Wetland Mapping and Management

Mt Adams Road, Dongara

Prepared for

Tiwest Pty Ltd

by

Endemic Pty Ltd

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Executive Summary

Tiwest Pty Ltd on behalf of the Tiwest Joint Venture (Tiwest JV) proposes to mine an area 20 kilometres to the south east of Dongara which contains a number of discrete titanium/mineral sand deposits. This extraction of mineral sands below the watertable is likely to cause drawdown of the superficial aquifer, which has the potential to adversely impact wetland habitats and phreatophytic vegetation (where present).

Tiwest commissioned Endemic Pty Ltd to characterise the wetland features within and surrounding the project area, and evaluate potential impacts arising from the proposed sand mining operations within the Dongara leases.

For the purpose of this investigation, wetland mapping and classification was undertaken in accordance with the *draft Framework for Mapping, Classification and Evaluation of Wetlands in Western Australia* (DEC, 2007). Determination of the wetland management category is based on 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).

The site is bounded to the east by the Gingin Scarp. The Gingin Scarp is characterised by a westerly facing slope and is the source area of two small relict ephemeral drainage systems that flow onto the project site (Mt Adams Creek and Tomkins Rd Creek). These drainage systems are poorly defined and terminate on site as a series of deltaic fans which recharge the aquifer locally. Streamflow in these ephemeral creek systems is infrequent and episodic, a reflection of their localised catchments, sandy soils and rainfall regime. The Mt Adams Creek has been gauged since July 2007, with the only streamflow recorded occurring within a single 2 hour period as a result of intense rainfall during Winter 2008.

The occurrence of a relict palaeo-lake system within the project area has been previously identified by Semeniuk (1994). It is assigned to the Beharra Spring consanguineous wetland suite and described as an intermittent dampland containing horizons of fossil wetland soils (Semeniuk, 1994). Where the relict palaeo-lake remains exposed within the project area it appears as a modern day dampland of irregular morphology, referred to as the Zeus and Hebe wetlands (Figure 3). In light of the palaeo-lake origins and short periods of inundation (likely to be exacerbated by a drying climate), and as confirmed by field investigation, the wetlands within the project area are classified as damplands.

The hydrology of the damplands is controlled by meteoric recharge and groundwater hydrology, with no surface water flows having been observed discharging to the wetlands during the course of this investigation. During peak groundwater conditions (August-October), the northernmost extent of the palaeo-lake system may contain surface water (~0.5m depth) for as long as 2-4 months of the year. Generally, the depth of burial of the relict palaeo-lake beneath the Eneabba Plain sand sheet progressively decreases from south to north across the project area. Accordingly, the duration of wetland inundation is at its greatest north of Mt Adams Road, where the palaeo-lake sediments exhibit their greatest degree of exposure.

Field surveys and groundwater monitoring verify that damplands within the project area are not generally subject to prolonged periods of inundated or waterlogging, although the periodicity of inundation does tend to progressively increase from south to north across the project area (and markedly so north of Mt Adams Road). The northernmost extent of the Zeus wetland may contain surface water (~0.5m depth) for approximately 2-4 months dependent upon seasonal rainfall.

The stratigraphy within the palaeo-lake system is highly variable and complex. In turn, the hydrological connectivity between the paleo-lake and the underlying superficial aquifer is thought to be as equally complex and to vary between ‘unconfined’ (direct expression of the superficial aquifer) through to ‘perched’ seasonal groundwater where clays, silts and silcrete may be present. In its present-day form, siliceous pans and clay and silt lenses associated with the palaeo-lake system serve to retard the vertical movement of meteoric rainfall, resulting in groundwater ‘perching’ and/or elevated soil moisture in the overlying sediments. The extent of this retardation appears to be spatially discontinuous due to the high variability of the soil profiles surveyed, some with an impeding subsurface layer, some without.

Generally, vegetation within the project area remains largely undisturbed and in Pristine to Excellent condition (Woodman, 2008). The limited areas of soil and vegetation disturbance are largely confined to areas associated with the Perth-Dampier gas pipeline which traverses the site from north to south; the Beharra Springs gas plant and exploration survey lines and (limited) access tracks.

In accordance with general provisions of EPA Bulletin 686, the wetlands mapped within the project area are considered ‘Conservation Category Wetlands’ (CCWs), due to low levels of disturbance and high degree of naturalness. As the project area lies outside the area of coverage of the *Wetlands of the Swan Coastal Plain* database (DEC, 2010) a detailed analysis of regional significance, consanguineous suite representativeness and conservation ranking has not been possible.

On reviewing the proposed mine plan, the two significant impacts likely to arise from the proposal were considered to be direct impacts from clearing and mining of wetland areas and immediate surrounds and indirect impacts arising from groundwater drawdown associated with groundwater abstraction and mine pit dewatering.

1. Introduction

1.1 Site description

Tiwest Pty Ltd on behalf of the Tiwest Joint Venture (Tiwest JV) proposes to mine an area 20 kilometres to the south east of Dongara which contains a number of discrete titanium/mineral sand deposits (Figure 1). The area covers six mining leases (M 70/1195, M 70/1196, M 70/1197, M 70/1198, M 70/1199 and M 70/1200) and is mostly composed of sandy soils, ferricrete and swamp deposits.

