

# Resource Management Technical Report XXX

## The Dandaragan Plateau zone: high priority area for targeted investment in salinity risk

Stanley Yokwe

Northern Agricultural Catchments Council

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## Summary

There are many important natural resource assets across the Northern Agricultural Region (NAR), but not all require investment to protect them from natural resource threats. The aim of this report is to provide a summary of the Dandaragan Plateau zone to help determine the actions necessary to protect specific assets at risk of future salinity and rising groundwater levels.

The Dandaragan Plateau zone was chosen as a high priority area for a Targeted Investment Program (TIP) because rising groundwater levels are threatening high value assets such as biodiversity, water resources, productive agricultural land and infrastructure. The evidence is not straightforward, however. Groundwater has been generally rising across the zone at an average rate of 0.5 metre per annum since 1998, yet a recent review of DAFWA groundwater monitoring sites shows variability across the Dandaragan Plateau and adjoining Otorowiri zone. Rising levels are observed at only one third of the monitoring sites; at the rest of the sites, groundwater levels are dropping or remaining static. The drop can be directly associated with prolonged dry conditions or climate change.

Despite this partial reversal in the trend, the Dandaragan Plateau zone was still found to be high priority as it has been more thoroughly researched than the other landscape zones in the Northern Agricultural Region (such as Northern Victoria sandplain zone) and has already attracted a degree of technical support. A number of options to manage salinity threats in the area are already in place. Moreover, according to Philip Commander (Department of Water) the geological features of the aquifers underlying the Dandaragan Plateau zone (the Parmelia formation and Otorowiri siltstone) display little complexity, and are comparable with those of other major aquifers in the northern Perth Basin (such as the Yarragadee, Cattamarra and Leederville aquifers). Investment incentives focused on lowering groundwater levels or reducing future salinity risk in the TIP area are therefore of significant importance.

## **Acknowledgments**

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## 1. Introduction

Salinity has become the greatest sustainability challenge confronting the Western Australian community. Earlier studies indicate that even with significant and immediate interventions, groundwater levels will continue to increase until well into the future, placing at risk assets such as biodiversity, water resources, rural towns, roads and rail infrastructure, private and public land as well as productive agriculture land (Frost et al. 2001; NLWRA 2000). In the south-west region alone, estimates of the extent of salinity indicate that approximately 1.8 million hectares of land are affected. It has been predicted that without intervention, saline affected areas will increase to more than 5.4 million hectares (McFarlane et al. 2004; Department of Environment 2003) before a new hydrological equilibrium is reached. Even with the most optimistic intervention options using perennial vegetation and engineering, some 4 million hectares will be affected and for most catchments, changes in land use will not have any significant impact for at least 20 years (Government of WA 2003, WA State NRM Office 2007).

The Northern Agricultural Region (NAR) is no exception. According to the Land Monitor Project (2002), most of the current extent of dryland salinity in the NAR occurs on the Yilgarn Craton. The Yilgarn underlies most of the Yarra Yarra subregion and parts of the Moore River and Greenough subregions. The amount of land affected by salinity is about 10 per cent of the area, but it is estimated this could expand to about 25 per cent of the area. In the entire West Midlands subregion and part of the Moore River which overlie northern Perth Basin where the Dandaragan plateau zone lies, groundwater levels are observed to be rising at higher rates and more consistently than in any other geological area in the NAR. It is within parts of subregions overlying the Perth basin that there is likely to be the greatest increases in the extent of dryland salinity. Presently the area of salinity is relatively small (around 1 per cent) but potentially it could rise to about 20 per cent (Land Monitor Project 2002; Hunt and Patterson 2004). Table 1 shows the areas of land (in ha) in the NAR considered most at risk of existing dry land salinity and future salinity risk, as determined by areas of consistently low production (AOCLP) and the height above valley floor (AHAVF) at risk. AHAVF is a topological output from analysis of the Land Monitor DEM. It uses four elevation classes (0–0.5, -1, -1.5 and -2.0 m) and expert derived decision rules (George et al. 2005).

**Table 1. Areas of NAR at risk of salinity**

NACC subregion	Total area (ha)	AOCLP* (ha)	AOCLP as % of total area	AHAVF** (ha)	AHAVF as % of total area
West Midlands	1 143 173	10 000	1	255 000	22
Yarra Yarra	1 791 584	73 000	4	332 000	19
Greenough	3 415 820	36 000	1	308 000	9
Moore River	1 598 948	175 000	11	482 000	30
Total	7 949 525	296 000	4	1 379 000	17

Source: Hunt and Patterson, 2004

These observations point to the need for a more targeted and integrated approach to managing our natural resources for future salinity risk. According to the Northern Agricultural Catchments Council (NACC), areas for managing existing and potential salinity risk must continue to be identified, documented and prioritised for action. This should enhance our focus in determining the action required to ensure that our investment is directed towards projects with the best potential to protect or restore assets of high environmental value that are most under threat by salinity. The aim of this report is to provide a summary of the Dandaragan Plateau zone as a high priority area for the Targeted Investment Program (TIP) in future salinity risk.

## **2. Methodology**

Prioritisation of geographic areas for investment is an important element in the National Action Plan (NAP) for salinity and water quality. It identifies the natural resources assets of the region and the risks or threats to those assets. The Salinity Investment Framework (SIF) was commissioned by the WA Government to guide public investment in salinity management initiatives at state, regional and catchment levels (State Salinity Council 2000). Its objective is to ensure that public investment is directed towards projects with the best potential to protect or restore assets of high public value that are most under threat by salinity (Sparks et al 2006).

The NAR (as one of the NAP regions) supports the concept of geographic targeting of investment in which a clear, transparent and defensible process is used to identify the priority investment areas and to set the level of funds available to each area according to priority. The NAR NRM team used the asset-based approach inherent in the SIF report (George et al. 2005) to prioritise areas of agricultural land under existing or potential salinity threat for NACC investment. Priority areas have been identified after careful consideration of the salinity hazard, distribution of natural resource assets, Land Monitor mapping, bore data and reports on the biological significance of the region.

The analysis adopted the spatial framework of soil-landscape zones defined by DAFWA's Natural Resource Assessment Group as these zones represent areas with comparable hydrogeological and farming-system attributes (Schoknecht et al. 2004; Bairstow et al. 2006). Of the 31 zones described for south-western Australia, 19 fall within the NAR. The SIF analysis urgency rating (timing of salinity) for each zone was also used, along with topological outputs from Land Monitor mapping (George et al. 2005). The areas of consistently low production (AOCLP) outlined by this mapping reflect potentially shallow watertables in valley floors, while the average height above valley floor (AHAVF) data represents future salinity risk. Together, all these factors were used to determine priority areas for managing existing salinity (Bairstow et al. 2006).

To ensure the SIF analysis was regionally relevant, each soil-landscape zone was assessed for its hydrological trend according to DAFWA's Agbores database and the regional hydrologist was consulted for local expert knowledge. Trends were then described and assigned a future risk category based on the general depth to groundwater. The rating scale for future salinity risk comprises four categories (Bairstow et al. 2006):

- **High** groundwater shallow (< 5 m) (salty or fresh) and rising
- **Moderate** groundwater shallow (< 5 m) (salty or fresh) and not rising (no imminent risk)
- **Low** groundwater deep (> 5 m) (fresh or salty), or reached equilibrium
- **Unknown** inadequate data to make a reasonable statement of risk.

According to these ratings, the Dandaragan Plateau soil-landscape zone (zone 222: see Figure 1) was identified as a high priority area for targeted investment, as described in the DAFWA SIF report (George et al. 2005), Bairstow et al. report (2006), State NRM report (State NRM Office 2007) and West Midlands region catchment appraisal (Stuart-Street 2007). The Dandaragan Plateau zone coincides with the two hydrological zones of the Parmelia formation and its basal Otorowiri siltstone member that were identified in the Earth Tech (2002) report.

