils of the Guildford formation are complex, and comprise a successive layering of soils formed from erosion of material from the scarp to the east. Rivers and streams have mostly carried the eroded material, which is deposited from the water as fans of alluvium. The Guildford formation is characterised by poor drainage due to the low permeability of sub-soil clays which prevent the downward infiltration of rainfall, consequently during the winter month's water logging and surface inundation can occur. In addition, the clay fraction of the Guildford formation is known to have highly variable Plasticity Indices (Hillman *et al.*, 2003).

The geology at the site as per the Geological Survey of Western Australia 1:50000 Environmental Geological Series Fremantle Map part of sheets 2033 I and 2033 IV and Rockingham Map part of sheets 2033 II and 2033 III are either (Figure 6):

- CPS – PEATY CLAY – Dark grey and black, soft, variable organic content, some quartz sand in places, of lacustrine origin
- S8 – SAND – Very light grey at surface, yellow at depth, fine to medium grained, sub-rounded quartz, moderately well sorted, of eolian origin

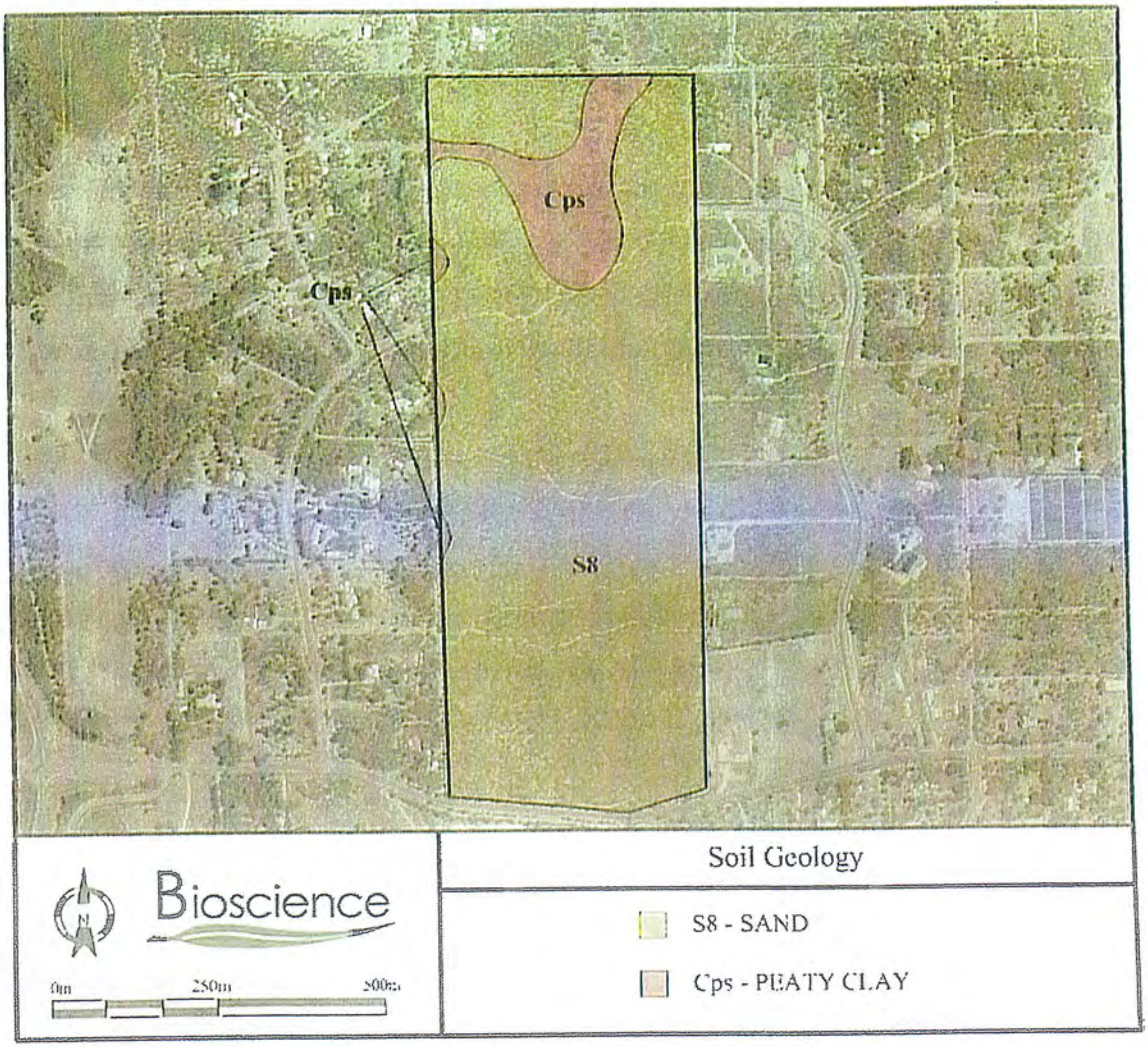


Figure 7: Soil Geology

3.5. Hydrogeology

According to Davidson and Yu (2006) the study area appears to be located within the Jandakot Mound, which is bounded to the north by the Swan and Canning Rivers, to the east by Southern River and Byford superficial aquifer, to the south by the Karnup Drain and to the west by the Ocean. Given this mapping was conducted on a regional scale the actual hydrogeology of the site may be rather complex.

The majority of groundwater recharge like other areas within the Swan Coastal Plain, results from rainfall infiltration, however additional recharge results from rainwater runoff from the Darling Scarp (Davidson and Yu, 2006). An estimated annual recharge of