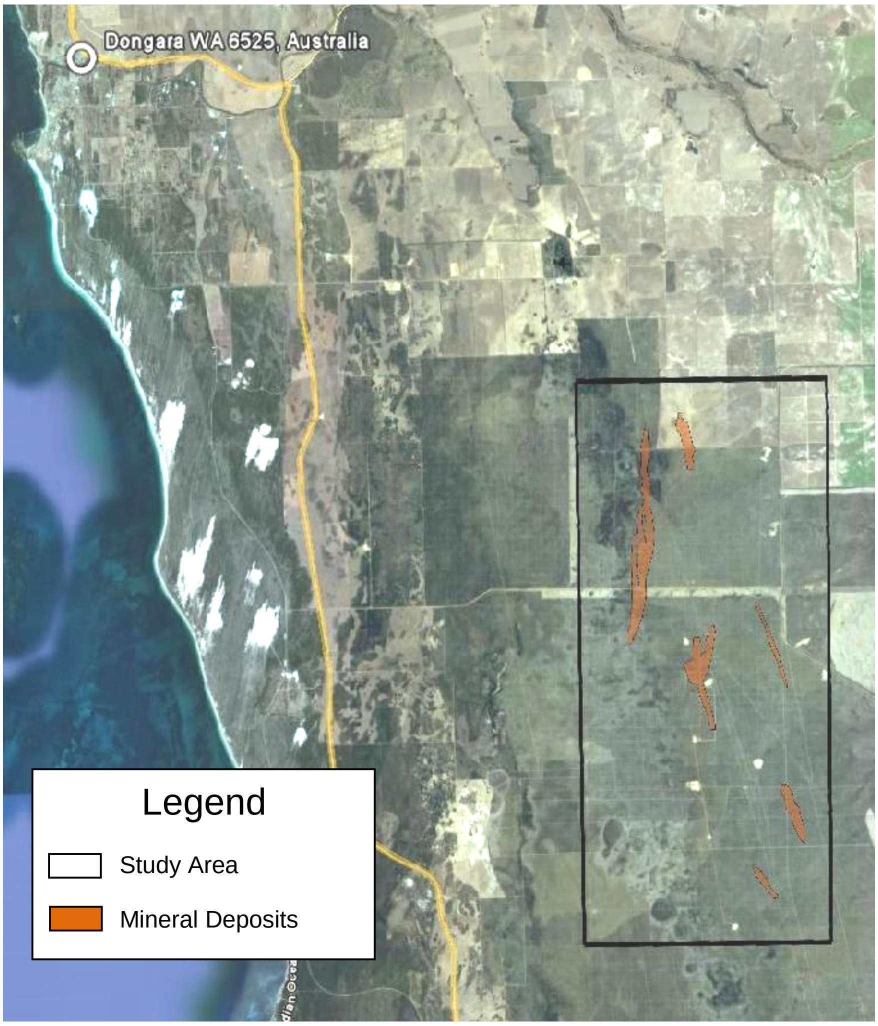

Figure 1: Tiwest Project Area with mineral sand deposits

Mining involves clearing of in-situ vegetation and excavation of the soil profile. This results in direct impacts due to land clearing and changes to the site environmental conditions. In addition to this, portions of the identified resources are below water table (within the superficial aquifer) necessitating dewatering during mining. This is likely to cause drawdown of the water table, which has the potential to adversely impact wetland habitats and phreatophytic vegetation (where present).

A general description of the proposal and associated impacts was referred to the Environmental Protection Authority (EPA) by Tiwest during 2007 in accordance with Section 38 of the *Environmental Protection Act 1986*. The EPA set a level of assessment of Public Environmental Review (PER) in September 2007 with the requirement for a four week public review period.

Tiwest commissioned Endemic to update the wetland mapping and to re-evaluate the associated management objectives for wetlands located within the mining leases. Endemic visited the site between 2007 and 2009 to undertake wetland mapping and verify wetland habitat assessments.

1.2 Study aims and objectives

The aim of this project was to evaluate potential wetland impacts arising from the proposed sand mining operations within the Dongara leases. This involved conducting field surveys to verify wetland boundaries and wetland management objectives within the mining leases. The resultant wetland mapping was then used to evaluate potential wetland impacts arising from direct and indirect factors.

This was achieved by:

- Reviewing the existing information on wetlands, soils, vegetation and landforms within the study area;
- Field inspections to map and verify wetland management objectives and assess the condition of vegetation communities within the wetland areas and identify potential buffers;
- Preparation of a report containing the various data collected, wetland management objectives and general discussion of potential wetland impacts.

2. Existing Environment

2.1 Climate

The region has a Mediterranean climate characterised by hot, dry summers and mild, wet winters. The average annual rainfall at the nearest Bureau of Meteorology stations, Carnamah (008025) and Eneabba (008225), is 384mm and 504mm respectively. Approximately 90% of the total annual average rainfall falls between April and October, with annual evaporation being 4.4 times the annual rainfall.

2.2 Geomorphological setting

The Dongara lease is located in the northern Perth Basin, which forms part of the Swan Coastal Plain.

The mining leases are located within the Geraldton Sandplains (GS) Bioregion (Environment Australia, 2000) and comprise undulating, lateritic sandplains mantling Permian to Cretaceous strata. The areas within the mining leases form part of the Lesuer Sandplain and comprise coastal aeolian sands and limestones, Jurassic siltstones and sandstones of the central Perth basin (Desmond and Chant, 2001).

The northern portion of the Swan Coastal Plain consists of a series of geomorphological elements which are sub-parallel to the present coastline (McArthur and Bettenay, 1960). Each of these geomorphic elements (Quindalup Sands, Spearwood Sands and Bassendean Sands) has distinctive geology, vegetation, topography and soils. The Dongara leases lie wholly within the Eneabba Plains (Blandford & Associates, 2007), with isolated overlapping calcareous Spearwood Sands, as shown in Figure 2.

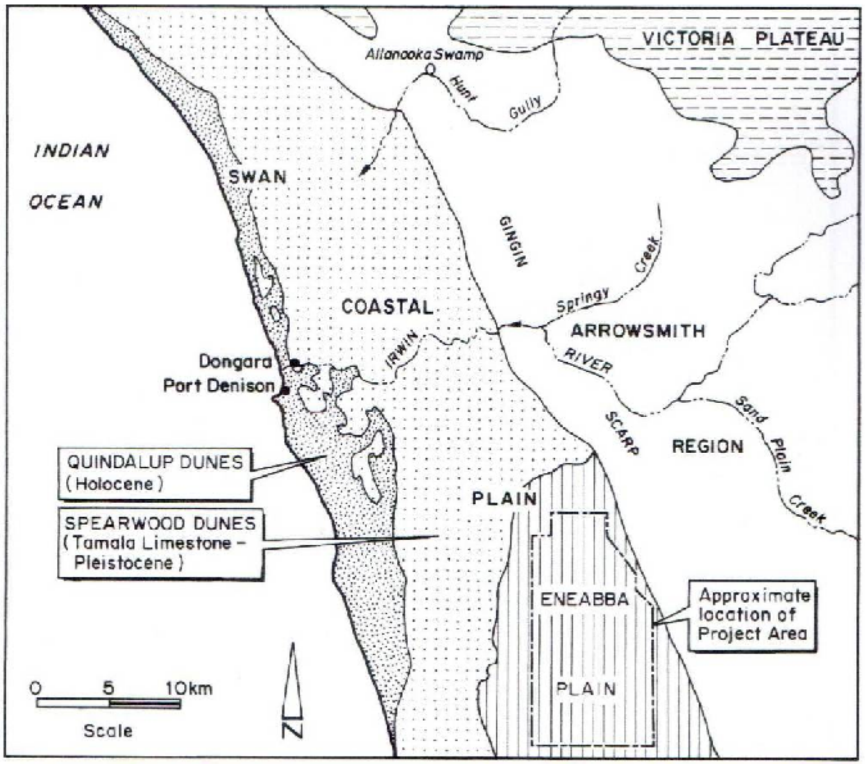

Figure 2: Stratigraphic framework covering the Tiwest leases (Blandford & Associates, 2007).