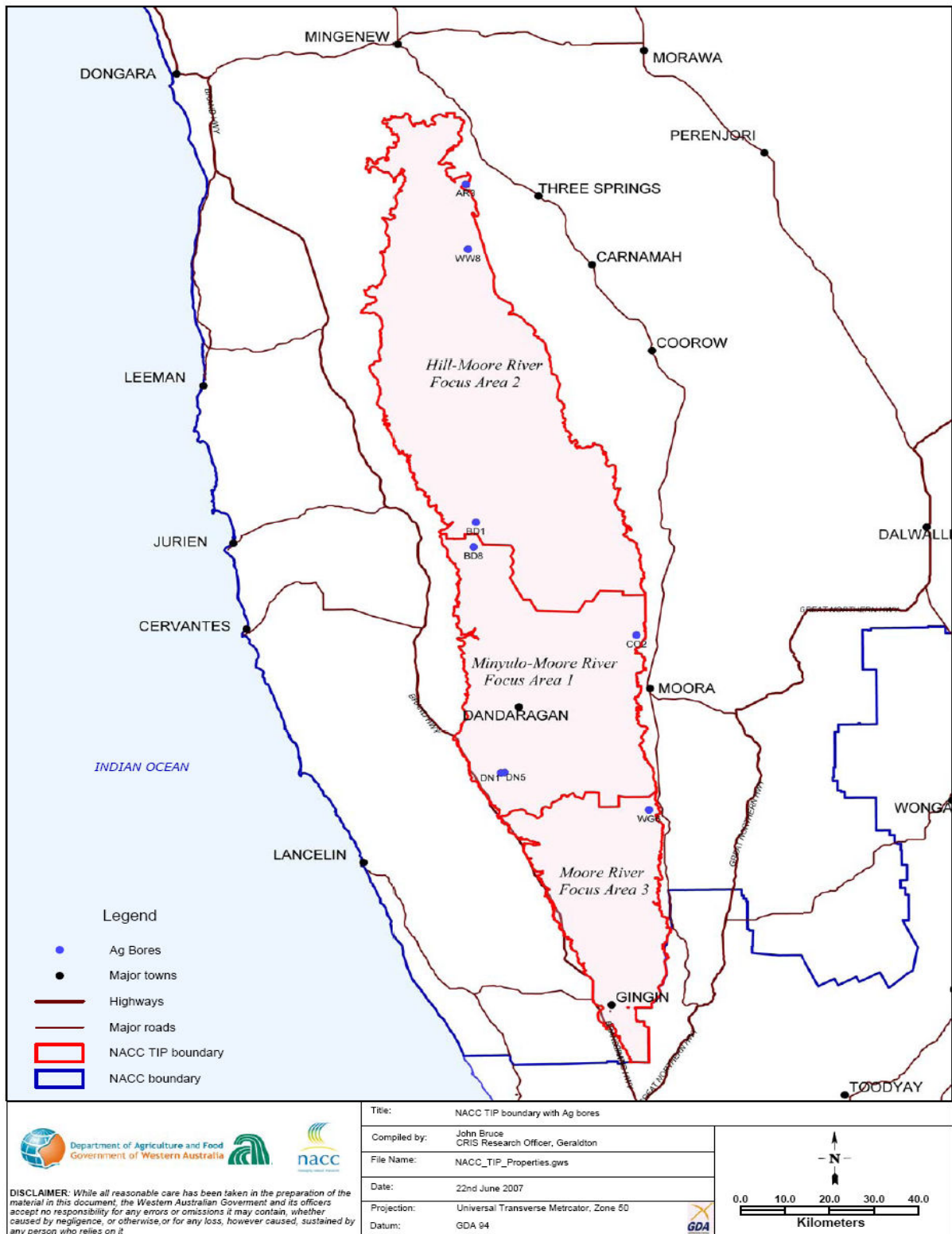


Figure 1. Priority areas for targeted investment in the NAR

### 3. Environmental features of the Dandaragan Plateau zone

This section briefly describes the environmental features of the targeted investment area and includes a short description of its physiography, soil, land use and climate (see Table 2).

**Table 2: Environmental features of the Dandaragan Plateau TIP area: facts and figures**

<b>Shires</b>	Dandaragan, Coorow, Carnamah and Three Springs
<b>Population</b>	Approximately 270 (NACC 2007)
<b>Land area</b>	Approximately 708,000 ha
<b>Vegetative land (land cover)</b>	Isolated pockets of remnant vegetation
<b>Cleared land</b>	Extensively cleared
<b>Biodiversity and species</b>	Banksia, low woodland, jarrah-marri woodlands, prickly bark and extensive heaths and scrub-heaths. the rare vertebrates include peregrine falcon, malleefowl, Carnaby's cockatoo, Baudin's cockatoo, chuditch and carpet python. Rare floras are also recorded in the area (A biodiversity audit of WA, 2002).
<b>Rivers/major water bodies</b>	Moore River, Hill River, Arrowsmith River, Minyulo River, Gingin Brook and Caren Caren Brook (State NRM office 2007).
<b>Wetland of national significance</b>	Hill–Moore River estuary and Irwin River estuary (A biodiversity audit of WA, 2002).
<b>Major national parks</b>	Tathra National Park (A biodiversity audit of WA, 2002).
<b>Major NRM issues</b>	Rising watertable (salinity), waterlogging, wind erosion, threatened river ecosystem (State NRM office 2007).
<b>Soil type</b>	Deep sands with ironstone gravelly soils, sandy duplexes and loamy earths (Stuart-Street 2007).

#### 3.1 Physiography

The Dandaragan Plateau is the dominant physiographic unit in the area, overlying Parmelia formation and Otorowiri member. It is a flat to gently undulating remnant of sand and laterite capped plateau overlying cretaceous sediments, with an elevation ranging from about 140 to 300 m above sea level. Valleys are deep and V-Shaped and the west boundary of the region is a marine erosion scarp (Water Authority 1995, Commander 1978, Earth Tech 2002).

### 3.2 Soil

The Dandaragan Plateau is made up of a range of soil types. The mix varies between districts and farms, and even within paddocks (Wiley and Wilson 2004). In the area overlying the Parmelia formation and Otorowiri siltstone member the soil types are dominated by yellow or pale deep sands with some duri-crust and sandy and duplex gravels. On the western edge, sandy duplex soils with sandy and loamy earths are more widespread, with minor areas of clay (Stuart-Street 2007; City of Swan, Land and Soil 2000).

### 3.3 Land use

Land use is highly diverse but dominated by large-scale broadacre agriculture such as grain cropping and grazing. Cropping is more common on the slopes where heavier and gravelly soils tend to occur. Significant planting of pine (*Pinus pinasta*) has occurred in the Minyulo and Gillingarra–West Koojan catchments, particularly in recent years. Irrigation for a range of purposes is used mainly in the south of the region. It has expanded considerably in recent years due to the development of horticulture (e.g. vegetables, grapes and olives) and tree crops. Most water for domestic and stock use comes from groundwater, soaks and springs. A number of nature reserves attract significant levels of tourism in the area.

The mining of mineral sands is a major non-agricultural activity on the Eneabba plain (to the north and east of Lancelin) in the south of the Dandaragan Plateau zone.

### 3.4 Climate

The climate is Mediterranean with hot dry summers and cool wet winters. As Figure 2 shows, the average annual rainfall ranges from 400 mm in the north to more than 650 mm in the south. Almost 90 per cent of the rainfall in the Dandaragan Plateau zone occurs between March and October. Summer is normally dry apart from scattered and irregular thunderstorms or rain from the formation of troughs and moist air from the north-west which form mid-level disturbances. Additionally there are very infrequent events from decaying tropical cyclones (Stuart-Street 2007).

The moderating influence of the coast is exhibited by the temperatures across the region. Average maximum summer temperatures on the coast range from 29 to 30 °C from January to March. Further inland the summer maximum temperatures are higher, generally peaking in February. These range from 34 °C in the south to 36 °C in the northern parts of the Dandaragan Plateau region. Winter minimum temperatures on the coast are also milder with a 9 °C average minimum in July and August compared to 6 °C inland (Stuart-Street 2007; Bureau of Meteorology 2006).