2.2.1 Soil Descriptions

The Eneabba Plain is an area of undulating but gently rising plain between the Tamala Limestone (formerly Spearwood Sands) and the Gingin Scarp. The Eneabba Plain is the north-western extension of the Bassendean Dune System and comprises a series of early Pleistocene shoreline lagoon and dune deposits having locally high concentrations of heavy minerals. These deposits are associated with a series of low alluvial fans fronting the Gingin Scarp (Playford *et al*. 1976).

Blandford and Associates (2007) described three soil landscape units within the Dongara project area, namely the Eastern Ferricrete/Clay unit, the Central Sand Plain and the Western Relict Paleo Lake System. Sands within these landscape units typically comprise alluvium sands silts and clays, ferruginous laterites, non-calcareous (aeolian) sands, Tamala limestone, diatomaceous earth deposits, swamp and lacustrine deposits.

Ferruginous laterites

Hard pan layers can form at the water table in the sands within the Eneabba Plain. They are mostly recognised as ferricrete, or "coffee-rock", where an indurated (cemented) layer is formed through the accumulation of interstitial iron oxide silt and clays. Ferricrete in the study area is weakly to moderately cemented.

Outcropping ferricrete in the vicinity of Mt Adams Creek has been observed shedding localised runoff during periods of rainfall, suggesting the permeability of these hard pans may be low when well lithified.

Non-calcareous sands (Aeolian)

Yellow Bassendean Sand

The yellow sand represents the original desert environment dunes formed on the Swan Coastal Plain during the Pleistocene period. It is comprised of medium to fine grained quartz sand with a distinctive yellow colouration formed by an envelope of iron oxide, kaolinite and quartz silt that surrounds the exterior of the grain.

White to Grey Bassendean Sand

This sand is the product of leaching of the yellow coating from the quartz grains from the original dune sand by infiltration of rainfall through the vadose zone into the water table below. The sand is thus white to grey, medium to fine grained quartz with no interstitial fine grained material. The white to grey sand was encountered in all bores on the site and is present as degraded dunes and inter-dunal sand plains overlying the Guildford Formation.

Tamala limestone

The Spearwood Sands are the central of three main ancient aeolian (or dunal) deposits found on the Swan Coastal Plain that increase in age sequence eastward of the present day coastline. The Spearwood Sands generally consist of variably indurated Tamala limestone (coastal limestone), yellow ferruginous quartz sand and minor clay. However, wetlands are known to be associated with the organic-rich phases commonly found in the inter-ridge depressions (swales) of the Spearwood Dunes and also in closed depressions (dolines) associated with cavernous limestone of the Spearwood Dunes.

Swamp and lacustrine deposits

The swamp and lake deposits have developed through the accumulation of vegetation in areas of shallow groundwater and surface water inundation. The majority of swamp deposits in the region coincide with areas that have been mapped as aeolian deflation hollows that have formed during the Late Holocene by wind erosion of the Bassendean

Sands. The erosion has occurred after the deposition of the Bassendean Sand, but prior to saturation of the sand by groundwater. The hollow remains as a topographic depression that accumulates surface water as an expression of a rising groundwater table, promoting localised vegetation growth.

In some areas, the absence of the overlying sand sheet (or its removal through deflation) has exposed the earlier palaeo-lake sediments and associated relict wetland features.

2.3 Hydrology

Surface water drainage into the mining leases originates from the Gingin Scarp to the east of the site. All water courses arising from the Scarp terminate in swamps or lakes in the inter-dunal depressions on the site.

At present rainfall is insufficient and the floors of the watercourses too permeable for the surface drainage systems to flow on a regular basis (that is, the watercourses are ephemeral). The surficial drainage pattern is towards the west, reflecting the general landscape of the sedimentary basin.

2.3.1 Watercourses

The site is bounded to the east by the Gingin Scarp, which reaches its maximum elevation of 256m at Mt Adams. The Gingin Scarp is characterised by a westerly facing slope and is the source area of two small relict ephemeral drainage systems that flow onto the project site (Mt Adams Creek and Tomkins Rd Creek). These drainage systems are poorly defined and endorheic, in so much as they are closed basins and do not outflow to rivers or the ocean. Rather, these watercourses terminate on site as a series of deltaic fans which recharge the aquifer locally.

Streamflow in these ephemeral creek systems is infrequent and episodic, a reflection of their localised catchments, sandy soils and rainfall regime (estimated to be 450mm/year). The Mt Adams Creek has been gauged since July 2007, with the only streamflow recorded occurring within a single 2 hour period as a result of intense rainfall during Winter 2008.

2.3.2 Groundwater Hydrology

The superficial aquifer is an unconfined aquifer hosted within the Tertiary-Quaternary sediments of the coastal plain. Within the project area, the superficial aquifer extends to approximately 30-40 meters below ground level and overlies the deeper (confined) Yarragadee aquifer.

Several studies and reports have detailed the hydrogeology within the project area and have been used as a source of information and data. The reports are summarised below:

- The West Midlands Hydrology Project (Earth Tech Engineering, 2002);
- Regional groundwater investigations by the Geological Survey of Western Australia (GSWA, 1986);
- Hydrogeological Assessment of Groundwater Availability from Superficial and Yarragadee Aquifers for Mineral Sand Mines near Dongara (Hydrosearch, 2008); and
- DoW AQWA database bore search.

The regional hydrogeological conditions are summarised from information contained in these reports as follows:

- The site is broadly divided into three soil landscape units, namely the Eastern Ferricrete/Clay unit, the Central Sand Plain and the Western Relict Paleo Lake System (Blandford & Associates, 2007).
    - The Eastern Ferricrete/Clay soil landscape is complex with 1-2 meters of alluvium and/or Bassendean sand horizons overlying lower horizons of ferricrete rubble and gravel associated with non-smectite clays. In some areas the sand horizon is almost completely eroded, leaving the clayey horizon just below the surface.
    - The Central Sand Plain soil landscape comprises deep and uniform fine to coarse alluvium and/or Bassendean sands. The maximum excavation pits defined the sands down to at least 3 meters. The sheet sands are complex and are likely to overlie the deeper ferricrete horizon towards the eastern side of the area. In some areas, the paleo lakes have been covered by the sheet sands, whereas in other areas, the old lakes remain uncovered by the sheet sand horizon.
    - The Western Relict Paleo-Lake System is the surface exposed remnant of a past, well developed fluvio-lacustrine system. The soil landscape comprises a discontinuous series of highly stratified sediments. The soil profiles in these areas are highly complex, with no two alike, although all profiles observed contained silica in the form of nodules, pendants and pinnacles. A number of sites displayed secondary precipitation of silica over partially cemented

and porous clean sands. In some parts, the silica was interbedded with, or infused with calcium carbonate. Field evidence suggests much of this system does not exhibit prolonged periods of inundation or waterlogging, although localised retardation of infiltration may promote soil moisture dependency in overlying vegetation communities;