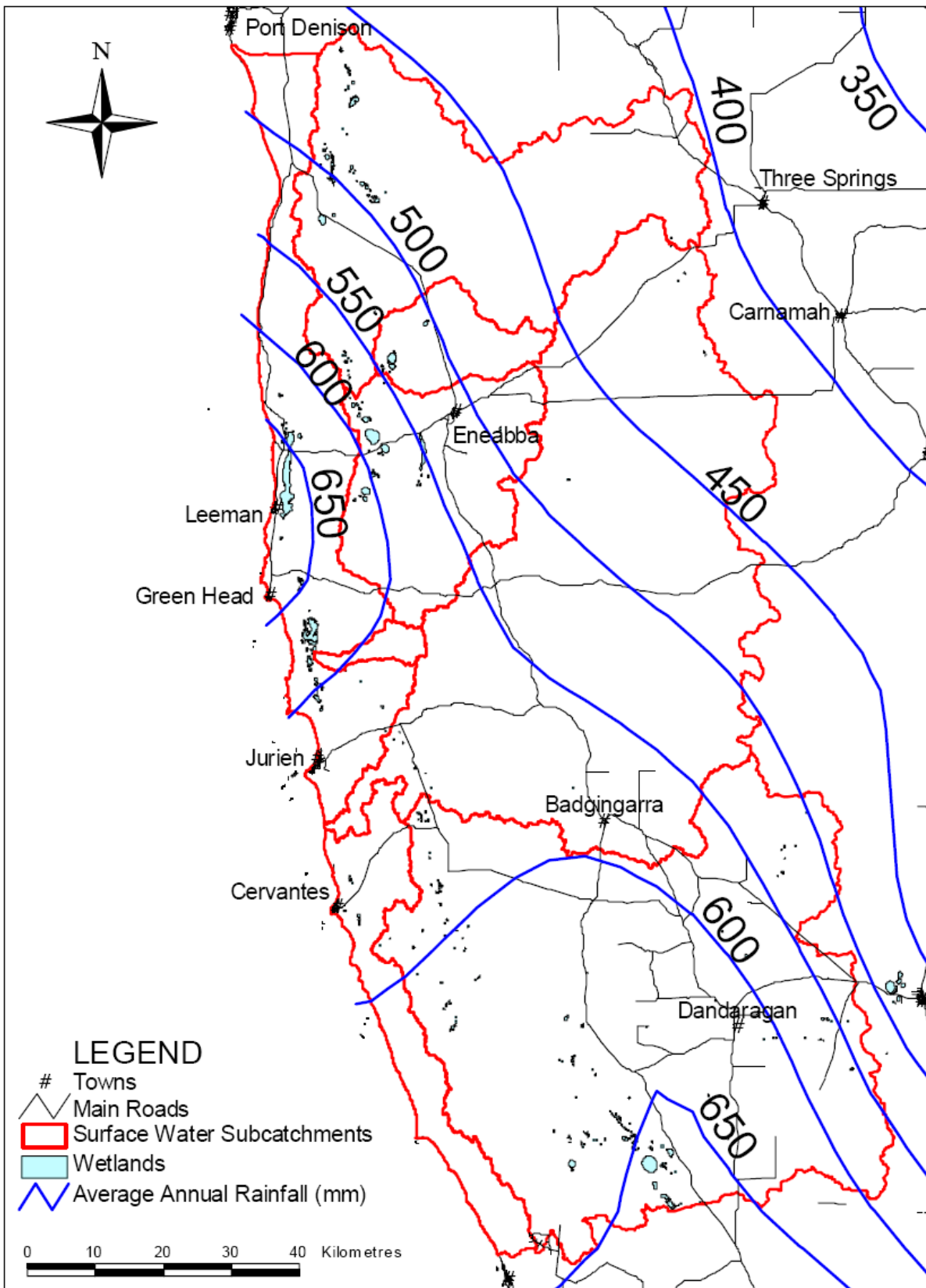


Figure 2. West Midlands average annual rainfall (Adapted from Stuart-Street 2007).

## **4. Hydrogeological aspects of the TIP area**

The ability to predict the future extent of salinity depends on several factors, primarily: the characteristics of the landscape, the climate, and the effects of human activities. An understanding of water movement associated with the rising watertable is also needed to determine the likely extent of any problem. This section briefly describes the hydrogeology of the area which underlies the Dandaragan Plateau—that is, the Otorowiri siltstone member, the Parmelia formation and its overlying surficial aquifer.

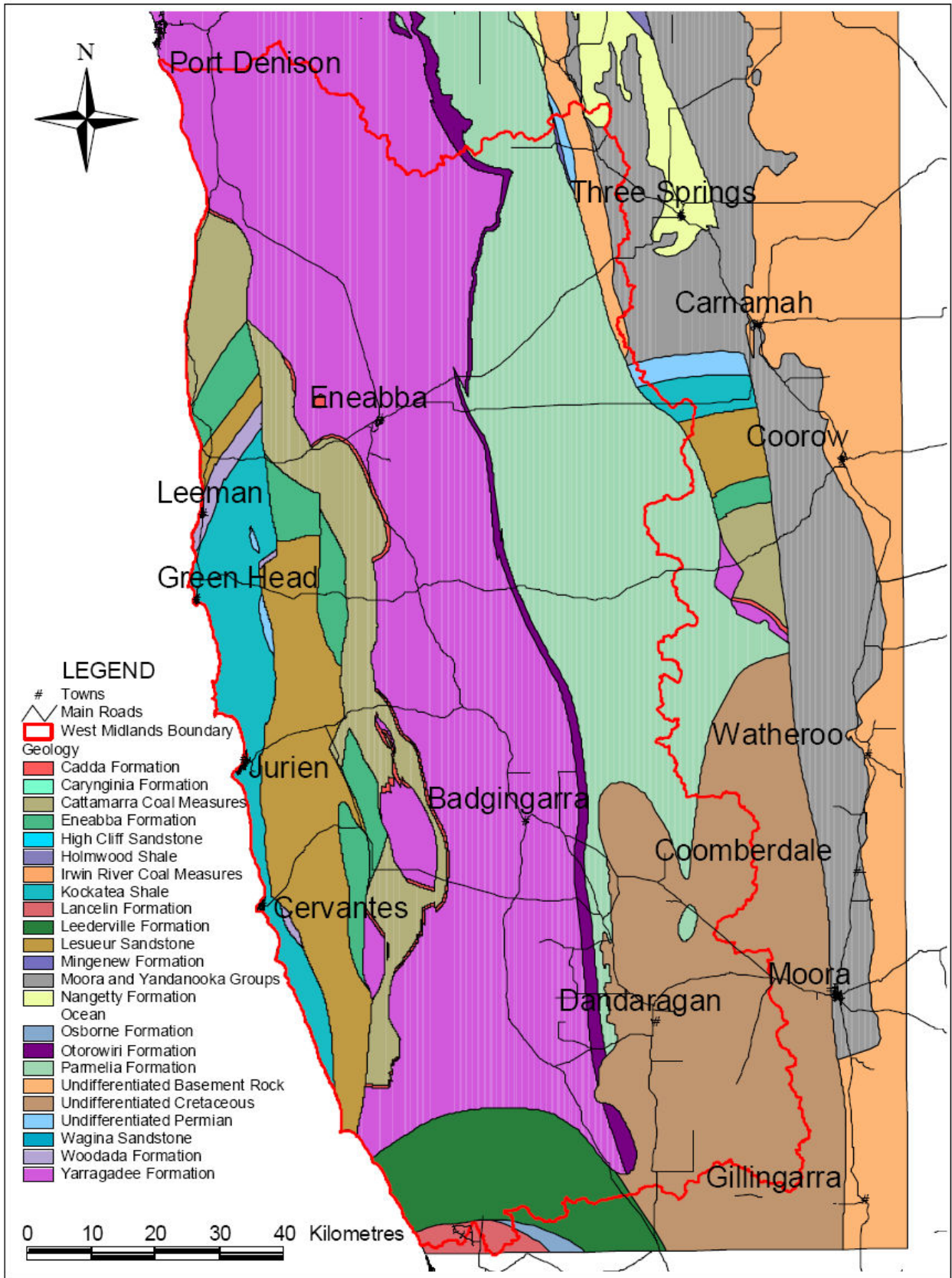
### **4.1 Parmelia aquifer and Otorowiri formation**

The northern Perth Basin is a major sedimentary basin that hosts several significant aquifers, the Parmelia formation being one of them. Overlying the Parmelia formation is the Leederville formation (also a significant aquifer), which is in hydraulic connection with it (Moncrieff, 1988). Groundwater within these two formations will be collectively referred to as the Parmelia aquifer (Dobson and Holmes 2005).

The Parmelia aquifer has historically been referred to as the upper unit of the Yarragadee formation (Backhouse 1984). It is bound to the east by the Darling and Urella faults and to the west by the Dandaragan scarp, which is coincident with the outcrop of the basal Otorowiri member of the Parmelia formation (Bekele et al. 2006a). The Otorowiri siltstone forms a continuous line of outcrop that stretches northward on the east of the Brand Highway and extends into the four regional shires of Dandaragan, Carnamah, Coorow, and Three Springs.

Figure 3 shows how the Parmelia formation and its basal Otorowiri member overlie the Yarragadee formation (Bekele et al. 2006a, Commander 1978). The Parmelia aquifer occurs in a semi-confined unit, locally capped by alluvial and colluvial sand and laterite and paleochannel deposits north of Badgingarra on the Dandaragan Plateau (Bekele et al. 2006b). The Yarragadee formation is similar to the Parmelia formation though there are shaly sections. The Otorowiri member is almost all siltstone, with very minor sand beds, though these may increase south of the Moora Line (Commander Pers. Comm. 2007). The Otorowiri member is an aquaclude; it does not contain a watertable, but is regarded as an impermeable layer that restricts the vertical and lateral flow of groundwater and limits the vertical hydraulic connection between the overlying Parmelia and underlying Yarragadee aquifers (Commander 1978).

The area underlying the Parmelia formation and Otorowiri siltstone is understood to be consistent in terms of its geological features compared to the other major aquifers in northern Perth Basin, such as the Yarragadee, Cattamarra and Leederville aquifers (Commander pers. comm 2007).



**Figure 3. Hydrogeology of the north Perth Sedimentary Basin (Adapted from Earth Tech 2002).**

### *Groundwater recharge*

The Parmelia aquifer is a layered sequence of sand, silt and discontinuous lenses of clay. It receives diffuse rainfall recharge on its outcrop and groundwater recharge occurs across the Dandaragan Plateau at different rates (Bekele et al. 2006). In the southern part of the Parmelia aquifer (within the Minyulo catchment) groundwater recharge occurs by direct rainfall infiltration on the Dandaragan Plateau where the Coolyena group is thin or absent (Earth Tech 2002).

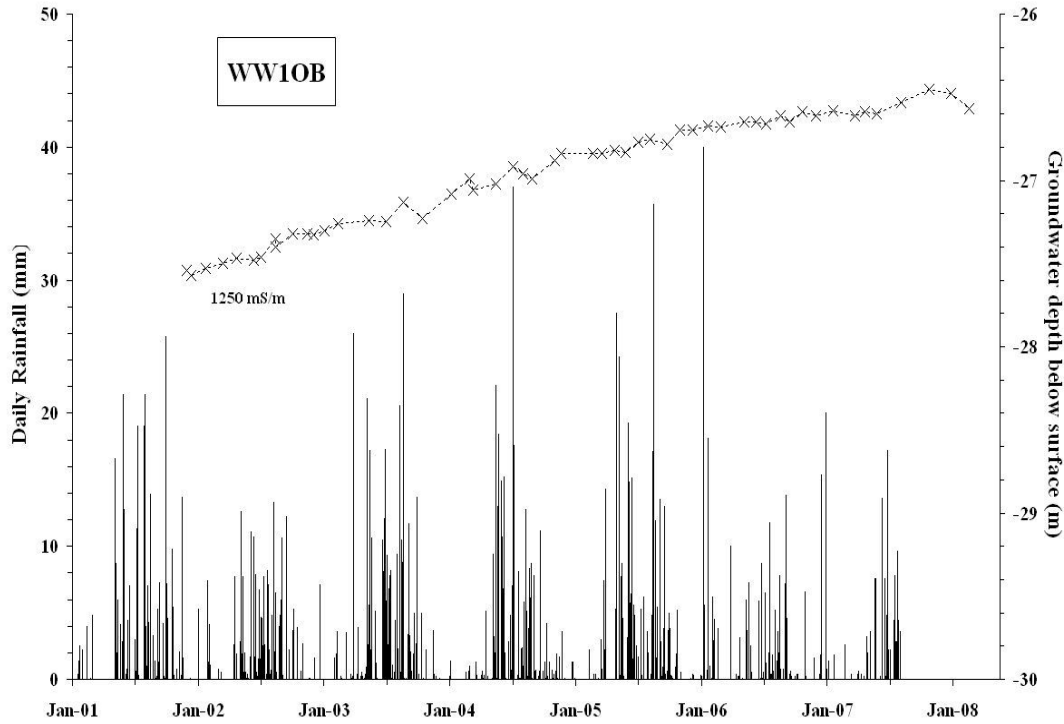
By measuring naturally occurring isotopes and tracers in the groundwater, it can be estimated that less than 20 per cent of groundwater recharge to the Parmelia aquifer occurs through rainfall. Other studies of recharge conducted on the unconfined aquifers in the Perth region estimate high rates of recharge from rainfall (up to 40 per cent), but these estimates vary with location, land use and topography (Sharma et al. 1983, Sharma & Hughes 1985, Thorpe 1989, Davidson 1995, Salama et al. 2002, Bekele et al. 2006b). Recharge is likely to be greatest in sand-filled valleys where laterite capping is absent, and along outcrops of dipping strata on the west side of the plateau (Bekele et al. 2006b, Commander 1978 & 1981).

### *Groundwater discharge*

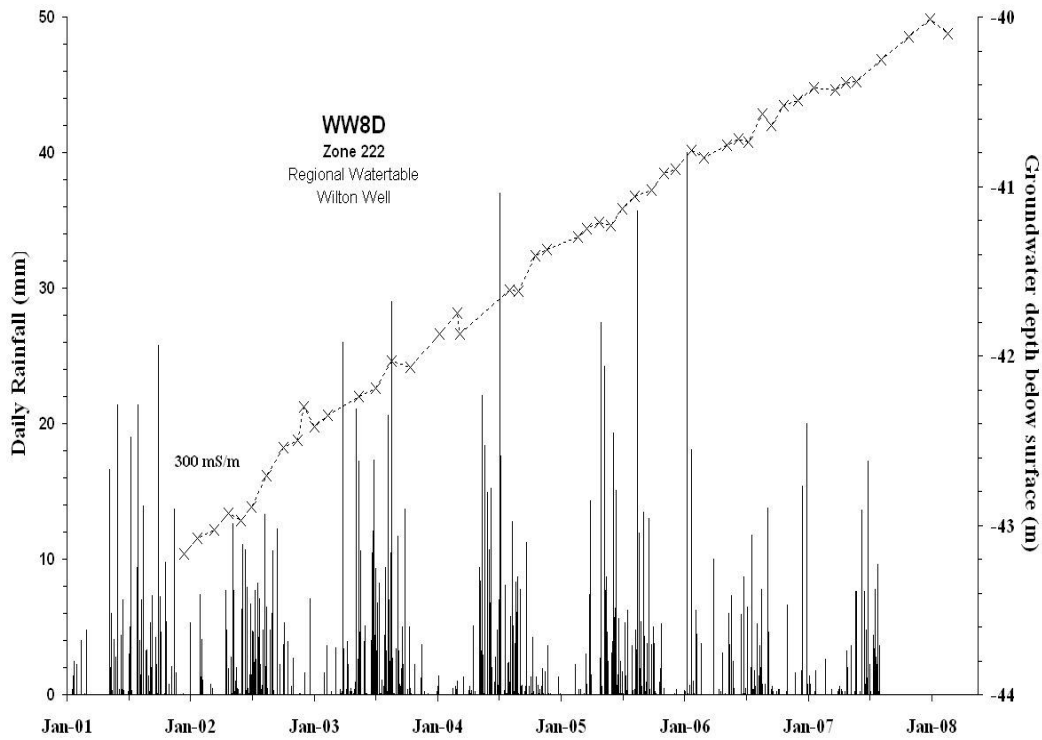
Groundwater flow in the Parmelia aquifer between the Otorowiri member and Urella fault in the middle of the catchment is towards the Hill River where it discharges. On the Dandaragan scarp, groundwater is discharged from the aquifer into the Arrowsmith River near its contact with the Otorowiri member. The discharge into the rivers occurs near the Otorowiri Springs, Dathaganarra Spring and Arrowsmith Well, and maintains river flow for part of the winter. In the Minyulo catchment, the Parmelia aquifer comes close to the surface at the Dandaragan scarp and Gingin anticline (Earth Tech 2002)

### *Groundwater levels*

Groundwater monitoring of the Parmelia aquifer has been conducted since the early 1970s with the drilling and installation of the Eneabba line of deep bores (Commander 1978). Past hydrographs of water level monitoring data indicate water level rises in the Parmelia aquifer in the order of 6 metres over a 30 year period (Dobson and Holmes 2005). Prior to 2000, hydrographs of the DAFWA monitoring bore east of the Otorowiri Mound Springs showed a steadily rising groundwater level of 0.3 metres per year (Speed 2004). However, this trend has slightly changed in recent years. The recent review of DAFWA monitoring sites (Speed 2008) shows variability in the groundwater trends across the Dandaragan Plateau and adjoining Otorowiri zone that comprise the targeted investment area. Rising groundwater trends are observed at only one third of the groundwater monitoring sites, while at the remaining sites levels are dropping or remaining static (see Figures 4A and 4B).