- the superficial aquifer is unconfined with median water levels ranging from 20 to 30 meters AHD across the site;
- groundwater recharge occurs mainly via rainfall infiltration of the sandy sediments of the Alluvium and/or Bassendean Sands. During periods of heavy rainfall and saturation of the near subsurface, waterlogging occurs and surface water flows westerly towards the wetlands;
- groundwater flow in the superficial aquifer is primarily to the west; and
- the groundwater table is at a minimum between January and March, and at a maxima from August to October.

2.4 Flora and Vegetation

Vegetation, soils and landforms within the Dongara project area were mapped and described by Beard (1976) and include the Illyarrie, Eridoon and Tathra Systems.

Regional vegetation complexes are dominated by Proteacea (*Grevillia*, *Banksia*), Myrtaceae (*Eucalyptus*, *Melaleuca*), Mimosaceae (*Acacia*), Casuarinaceae (*Casuarina*, *Allocasuarina*), Asteraceae (daisies), Chenopodiaceae (salt bushes) and Poaceae (grasses).

The Illyarrie System consists of open woodlands of *Eucalyptus erythrocorys* (up to 10m) over an open shrub understorey of *Acacia blakelyi*, *A. pulchella, A. spathulata, Dryandra sessilis, Hakea costata, Hibbertia hypericoides, Hibiscus huegelii, Hybanthus calycinus, Scholtzia* sp. and Restionaceae (Beard, 1976). North of the Arrowsmith River the vegetation complexes include thickets of *Acacia, Melaleuca* and *mallee*.

The Eridoon System consists of scattered small trees up to 5m, with an open layer of tall shrubs of 1-3 m and a closed layer of small heath like shrubs <1m (Beard, 1976). In the low lying areas, heaths are present to approximately 30cm with scattered *Xanthorrhoea, Calytrix strigose, Eremaea pauciflora, Grevillia eriostachya, Melaleuca scabra, Petrophile media* and Restionaceae. In the wetter areas, *Melaleuca thyoides, M. lanceolata and M. rhaphiophylla* are present.

The Tathra System consists of low, lateritic heaths including *Hakea auriculate*, *Dryandra fraseri, Melaleuca scabra, Allocasuarina humilis, Petrophile sp., Melaleuca* *radula* and Restionaceae (Beard, 1976), with *Eucalyptus macrocarpa* present at the tops and breakaways. The scrub heath is diverse, heterogenous and consists of scattered shrubs to 2m over a dense layer of small shrubs <1m with occasional *Nuytsia floribunda*. The taller trees (*Eucalyptus todtiana, Banksia attenuata, B. menziesii,* and *B. prionotes*) were confined to the valleys and deeper sands.

A detailed vegetation survey was conducted in November 2006 over the project area. A total of 376 vascular plant taxa belonging to 59 plant families were recorded within the study area (Woodman, 2007). Vegetation associations (VA) encountered within the project area (as defined in Shepard *et. al.,* 2000) included:

- Medium Yorkgum woodland (VA 352);
- Shrubland mosaics typical of the Illarie System (VA 377);
- Scrub heath with scattered *Banksia* spp., *Eucalyptus todtiana* and *Xylomelum angustifolium* (VA 378);
- Scrub heath on the lateritic sandplains (VA 379);
- *Melaleuca thyoides* thickets (VA 392);
- Shrubland mosaics of *Acacia rostellifera* and *Melaleuca cardiophylla* thickets with sparse low Illarie woodland (VA 433);
- Medium Rivergum (*Eucalyptus camaldulensis*) woodland (VA 619); and
- *Melaleuca* thyoides thickets with scattered rivergums (VA 748).

An addition spring flora survey was conducted in 2007 and a statistical analysis was undertaken to map the distribution of floristic community types (FCTs) (Woodman, 2008).

Where appropriate, the above vegetation mapping has been used to supplement wetland interpretative mapping within the project area. It should be noted, however, that in some cases the transition from dampland (wetland) habitat to dryland vegetation can be subtle and gradational and often difficult to discern both in the field and from the vegetation mapping (alone). In such cases, the depth-to-groundwater data has been used to further differentiate and define these gradational associations.

3. Wetland Mapping and Methodology

3.1 Methodology

A wetland is defined in Schedule 5 of the *Environmental Protection Act 1986* as 'an area of seasonally, intermittently or permanently waterlogged or inundated land, whether natural or otherwise, and includes a lake, swamp, marsh, spring, dampland, tidal flat or estuary'.

Identification and delineation of wetlands is reliant upon characteristics of hydrology, hydric soils and wetland vegetation (Hill et al. 1996). Wetland identification, delineation, classification and evaluation methods are described in detail in Hill et al. (1996), V & C Semeniuk Research Group (1998) and EPA Bulletin 686 *A Guide to Wetland Management in the Perth and Near Perth Swan Coastal Plain Area* (EPA, 1993).

For the purpose of this investigation, wetland mapping and classification was undertaken in accordance with the *draft Framework for Mapping, Classification and Evaluation of Wetlands in Western Australia* (DEC, 2007).

Experienced personnel from Endemic conducted wetland field mapping during 2008 and 2009. Transects were selected to aid interpretative mapping based upon the varying geomorphologies evident within the study area. Each transect was traversed by vehicle and/or by foot and the wetland habitat boundaries mapped using GPS. Standard recording sheets were used to ensure consistency of wetland mapping between each site and the following parameters were recorded:

- Site location including GPS coordinates
- Dominant soil types and characteristics
- Position of the site in the landscape
- Height above datum (AHD)
- Wetland boundaries

The wetland survey sites were overlain onto a Digital Elevation Model (constructed for the purpose of assisting interpretative mapping) and reconciled with groundwater level monitoring data and soil bore logs for the project area.

3.2 Wetland Classification

Wetland classification is the process of assigning wetland type on the basis of landform and water permanence using the classification system developed by the Semeniuk Research Group (1995) (Table 1).

Table 1: Wetland types defined within the geomorphic classification system (adapted from Semeniuk & Semeniuk 1995).

	Basin	Flat	Channel	Slope
Permanently inundated	Lake		River	
Seasonally inundated	Sumpland	Floodplain	Creek	
Seasonally waterlogged	Dampland	Palusplain		Paluslope

The Swan Coastal Plain Wetlands Atlas (Hill et al., 1996) identifies management objectives for wetlands and watercourses between Moore River and Dunsborough. As such, wetland mapping associated with this atlas does not extend as far north as the project area and any evaluation of onsite wetlands will thus likely require verification by the Department of Environment and Conservation.

It is understood that the Northern Agricultural Catchments Council (NACC) has recently commissioned a consultant to undertake wetland mapping and evaluation in the region, however the results from this mapping is not expected to be available for the foreseeable future.

The lease area is within an area previously assigned to the Beharra Spring consanguineous wetland suite based upon geomorphological characteristics and described as an intermittent dampland containing horizons of fossil wetland soils (Semeniuk, 1994).

The Beharra Spring Suite has been identified as being locally significant as the geographical area is commonly water-deficient, however, these wetlands increase the diversity of the local biota by providing unique conditions and niches for plants and animals that are adapted to seasonal waterlogging (Semeniuk, 1994).

Generally, the depth of burial of the relict palaeo-lake beneath the Eneabba Plain sand sheet progressively decreases from south to north across the project area. Accordingly, the duration of wetland inundation is at its greatest north of Mt Adams Road, where the palaeo-lake sediments exhibit their greatest degree of exposure. During peak groundwater conditions (August-October), the northernmost extent of the palaeo-lake system may contain surface water (~0.5m depth) for as long as 2-4 months of the year.

In light of the palaeo-lake origins and short periods of inundation (likely to be exacerbated by a drying climate), the wetlands within the project area are classified as damplands.

The absence of permanent surface water or seasonal inundation should not be taken to mean that wetland habitat is not present. In fact, dampland wetland-types can exhibit a greater range of niches and hence higher levels of biological diversity than permanent open water wetlands (i.e. lakes) (WRC, 2000). For example, the most important wetland on the Swan Coastal Plain (in terms of biological diversity) is generally considered to be the Greater Brixton Street seasonal wetland which contains 518 taxa or more than 30% of all species recorded from the Swan Coastal Plain in an area of only 127 hectares (Govt of WA, 2000).

3.3 Wetland Management Category

The 'wetland management category' refers to one of three categories in which wetlands can be placed for future management purposes, depending upon the degree of naturalness and human use values ascribed to it.

The three management categories are CCW (Conservation category wetland), REW (Resource Enhancement wetland) and M (Multiple use wetland). Determination of the wetland management category is currently based upon the evaluation method outlined 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).

The project area lies outside the area of coverage of the *Wetlands of the Swan Coastal Plain* database (DEC, 2010) and hence a detailed analysis of regional significance, consanguineous suite representativeness and conservation ranking have not been possible.

Generally, vegetation within the project area remains largely undisturbed and in Pristine to Excellent condition (Woodman, 2008). The limited areas of soil and vegetation disturbance are largely confined to areas associated with the Perth-Dampier gas pipeline which traverses the site from north to south; the Beharra Springs gas plant and exploration survey lines and (limited) access tracks.

Due to the low levels of disturbance and high degree of naturalness, the wetlands mapped within the project area are designated as 'Conservation Category Wetlands' (CCWs), in accordance with general provisions of EPA Bulletin 686.

Endemic considers the key conservation values ascribed to wetlands within the project to be their high degree of naturalness and their local significance as a model of wetland and dune evolution, noting the presence of horizons of relic palaeo-lake sediments underlying portions of the area.

3.4 Wetland Mapping and Delineation

Consistent with methods outlined by Hill (1996) and the *draft Framework for Mapping, Classification and Evaluation of Wetlands in Western Australia* (DEC, 2007), the identification and delineation of wetlands is reliant upon an understanding of wetland soils, hydrology and vegetation types.

3.4.1 Soil mapping

Tiwest has extensively explored the superficial sediments of the lease for mineral sands and established more than 2000 air drill holes within the project area (Hydrosearch, 2008).

Two detailed soil surveys have been completed to date using these soil core logs and additional test pits. The first study was undertaken in order to broadly characterise the landform and soil landscapes within the project area (Blandford, 2007). The second soil study focussed on those areas and issues specific to the project in terms of landform rehabilitation and soil reconstruction and groundwater drawdown, including soil profiling and potential groundwater dependence (Blandford, 2008).

Palaeo-lake Sediments

The occurrence of a relict palaeo-lake system within the project area has been previously identified by Semeniuk (1994).

A large portion of the relict palaeo-lake system is now buried beneath the Eneabba Plain sand sheet and what remains exposed at the surface is all that remains of an ancient, and much larger lacustrine system that was probably continuous along the length of the western portion of the project area (Blandford, 2008) (Figure 3).

Data suggest that the palaeo-lake system was once a series of discrete shallow basins, probably alternating between being interconnected and to being isolated. The scale of the interconnected basins was probably in the order of tens of metres up to hundreds of metres (Blandford, 2008). As a result, the stratigraphy within these sediments is highly variable and complex and comprises sands, clays, silts, diatomaceous earths and silcrete.

Figure 3: A palaeo-lake system underlies the western portion of the project area (Blandford, 2008).

3.4.2 Wetland Hydrology

Wetland hydrology within the project area is controlled by meteoric recharge and groundwater hydrology, with no surface water flows having been observed discharging to the wetlands during the course of this investigation.

As discussed above, the stratigraphy within the palaeo-lake system is highly variable and complex. In turn, the hydrological connectivity between the paleo-lake and the underlying superficial aquifer is thought to be as equally complex and to vary between 'unconfined' (direct expression of the superficial aquifer) through to 'perched' seasonal groundwater where clays, silts and silcrete may be present.

In its present-day form, siliceous pans and clay and silt lenses associated with the palaeo-lake system serve to retard the vertical movement of meteoric rainfall, resulting in groundwater 'perching' and/or elevated soil moisture in the overlying sediments. The extent of this retardation appears to be spatially discontinuous due to the high variability of the soil profiles surveyed, some with an impeding subsurface layer, some without.

Where the relict palaeo-lake remains exposed it appears as a modern day dampland of irregular morphology, referred to as the Zeus and Hebe wetlands (Figure 3).

Field surveys and groundwater monitoring verify that damplands within the project area are not generally subject to prolonged periods of inundated or waterlogging, although the periodicity of inundation does tend to progressively increase from south to north across the project area (and markedly so north of Mt Adams Road).