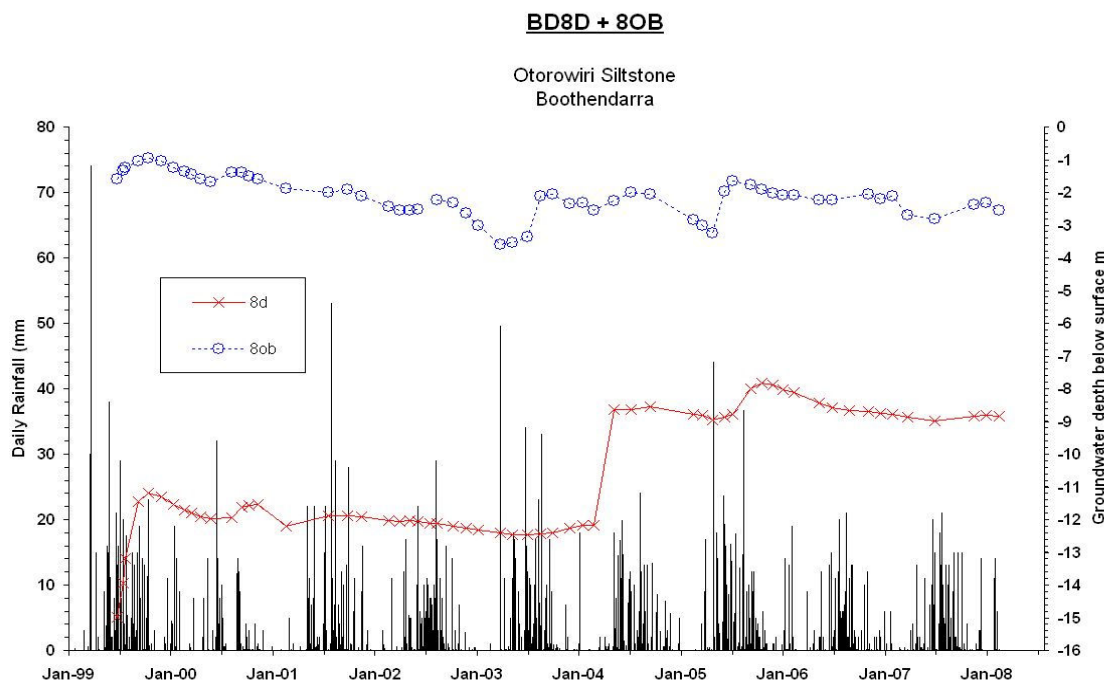
**Figure 4A. Hydrograph for Agbore WW10B located in the Wilton Well catchment in the north-east part of the TIP area (Speed 2008)**



**Figure 4B. Hydrograph for Agbore WW8D located in the Wilton Well catchment in the north-east part of the TIP area (Speed 2008)**

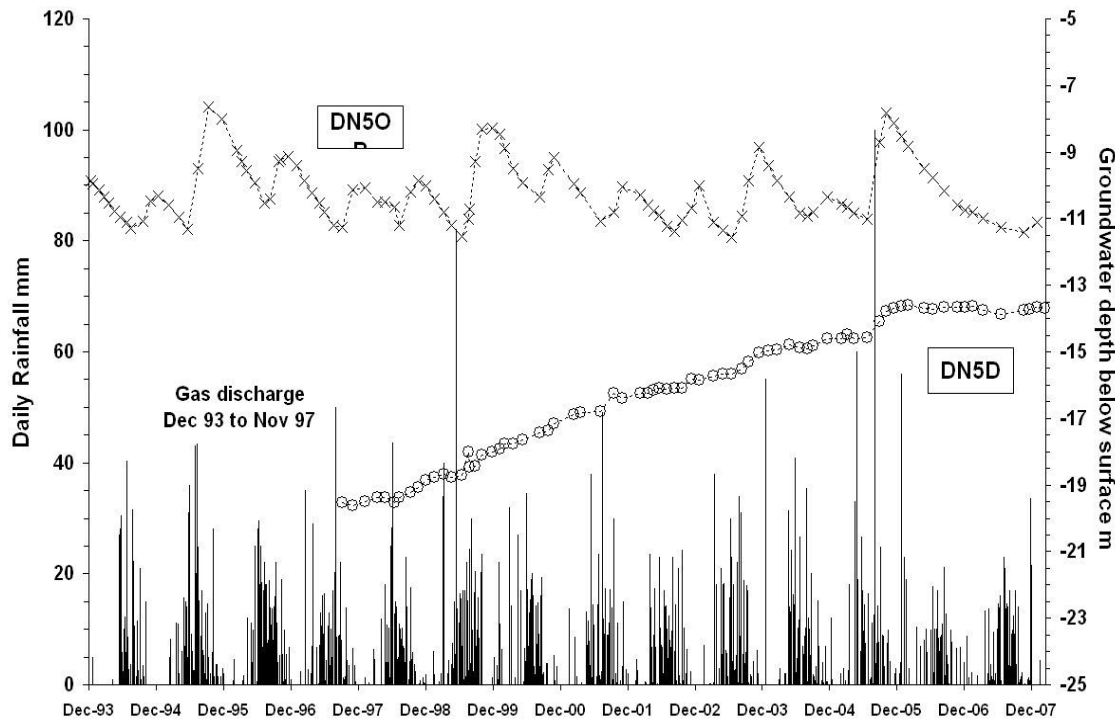
As can be seen from the last couple of data points in Figures 4A and 4B, sustained rising trends from 2002 to 2007 in the north-east part of the TIP area tapered off in 2008, as might have been expected in response to the changing climate. There used to be intermittent perched watertables at site WW8, however the deeper one dissipated in 2005 and has not redeveloped. The shallower one dissipated in 2006 and only redeveloped briefly in 2007. The significant depth of the regional watertable (i.e. 26.5 m in Figure 4A and 40 m in 4B) probably explains the delay in response, as residual water higher in the profile drains away and regional groundwater through-flow lowers the watertable. This tapering off shows why declining trends are expected in sites WW10B and WW8B (Speed 2008).

Figure 4D shows sites BD8D and 8OB in the Boothendarra catchment to the west of the Otorowiri degradation zone. There appears to be two episodic jumps in the piezometric pressure in BD8D that produce a net rise, however between these jumps the trend is slowly declining. The watertable trend observed in 8OB is clearly falling. These data indicate little threat from rising groundwater as there is a strong downward head between the observation bore and the piezometer (Speed 2008).



**Figure 4C. Hydrograph for Agbore BD8D & 8OB located west of the Otorowiri degradation zone (Speed 2008)**

Site DN5 is located south of Dandaragan. Between 1996 and 2005 there was a rising trend of 70 cm per year in the piezometer DN5D (see Figure 4D). Since 2005 the piezometric pressure has remained relatively stable (Speed 2008). Before the 2008 review of groundwater monitoring sites within the TIP area, it was believed that this was the only area in the NAR region with consistent rising groundwater trends. However, the conclusion from the 2008 review is that we are only observing rising trends in one third of the monitoring sites in the area, which is not significantly different from our observations in most other soil-landscape zones in the NAR (Speed 2008).



**Figure 4D. Hydrograph for Agbore DN50 & DN5D located south of Dandaragan (Speed 2008)**

*Current extent of salinity*

Results from revised Land Monitor data indicate more than 11,656 ha in the Dandaragan Plateau soil-landscape zone (222) is currently affected by dryland salinity. Based on the Land Monitor AOCLP estimate and the available catchment-scale estimate, 2.1 per cent of land in the Dandaragan Plateau is affected by dryland salinity. Compared with other salt-affected zones in the NAR, the Dandaragan Plateau zone represents the smallest area currently affected by salinity (See Table 3). The comparison, however, underestimates the true situation as it excludes revegetation of salt-affected land with salt-tolerant and waterlogging tolerant species.

*Salinity hazard and risk*

Evidence of rising groundwater trends is prominent and consistent in the Dandaragan Plateau zone. Evidence suggests that the highest rates of groundwater rise are associated with significant salinity risk. The Dandaragan Plateau zone represents a significant area with high value natural resources at threat of future salinity. Table 3 shows the current extent of salinity and future salinity risk across the NAR.

**Table 3. Salinity estimates for soil-landscape zones in the NAR (Bruce 2007; Land Monitor 2002)**

Zone	Code	Area of agricultural land (ha)	Area currently affected by salinity (ha)	% of land affected by existing salinity	Area of land affected by future salinity risk (ha)	% of land affected by future salinity
Dandaragan Plateau zone	222	558 117	11 656	2.1	202 900	36.4

Eastern Darling Range zone	253	77 569	1 692	2.2	13 585	17.5
Northern zone of rejuvenate drainage	256	370 114	55 559	15.0	106 301	28.7
Northern zone of ancient drainage	258	968 335	242 037	25.0	310 978	32.1
Karara zone	270	80 967	25 253	31.2	39 438	48.7
Irwin River zone	271	771 646	138 684	18.0	264 423	34.3
<b>Totals</b>		<b>2 268 631</b>	<b>463 225</b>	<b>20.4</b>	<b>734 725</b>	<b>32.38</b>

### *Salinity distribution*

Groundwater distribution is variable within the multi-aquifer systems but is mostly less than 1000 mg/l total dissolved solids (TDS), except in the North West part of TIP area near Dongara (Figure 4). Results from the Earth Tech 2002 report found groundwater qualities of less than 1000 mg/l TDS extended to a depth of 1500 m. In the Otorowiri outcrop the salinities of groundwater are however extremely high, reaching 2190 mg/l (see Figure 5).