The northernmost extent of the Zeus wetland may contain surface water (~0.5m depth) for approximately 2-4 months dependent upon seasonal rainfall.

Groundwater levels have been monitored across the project area on a quarterly basis since October 2006 (Hydrosearch, 2008), with peak wetland water levels occurring between August and October. This database has been used to inform wetland mapping in the project area.

3.4.3 Vegetation mapping

Wetland vegetation is commonly a reflection of hydrology and hydric soils. In particular, obligate wetland species (that is, those plants generally restricted to wetland habitats) are considered reliable wetland indicators (DEC, 2007).

When considering wetland identification and delineation, it is also important to note that facultative species (that is, plants that can occur in both wetland and dryland habitats) can be common in damplands, or peripheral to sumpland wetlands (DEC, 2007). The occurrence of facultative species can often confound wetland mapping and hence knowledge of wetland hydrology, depth to groundwater and soil mapping is a valuable adjunct to vegetation mapping alone.

It is also important to consider the density of plant species. Plant access to elevated soil moisture levels and/or groundwater perching can give rise to increased vegetation density. This is particularly the case in the hot dry summers experienced at the project area, where rooting depths observed in test pits and topographic associations strongly suggest the plants are likely to be accessing elevated soil moisture levels where the depth of burial of the palaeo-lake sediments is <4m.

Mapping of floristic communities within the project area has been completed (Woodman, 2008) and used as an aid to wetland habitat mapping. Although the vegetation mapping is by its nature quite broad, the influence of soil moisture levels on vegetation communities in the area is pronounced and provides a useful point of reference for wetland mapping.

Wetland mapping undertaken during the course of this study has been overlain on the Regional Floristic Community Type (FCT) Analysis undertaken by Woodman (2008) and summarised in Table 2.

Table 2: Floristic Community Types (FCTs) Coincident with Wetland Habitat Mapping (after Woodman, 2008)

Floristic Community Type	Description	Geomorphology	Wetland Occurrence
FCT3b	Low Woodland to Thicket of *Banksia attenuata* and *Banksia menziesii* over mixed shrubs dominated by myrtaceous species Indicator species include myrtaceous species with shallow depth to groundwater/transitional slopes	On brown or yellow sands on lower to mid slopes and plains	Zeus
FCT9b	Low Woodland to Low Forest of *Eucalyptus camaldulensis* over Open Scrub of *Acacia rostellifera, Chamelaucium uncinatum* and *Melaleuca spp*. FCT9b differs from FCT9a due to the presence of *Eucalyptus camaldulensis* which is indicative of higher water availability. Indicator species include *Acacia rostellifera*, *Eucalyptus camaldulensis* and *Chamelaucium uncinatum*.	On grey or brown sandy clay in drainage lines and depressions. These wetlands are considered to be seasonally damp, with isolated occurrences of water ponding during winter months with high rainfall.	Zeus
FCT11	Heath dominated by *Melaleuca systena* and *Melaleuca huegelii* subsp. *huegelii* Common understorey species include *Allocasuarina lehmanniana* subsp. *lehmanniana*, *Acacia lasiocarpa* var. *lasiocarpa* and *Poranthera microphylla.* Indicator species include *Allocasuarina lehmanniana* subsp. *lehmanniana*, *Austrostipa flavescens*, *Thysanotus patersonii*, *Samolus repens* var. *floribundus*, *Acacia lasiocarpa* var. *lasiocarpa* and *Melaleuca systena*.	On grey or brown sand and sandy clay in depressions FCT11 is considered to be a seasonal dampland	Hebe

Floristic Community Type	Description	Geomorphology	Wetland Occurrence
FCT17	Shrublands and Thickets dominated by *Melaleuca* spp. and *Banksia* spp. Common understorey species include *Banksia leptophylla*, *Melaleuca leuropoma* and *Calothamnus hirsutus*. There are no indicator species recorded for this FCT.	On grey or brown sandy clays and sandy loams with some lateritic gravel on flats, depressions and creek-lines. FCT17 were recorded within seasonally damp wetlands.	Heracles Zeus Hebe
FCT18	Thicket dominated by *Melaleuca concreta* and/or *Allocasuarina campestris*. Common species include *Melaleuca huegelii* subsp. *huegelii* and *Acacia saligna*. There are no indicator species recorded for this FCT.	On grey sandy clay in depressions and clay pans FCT18 was recorded in several locations, usually within isolated, seasonally damp basins but also fringing wetter sites.	Zeus
FCT19a	Heath to Thicket dominated by *Allocasuarina campestris* and/or *Banksia leptophylla* var. *leptophylla* Common species include *Calothamnus hirsutus*, *Verticordia densiflora*, *Kunzea micrantha* subsp. *petiolata* and *Acacia saligna*. Indicator species include *Stylidium burbidgeanum* and *Calothamnus hirsutus*.	On grey or brown sandy clay in drainage lines FCT19a is located in a number of small isolated, seasonally damp basins	Heracles Zeus
FCT20	Thicket dominated by Actinostrobus pyramidalis Indicator species include *Actinostrobus pyramidalis*, *Kunzea micrantha* subsp. *petiolata* and *Hakea trifurcata*.	On grey diatomaceous earth on lower slopes and depressions FCT20 is associated with powdery, diatomaceous earth in low lying, seasonally damp depressions.	Hebe Zeus

3.5 Digital Elevation Model (DEM)

Where the transition from dryland to wetland habitat is abrupt and obvious the extent of wetland habitat can readily discerned and mapped. This is particularly the case within the project area where the wetland form is topographically controlled (for example, the wetland habitat is truncated by a dune or constrained by a basinal landform). The circular dampland located near the Hebe mineral deposit (Figure 3) is an example of this topographic control.

More commonly, however, the transition from wetland to dryland (non–wetland) vegetation within the project area is subtle and gradational. This is particularly the case in the vicinity of the Zeus wetland (Figure 3).

In many instances this transitional zone includes groundwater-dependent vegetation. This appears to be related to elevated soil moisture and/or groundwater-dependency and is generally limited to areas where the depth of burial of the palaeo-lake sediments is <4m beneath the Bassendean sand sheet. To aid wetland mapping, a digital elevation model (DEM) was constructed for the project area using the Western Australian Land Information System topographic dataset (2008, 1m vertical resolution).

DEM analysis confirms that strong associations exist between depth to groundwater; burial depth of the palaeo-lake system beneath the Bassendean Sand sheet and vegetation groundwater dependency. In particular, the presence of wetland species (sedges and Melaleuca) on Bassendean Sands some 2-4m above the exposed palaeo-lake datum is good evidence of this association (Figure 4). Soil profiles and root penetration depths were previously recorded in soil test pits excavated at the site (Blandford, 2007), which were found to generally agree with the soil/vegetation associations observed in the field.

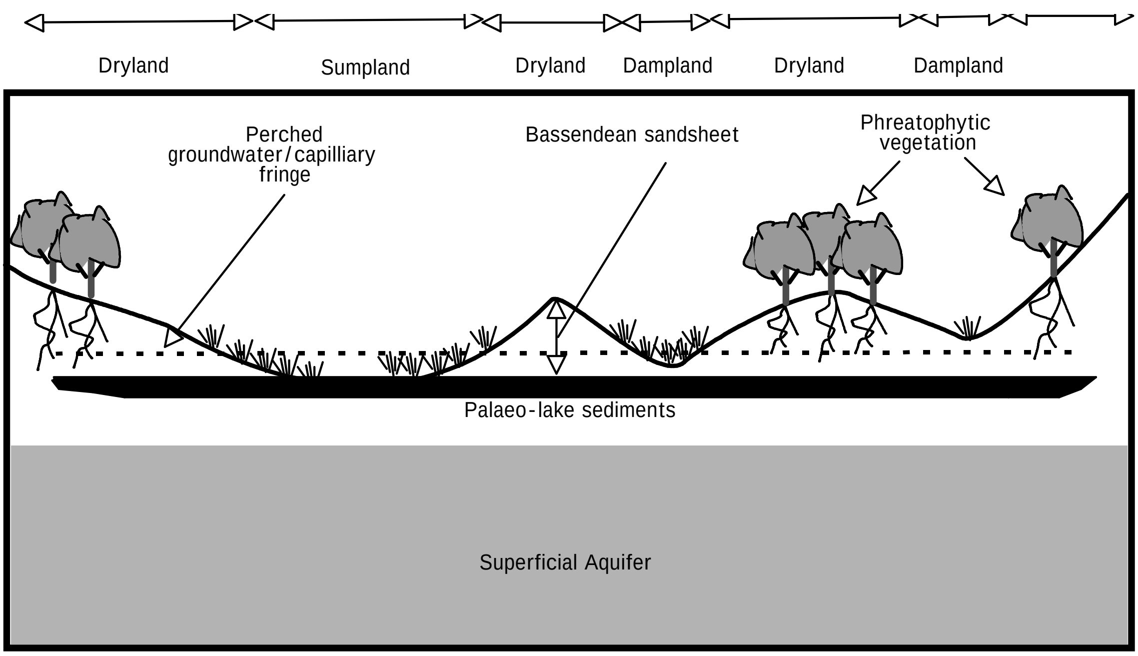

Figure 4: Generalised east-west section through the Zeus wetland north of Mt Adams Road showing relationship to palaeo-lake sediments, thickness of the overlying Eneabba Sand sheet and water dependency.

The observed relationships were used to 'calibrate' the DEM and to evaluate the significance of the depth of burial of the palaeo-lake sediments as an important factor influencing the distribution of present-day wetland habitats.

It should be noted that the project area is large with limited all-weather vehicular access and it was not possible to inspect the entire perimeter of all wetland habitats within the project area. Field mapping was, however, intensified in wetland areas likely to be either directly impacted by mining activities or predicted (through modelling) to be indirectly impacted by groundwater drawdown.

The DEM has been used to supplement field mapping and interpretation within the project area, particularly in those areas where vehicle access is limited.

In terms of ground-truthing the DEM, particular attention has been given to the north/south access track which provides all-weather access and transect of the Zeus wetland (north of Mt Adams Road). This track includes a large number of transitions from wetland to dryland habitats which has greatly aided interpretative wetland mapping across the broader project area.

As described above, the thickness of the Bassendean Sand sheet over the paleo-lake system is a strong determinant of the presence of soil moisture and/or groundwater-dependent vegetation types. Previous experience garnered from Tiwest's Falcon lease (Cooljarloo) would suggest that groundwater dependency of dryland vegetation types is likely to diminish significantly where maximum groundwater is >6m below ground level (bgl) (Zencich and Froend, 2001).

Similarly, Froend and Zencich (2001) has previously reported vegetation groundwater-dependency categories of >10m gbl (low likelihood), <6m bgl (medium likelihood) and <3m bgl (high likelihood) for the Gnangara Mound.

3.6 Wetland complexes

Wetland habitats within the project area have been assigned to wetland complexes as shown in Figure 5.