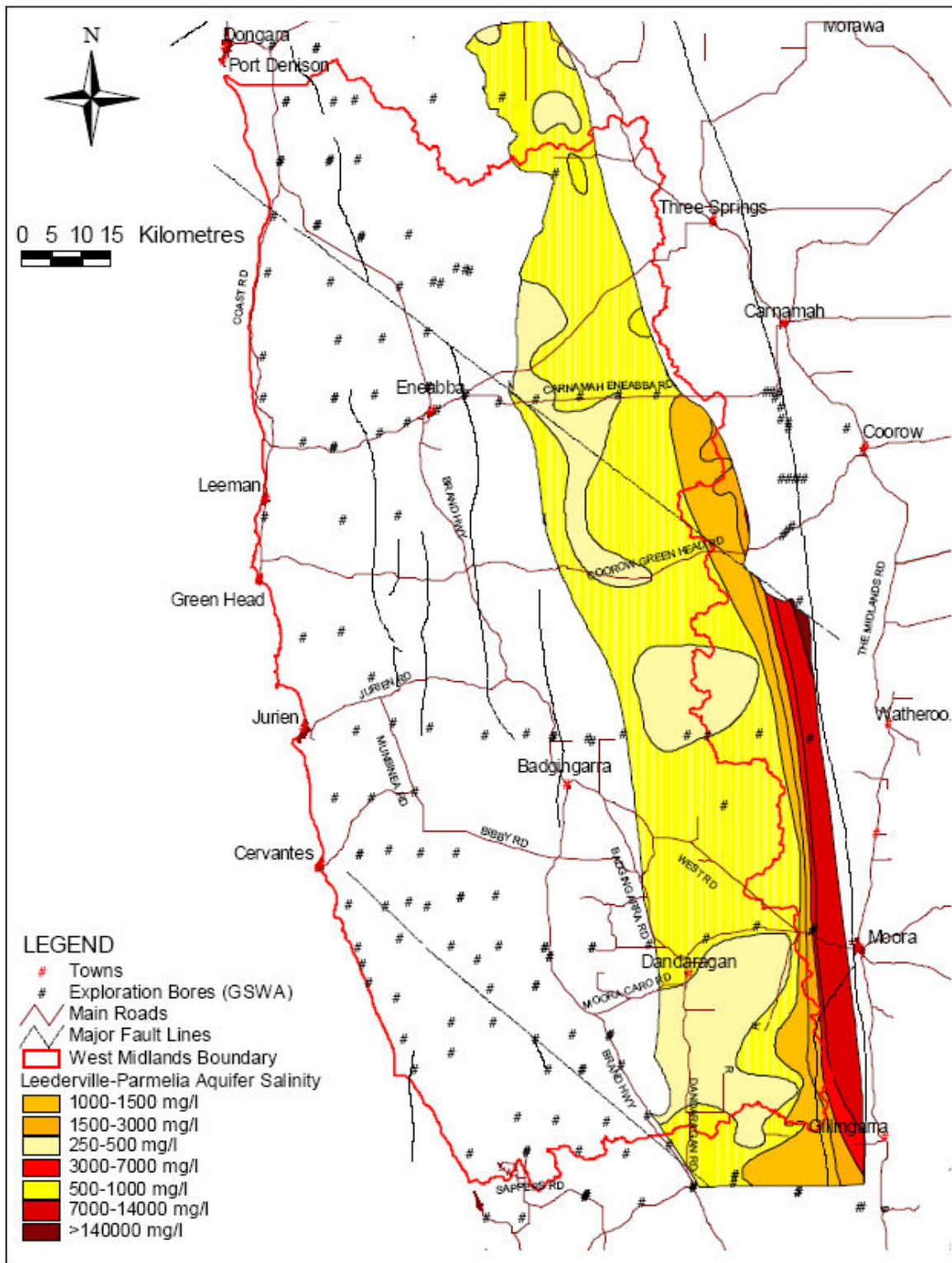
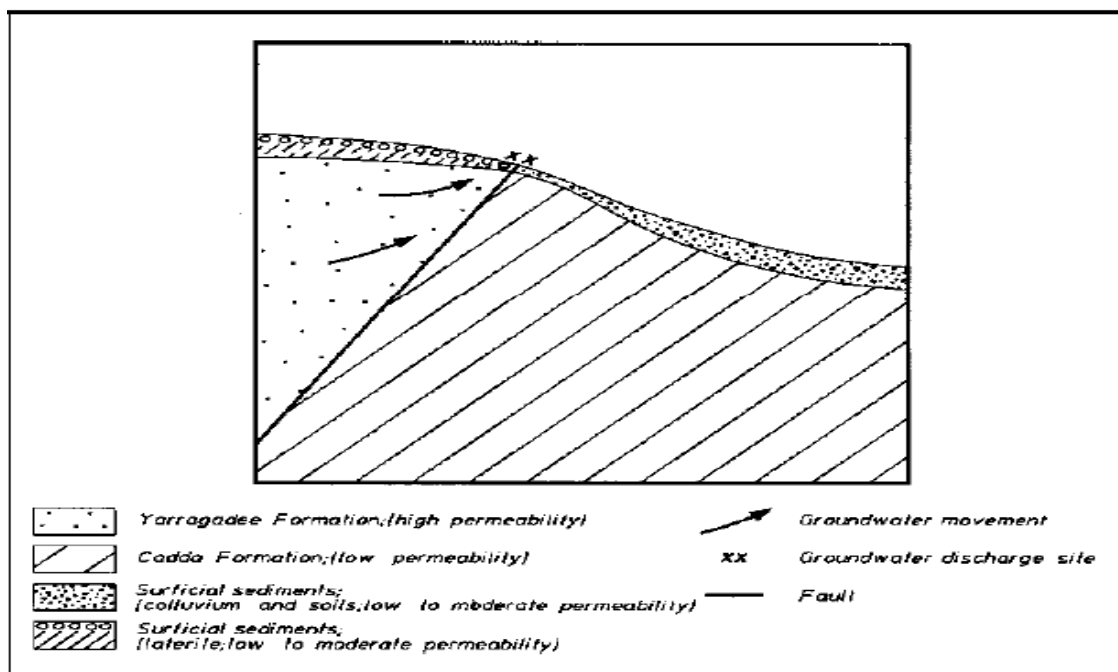


Figure 5. Salinity distribution of Leederville–Parmelia aquifer (Earth Tech 2002)

## 4.2 Surficial groundwater system

In the Dandaragan Plateau zone shallow groundwater is perched in the quaternary sediments above the less impermeable cretaceous sediments. Water movement is dominated by local groundwater flow systems in which the shallow groundwater system is recharged from direct infiltration of rainfall and local runoff, with discharges taking place in small springs, swamps and ephemeral lakes (see Figure 6A). There is little leakage from the surficial groundwater systems into the underlying Parmelia aquifer east of the Dandaragan scarp (Earth Tech 2002). In the eastern portion of the Gingin groundwater area, the Parmelia aquifer is overlain by a thick confining layer of fairly impervious shale, which restricts vertical leakage. In the same area, the Yarragadee aquifer is also overlain by layer of impermeable material that restricts vertical recharge to this aquifer system (Water and Rivers Commission [WRC] 2002). According to the WRC, the smaller recharge for these aquifers has resulted in a reduced allocation limit and hence a reduction in the volume of water available for allocation.



**Figure 6A. Groundwater discharge: Leederville–Parmelia aquifer** (Earth Tech 2002)

To the east of the Hill River catchment, extensive Aeolian sands overlie relatively impermeable sediments on the eastern Dandaragan trough and southern Irwin sub-basin. The sediments are partially saturated, providing localised groundwater supplies. South of the Irwin sub-basin the Aeolian sands form a shallow aquifer. To the east of the Urella fault the sands overlie impermeable bedrock. The topography east of the Urella fault strongly influences the shallow depth of the groundwater and encourages flow towards the Yarra Yarra lakes (Commander 1981). Where water levels of the localised groundwater system are above the potentiometric head of the surface (see Figures 6B and 6C), there is the possibility of downward leakage to the underlying regional aquifer (Earth Tech 2002).

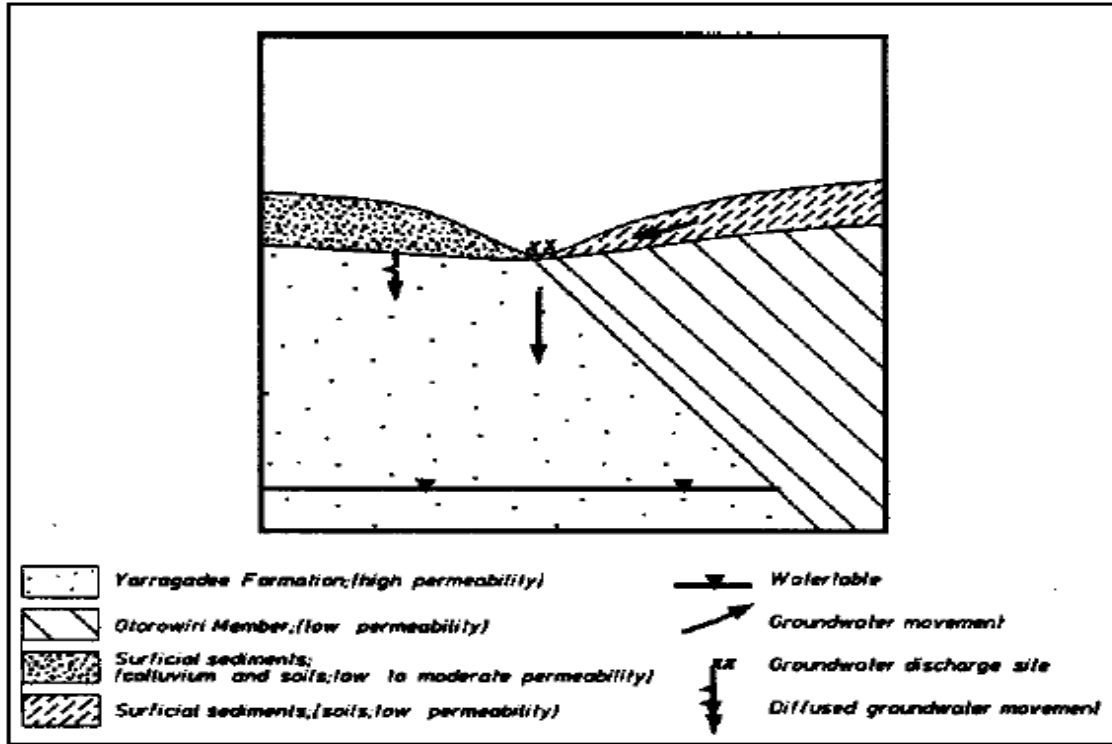


Figure 6B. Groundwater discharge: permeability contrast (adapted from Earth Tech 2002).

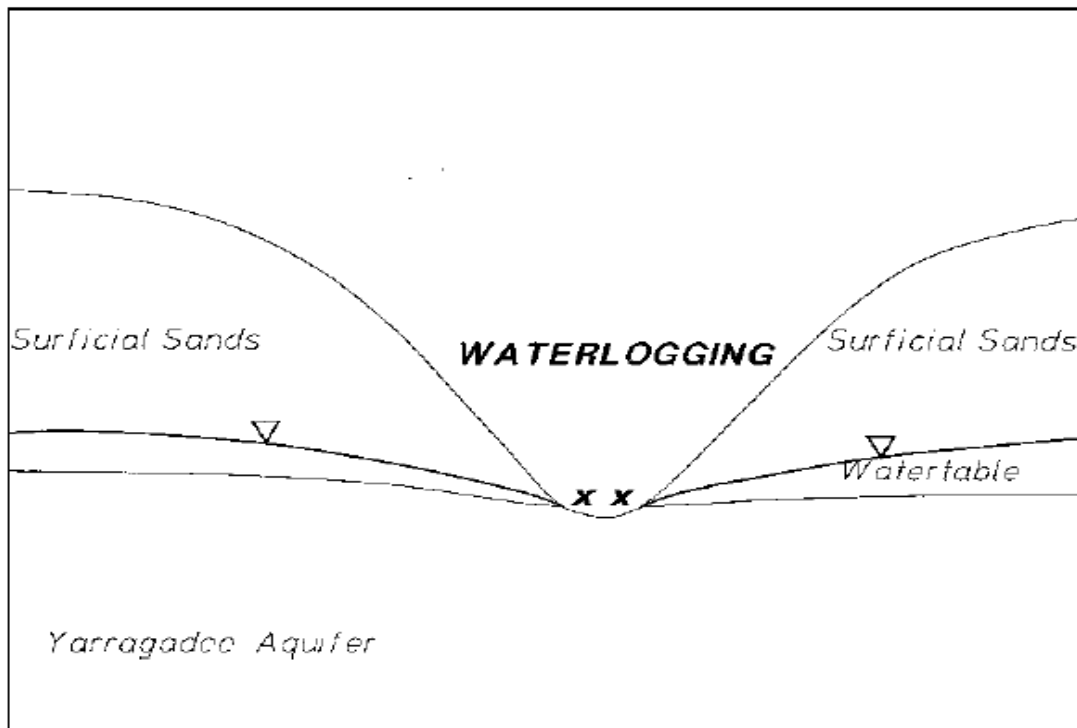


Figure 6C. Groundwater discharge at valley floor of Leederville–Parmelia aquifer (Earth Tech 2002).

## 5. Salinity threats to key natural assets in the NACC's targeted investment area

There are many natural resource assets in the NACC TIP area of the NAR, and not all require investment in management systems to protect them. This section summarises three key assets (biodiversity, water and land) in areas considered to be at risk of salinity. Most of the information in this section is taken from the State NRM Office Report (State NRM Office 2007).

**Table 4: Key assets in areas at risk of salinity in the TIP and other areas of the Northern Agricultural Region**

	Assets	Value	Threat	Key threatened Assets	Threatening processes
Biodiversity	Dandaragan Plateau	Medium	High	Banksia, jarrah-marri woodlands, heaths and scrub-heaths. Vertebrates including peregrine falcon, malleefowl, Carnaby's cockatoo, Baudin's cockatoo, chuditch and carpet python are found in the area. Rare floras are also recorded in the area (see Appendix 2).	Vegetation clearance; changing land uses; introduced plants.  Animals, diseases and pollution.
	Edel	Low	Medium		
	Tallering	Low	Medium		
	Lesueur sandplain	Low	Medium		
Water resource assets	Dathagnoorara water resource (WR)	High	High	Water resource (water supply asset)	Natural recharge: spring, lakes, rivers and ponds.  Human factors: high water use, leakage, disposal of drainage water.
	Gingin groundwater area (GWA) Rights in Water and Irrigations (RIWI)	High	High		
	Gingin WR	High	High		
	Arrowsmith groundwater RIWI	High	Medium		
	Lancelin WR	High	Medium		
	Arrino Bores WR	Medium	Medium		
	Badgingarra WR	Medium	Medium		
	Cervantes WR	Medium	Medium		
	Coomberdale WR	Medium	Medium		
	Dandaragan WR	Medium	Medium		
	Mingenew WR	Low	High		
	Three Springs WR	Low	High		

	Hill River	High	High	Wannamal lake system, Hill River, Moore River.  Minyulo Brook, Caren Caren Brook, Gingin Brook and Irwin River.	Increased inundation; mining; trampling by recreational users; urban development pressure; agrochemical pollution.
	Gingin Brook	High	High		
	Irwin River	High	High		
	Lower Moore River and Wannamal Lake system	High	High		
	Arrowsmith River	High	High		
	Caren Caren Brook	High	High		
	Minyulo Brook	Medium	Medium		
	Irwin River	Medium	Medium		
		Low	High		
Agricultural land	Northern Victoria Sandplain zone	High	High	Private broadacre crop land; native vegetation land; planted forestry land, Aboriginal land and crown land including national park, and game reserves.	Vegetation clearance; changing land uses; introduced plants.  Animals, diseases and pollution.
	Dandaragan Plateau	Medium	High		
	Arrowsmith zone	Medium	Low		
	Irwin river zone	Low	Low		

\* Asset values and threats are based on the work of the State NRM Office Report 2007

## 5.1 Biodiversity

Salinity is a serious threat to biodiversity in the TIP area of the NAR as it has impacts on native species, ecological communities and ecosystem function. While substantial information and understanding is available about the impacts of salinity on agricultural land, less is known about its impacts on biodiversity. Some of the current knowledge regarding salinity impacts on biodiversity is summarised in Table 3, which shows that the most highly threatened biodiversity assets in the region are in the Dandaragan Plateau TIP area. In this zone, remnant native vegetation in lower parts of the landscape (such as banksia, jarrah-marri woodlands, prickly bark and extensive heaths and scrub-heaths) and associated native fauna are all potentially at risk from rising groundwater levels or future salinity.

Although the remnant vegetation represents only a small part of the TIP area, it is something to build from and a potential model for investment in other areas. Investigation here suggests the need for integrated plans setting out the management actions necessary to reduce the decline of threatened species and ecological communities and support their recovery. These recovery plans should set out the necessary steps to protect and restore important populations of threatened species and habitat, at the same time as managing and reducing rising groundwater levels.