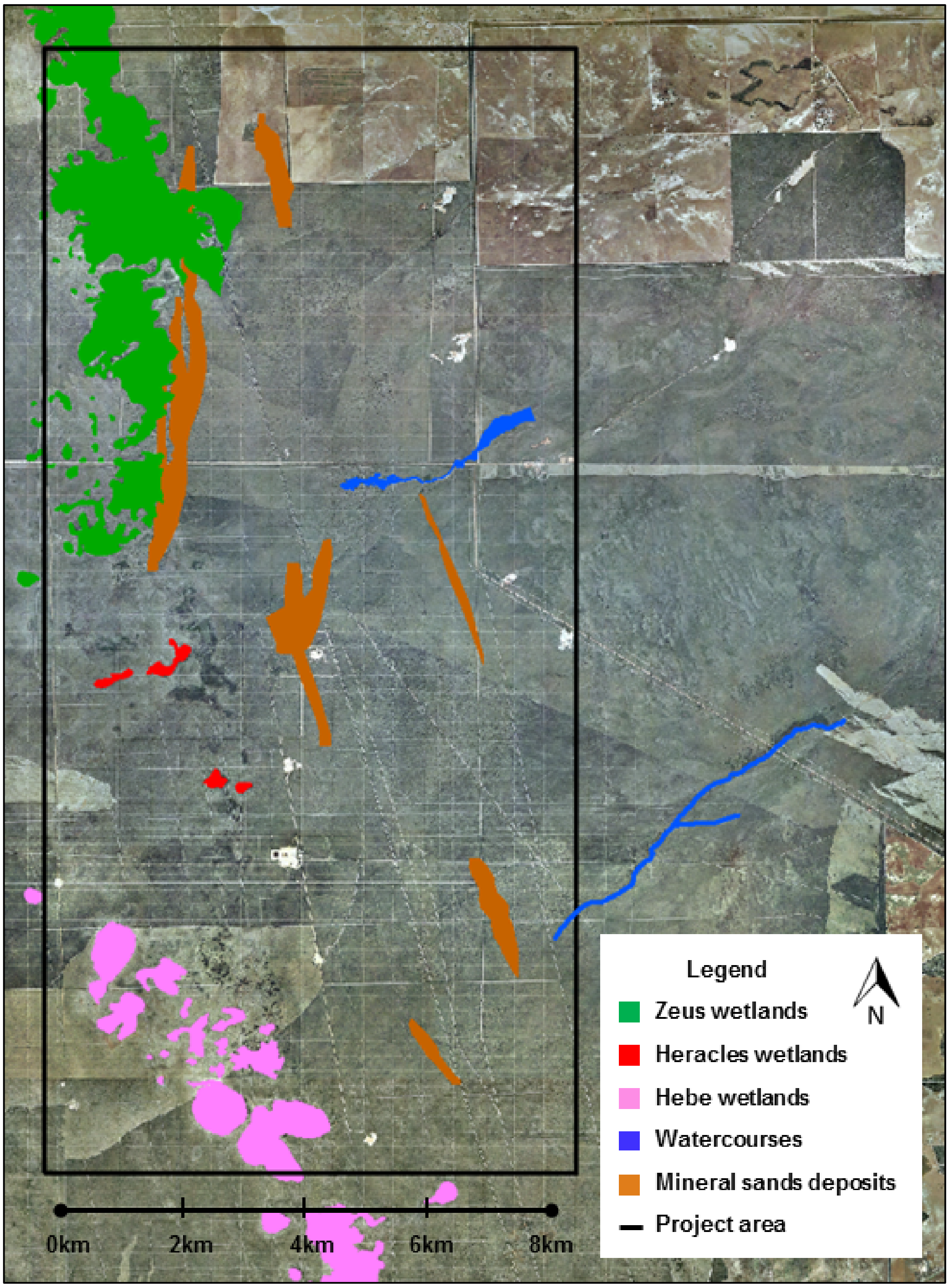

Figure 5: Wetland complexes and watercourses within the project area.

4. Wetland Impacts General Discussion

4.1 Regional Significance

Wetland habitats located within the lease area have been previously assigned to the Beharra Spring consanguineous wetland suite based upon geomorphological characteristics and described as an intermittent dampland containing horizons of fossil wetland soils (Semeniuk, 1994).

The Beharra Spring Suite of wetlands has been identified as being locally significant, as the geographical area is commonly water-deficient; however, these wetlands also increase the diversity of the local biota by providing unique conditions and niches for plants and animals that are adapted to seasonal waterlogging (Semeniuk, 1994).

The lack of a systematic wetland database (such as that which exists for the Swan Coastal Plain between Wedge Island and Dunsborough) prevents a regional analysis of representativeness of the wetland habitats found within the lease area. Notwithstanding, Endemic is of the view that the palaeo-lake system which occurs on the site is likely to provide a valuable insight into the geological and sea level history of the region. In this regard, Endemic believes the Zeus wetland complex is worthy of protection due to its importance as a geological record of the palaeo-history in the region and the scientific and educational value this affords.

4.2 Direct wetland impacts

Direct impacts likely to result from the proposal are those impacts associated with removal of overburden and mining and hence which will result in direct vegetation clearing and habitat removal. In addition to direct impacts associated with mine pit construction, direct impacts associated with infrastructure and servicing (for example, haul roads, pipelines, power supply, etc.) are also likely to occur.

4.3 Indirect wetland impacts

Indirect impacts are those impacts likely to arise as a result of mining, but which are outside the (direct) footprint of the mining operations. These impacts therefore include the cumulative groundwater drawdown impacts associated with groundwater abstraction from the Yarragadee aquifer and mine pit dewatering. Other potential indirect impacts include dieback disease, dust, weeds and bushfire.

The effect of reduced groundwater levels on vegetation varies depending upon the species of plant, position in the landscape, prevailing soil moisture conditions, the seasonality and magnitude of drawdown, rate of drawdown and the degree of groundwater access to which the plants are accustomed.

Altered water regimes can demonstrate the dependency of vegetation, as populations are adapted to specific water level regimes and changes may cause a shift in vegetation community composition and structure. Lowering water tables can result in the loss of species intolerant of drying and their gradual replacement by xerophytic species. Vegetation and habitat impacts arising from reduced groundwater levels have the potential to also result in faunal impacts.

The extent of vegetation decline arising from groundwater drawdown has been previously associated with not merely the absolute water level change, but also the rate and seasonality of groundwater decline. A rapid rate of groundwater decline has the potential to result in the collapse of certain populations of susceptible species (Froend and Loomes, 2004). In order to evaluate the potential impact of 'rate of drawdown' on wetland habitats it would be beneficial to be able to relate this to the observable water level regimes pre-development for these same habitats.

The current understanding is that the complex stratigraphy of the palaeo-lake system serves to dampen the influence of drawdown in the superficial aquifer on these wetland habitats. The degree of hydraulic connection between the superficial aquifer and palaeo-lake system in the region of the Zeus wetland complex remains contentious due the complexity of the stratigraphy in this area.

The risk of drawdown in the superficial aquifer adversely impacting wetland vegetation is likely to be significantly reduced where an aquitard and/or groundwater perching occurs.

The effect of the presence of an aquitard is two-fold. Firstly, the retardation of infiltration may lead to localised elevated soil moisture levels or the formation of perched groundwater. Secondly, the aquitard may also serve to dampen the hydraulic connectivity between the superficial aquifer and perched groundwater, where this has developed.

It is understood that impact analysis studies have been recently commissioned by the Tiwest JV to more accurately map depth to groundwater across the site for the purpose of refining the areas likely to be impacted by groundwater level reductions and to evaluate the likely cumulative wetland impacts for the project area.

4.1 Watercourses

Tomkins Rd Creek and Mt Adams Creek are ephemeral watercourses with much of their catchments and headwaters rising on the Gingin Scarp (to the east of the site).

Notwithstanding, short duration runoff has been observed originating from soils of low permeability within the project area (for example, lateritic outcropping) following periods of high rainfall intensity. The only streamflow at the Mt Adams Creek gauge station to date was observed during Winter 2008 and was less than 2 hours in duration.

Groundwater in the superficial formation is limited to the western half of the project area (Hydrosearch, 2008). Accordingly, groundwater drawdown impacts are limited to the Yarragadee aquifer in the vicinity of Mt Adams Creek and Tomkins Rd Creek.

Inspection of the groundwater database shows the Yarragadee aquifer in these areas ranges from 27m to >36m bgl (PZS07 and PZN08). These watercourses are therefore not groundwater-driven ecosystems.

Due to the depth to groundwater, lowering of the Yarragadee aquifer is not considered likely to adversely impact the flow regimes or riparian habitats associated with these watercourses.

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