## 5.2 Water resource assets

According to Ridley and Pannell (2005), water resource assets fall into two classes: water supply and waterscape. Values associated with water supply assets include economic values (industry, drinking water, aquaculture), social and recreational values (fishing, swimming, bird watching, boating and other pursuits; cultural and spiritual pursuits), and environmental value (biodiversity, uniqueness, aesthetics and ecological functions i.e.

flood mitigation and natural land drainage) (State NRM Office 2007). As can be seen in Table 3, the highest priority water supply assets based on the value and level of salinity threat are the Gingin RIWI (*Rights in Water and Irrigations Act 1994*), Gingin water resource (WR), Arrowsmith groundwater RIWI, and Lancelin WR. As the population grows, the water supply assets become increasingly valuable as they are the source of drinking and irrigation water for the increased populations. Incentives focused on reducing salinity risk and promoting water quality are therefore needed.

In terms of waterscapes, priority assets include the Hill River, Gingin Brook, Irwin River, Lower Moore River, Wannamal Lake system and the Arrowsmith River. These are all under increasing pressure not just from rising watertables but also from mining, trampling by recreational users, urban development and agrochemical pollution (A biodiversity audit of WA, 2002). Incentives focused on minimising the groundwater recharge by fencing off affected areas and revegetating with perennial species are indicated.

### **5.3 Agricultural land assets**

Agricultural land assets value and threat information are based on the soil-landscape zones as defined by DAFWA's Natural Resources Assessment Group (Schoknecht et al. 2004). These zones delineate broad terrain types based on geomorphological criteria and provide a regional perspective of the landscape on a number of issues, including salinity. Table 3 shows the highest priority agricultural land for investment in the NAR is the Northern Victoria sandplain zone (223) and the Dandaragan Plateau zone (222). Both have moderate to high asset value in the TIP area (DOW agency statement 2007) and are under threat of future salinity.

The Dandaragan Plateau zone has the highest priority for investment as it has been more thoroughly researched than the Northern Victoria sandplain zone and has already attracted a degree of technical support. Moreover, in the Dandaragan Plateau zone a number of options to manage salinity threats in the area are in place. In addition, recent studies on the geographic priority areas for agricultural land indicates that the Dandaragan Plateau exhibits groundwater levels that are typically shallow, rising with variable quality and are difficult to manage. As a result the area is likely to display greater increases in dryland salinity (Bairstow et al. 2006).

## 6. Conclusions

A summary of the natural assets for the Dandaragan Plateau zone was undertaken and related to the hydrogeology of the Parmelia formation, the Otorowiri siltstone member and surficial aquifer. The conclusions are that:

- Due to the clearing of native vegetation, increased groundwater recharge has resulted in the development of shallow watertables and increased waterlogging with significant implications for the diversity of native vegetation and fauna, wetlands, high value agricultural land and other assets of regional significance.
- The highest priority zone (based on asset values and rising watertables) for investment in managing the future salinity risk in the NACC region is the Dandaragan Plateau. In this area, assets in the low-lying parts of the landscape—including remnant native vegetation, native fauna, productive agricultural land, reserves, wetlands and water supply assets—are all potentially at risk from rising groundwater tables or future salinity.
- While this area represents only a small part of the area affected by salinity in the NAR, with its significant technical support and research information already in place, as well as options for managing salinity threats, the Dandaragan Plateau zone would be comparatively easy to build from and provide a model for other regions.

Investment incentives focused on lowering groundwater tables or reducing future salinity risk in the TIP area therefore important. These may include:

- planting, regenerating and maintaining native vegetation in recharge and discharge zones;
- establishing the development of sustainable agricultural practices, including planting perennials pastures (to replace annual pastures) as well as planting salt-tolerant species in the discharge areas;
- fencing off of salt affected areas and strategically revegetated the discharge areas with with tree crops and some mix of salt-tolerant species;
- engineering options such as surface water control structures to alleviate waterlogging and reduce the affects of salinity;
- examining the quality of groundwater as a potential asset for new or expanding industries in the region, such as horticulture;
- the use of refined land assessment tools that locate native vegetation, tree crops, perennial pastures, and high-value annuals, as well as tools that enhance our understanding of landscape process and function, including salt storage and groundwater flow.

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**Appendix 1: Regional priorities for water resources****Table 1. Waterscape assets (Northern Agricultural Region)**

Waterscape s		Value		
		High	Medium	Low
Threat	High	Gingin Brook Hill River estuary Hutt River Irwin River estuary Lake Logue/ Indoon system Lennard Brook Lower Moore River and estuary Wannamal Lake system	Chapman River Chapman River estuary Greenough River Pools Moore catchment/ River	Irwin River Lake Moore Lake Pinjarrega Mongers Lakes Yarra Yarra Lakes
	Medium	Gingin catchment Lakes Greenough River Estuary Guraga Lake Hutt Lagoon system Karakin Lakes Lake Logue/ Indoon system Lake Thetis Namming Lakes	Arrowsmith River Bowes Estuary Caren Caren Brook Greenough River Hutt Estuary Minyulo Brook Murchison River	Bowes River Buller River Eneabba Creek Oakagee River
	Low			Boothendarra Creek Eneminga Swamp Frederick Smith Creek Leeman Lakes Mullering Brook Nambeing Swamp Nambung River Yarra Monger tributary

**Table 2. Water supply assets (Northern Agricultural Region)**

Water supply		Value			
		High	Medium		Low
Threat	High	Allanooka/Dongara/Denison WR	Kalbarri WR	Gascoyne GW area	Miling WR
		Arrowsmith WR (Perenjori)	Leeman WR (Midway bore)	Greenough River Pools	Mingenew WR
		Calingiri WR	Moora eastern WR	Guilderton WR	Northampton WR
		Dathagnoorara WR	Mount Peron WR	Hutt Lagoon system	Perenjori WR
		Dookanooka WR	Nabawa WR	Jurien WR	Three Springs WR
		Eneabba WR	New Norcia WR	Karakin Lakes	Watheroo WR
		Gascoyne GW area (Northampton block)	Port Gregory WR	Lancelin WR	Yerina Spring WR
		Gingin GWA RIWIA	Wicherina CA	Ledge Point WR	Yuna WR
		Gingin WR	Woodridge WR		
		Jurien-Turquoise Coast WR	Yalgoo WR		
		Jurien GW Area RIWIA	Yerecoin WR		

	Medium	Arrowsmith GW RIWIA Buntine/Marchagee braided saline drainage line	Arrino bores WR Badgingarra WR /Cervantes WR Coomberdale WR /Dandaragan WR Gascoyne (RIWIA) Gascoyne GW area (Yilgarn Craton) Green Head WR Guragara Lakes	Horrocks beach WR Moora WR Port Gregory WR Private sources for industry & commerce (RIWIA) Private stock & irrigation sources (RIWIA) MW Utcha Swamp	
	Low	Seabird WR			Yenart (RIWIA) Yerecoin GW area

**Appendix 2: Region priorities for land management****Table 1. Threat to agricultural land resource asset based on land salinisation threat**

Ag land (land salinisation)		Value		
		High	Medium	Low
Threat	High	Eastern Darling Range zone Northern zone of Rejuvenated Drainage Pinjarra zone Warren-Denmark Southland zone Western Darling Range zone	Chapman zone Dandaragan Plateau zone Northern zone of Ancient Drainage Pallinup zone Southern zone of Rejuvenated Drainage Stirling Range zone Esperance Sandplain zone	Jerramungup zone South-eastern zone of Ancient Drainage South-western zone of Ancient Drainage
	Medium	Bassendean zone Perth Coastal zone	Albany Sandplain zone	Lockier zone Ravensthorpe zone Northern Victoria Sandplain zone
	Low	Donnybrook Sunkland zone Leeuwin zone Scott Coastal zone	Arrowsmith zone Kalbarri Sandplain zone Port Gregory Coastal zone	Geraldton Coastal zone Irwin River zone Salmon Gums-Mallee zone Southern Cross zone

### Appendix 3: Region Priorities for Biodiversity Management

**Table 1: Threat to biodiversity resource asset based on land salinisation threat**

State Level		Biodiversity Value			
Biodiversity Assets		High	Medium	Low	
Landscape Context and Threat	High	Ancient Drainage Rejuvenated Drainage Pindanland Hart South Kimberley Interzone Fitzroy Trough	Western Mallee Dandaragan Plateau Pentecost Mount Eliza	Perth Mitchell Berkeley Geraldton Hills Southern Jarrah Forest	
	Medium	Fortescue Western Murchison	Roebourne Chichester Wooramel Eastern Murchison Victoria Bonaparte	Ashburton Cape Range Ord Lesueur Sandplain Fitzgerald Southern Cross Northern Jarrah Forest	Edel Tallering Warren Augustus Eastern Mallee Tallering
	Low	Tanami Kintore Mackay McLarty Dune Field Central band, Nullarbor Plain Trainor Mann-Musgrave Block Eastern Goldfields	Carnegie Eastern Maralinga Central Shield	Lateritic Plain Hampton Mardabilla Recherche Rudall Northern band, Carlisle Hamersley	

