Department of Conservation and Land Management

The Hydrogeology of the Southern and Scott River Ironstone Communities South West Western Australia

FINAL

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GCS Groundwater Consulting Services Pty Ltd

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1. INTRODUCTION

1.1 BACKGROUND

The Department of Environment and Conservation (formerly the Department for Conservation and Land Management) is responsible for managing a number of threatened ecological communities. Flora assemblages comprising rare, threatened plants, or rare assemblages of such plants, occur on ironstones in the south-west of Western Australia.

The ironstone communities are described as "*...winter wet shrublands that occur on skeletal soils over the massive ironstone on the coastal plains and the foot slopes of the Whicher Range*" (Gibson *et al*, 2000). The ironstone communities are indicated in the field by typically low shrubby vegetation, red/brown ironstone or ironstone-derived soils and a flat-lying setting which is inundated in winter. The transition from the normal regional vegetation assemblages can be gradational to sharp. Approximately 90% of the ironstone communities have been cleared and the occurrences that remain were probably left because of the low agricultural production capacity of the shallow ironstones.

For management purposes the ironstone communities are divided into two groups by the Department of Environment and Conservation:

- The Southern Ironstones are those which occur on the Swan Coastal Plain and adjacent parts of the Blackwood Plateau. For convenience, these communities are further divided into the Busselton and Tutunup groups in this report (refer to *Figure 1, Appendix A).*
- Scott River Ironstones occur on the Scott Coastal Plain and nearby parts of the Blackwood Plateau.

Tille and Lantzke (1990a, 1990b) mapped the extent of the ironstones which are shown on *Figure 2 (Appendix A)*.

The remaining ironstone communities (90 hectares of Southern Ironstones and 325 hectares of Scott River Ironstones) are under various levels of threat. A full description of the communities, their importance and CALM's management is provided in Interim Recovery Plans prepared by Meissner and English (2005) and Luu and English (2004).

The objective of this project was to understand the surface water and groundwater processes that support the communities, with a view to on-going monitoring and protection of the communities from development pressures.

2. SITE INSPECTION

Selected ironstone communities were inspected by Groundwater Consulting Services on (25 and 26 May 2006) in conjunction with key Department of Environment and Conservation staff. Mr Aarron Grant provided a guide to the communities on the Swan Coastal Plain, and Mrs Janine Liddelow guided Groundwater Consulting Services through selected communities on the Scott Coastal Plain.

The communities inspected are summarised in *Table 2.1* below. Occurrence locations are shown on *Figure 2 a to c, Appendix A.* A summary of the ironstone occurrences as provided by DEC is presented in *Appendix B.*

Table 2.1 – Records of Ironstone Occurrences Inspected in June 2006

Date	**Occurrence Number**	**Location**
Southern Ironstone Communities – Busselton (Figure 2a)		
25/5/06	13	Price Road
25/5/06	14	Payne Road
Southern Ironstone Communities – Tutunup (Figure 2b)		
25/5/06	1 to 5	Tutunup Road
25/5/06	6	Oates Road
25/5/06	7 & 8	Williamson Road
Scott Ironstone Communities (Figure 2c)		
26/5/06	4 & 5	Dennis Road
26/5/06	15-18 Drive-by only	Governor-Broome Road

Several small soaks on the Scott and Swan Coastal Plains were inspected. These soaks were excavated by graziers, and the interaction between groundwater and the ironstone could be directly observed. Selected photographs of communities and soaks are reprinted in a series of plates in *Appendix C.*

The inspections above provided an overview of the ironstone communities and their setting in the environment. They show the nature, thickness, depth of soil cover, and groundwater level variations at discrete locations.

3. OBSERVATIONS

3.1 OCCURRENCE AND DISTRIBUTION

The remaining ironstone communities occur on the inland portion of the Swan and Scott Coastal Plains, and the adjacent parts of the Blackwood Plateau. The Department of Environment and Conservation holds records of historical ironstone communities that were destroyed by clearing, however these were not considered in this study.

There does not appear to be a characteristic pattern of distribution of the communities, however, only the remaining communities are available for consideration.

3.2 GEOLOGY

3.2.1 *Surface and Underlying Geology*

The surface material at all of the inspected sites comprised a variable cover of sand and exposed ironstone.

The Southern ironstone communities lie on either sand/clay sediments of the superficial formations, or on older shales on the Blackwood Plateau (*Figure 3a, Appendix A*). The sediments of the coastal plains (near the remaining communities) comprise a layer of Bassendean Sand, up to several metres thick, which overlies the Guildford Formation (mostly silt and clay, with minor sand). The Yoganup formation (sand with minor clay) is exposed at the foot of the Whicher Scarp, and hosts the mineral sands deposits that are mined in the region. Nearer the coast, the sediments are dominated by sand and limestone. The soils on the Blackwood Plateau are developed on the shales and sandstones of the Leederville Formation and other older units. The occurrences all overlie shaley sediments at depth. These older units (which include the Yarragadee Formation, which is a major regional aquifer) extend beneath the superficial formations at the coastal plains.

The surface geology for the Scott ironstone communities is also shown on *Figure 3a, Appendix A*. These communities are developed in Bassendean Sand overlying the Vasse Member of the Leederville Formation, which forms a regional aquifer system. The Yarragadee Formation is not present beneath the Scott communities – they are underlain at depth by the Lesueur Sandstone which abuts the Yarragadee Formation to the east of the communities.

There is no clear link between the ironstone occurrences and the underlying geology *Figure 3b, Appendix A*. The majority of the ironstone communities in the Busselton area are underlain by the shales of the Leederville Formation which form an extensive aquitard. The superficial formations in the Tutunup and Scott Coastal areas are underlain by the interbedded sandstones and shales of the Vasse member of the Leederville Formation which forms a regional aquifer system. It is noted that the remaining ironstone communities on the Swan and Scott coastal plains do not occur in the areas where the Yarragadee Formation outcrops (in the middle of the Blackwood Plateau) nor where the Yarragadee Formation is in good hydraulic connection with the superficial formations.

A generalised cross-section is shown as *Figure 4 (Appendix A).*

3.2.2 *Ironstone*

There was clear evidence of near-surface ironstone at all of the communities that were inspected. The lithology of the ironstone varied from nodular, laminar and irregular ferruginous concretions, which probably formed in place under the current hydrogeological regime. The ironstones are still in the process of accumulating whilst the shallow groundwater level fluctuates and form in the pore spaces in the existing geological materials.

Beneath the Swan Coastal Plain, the ironstone materials appear to be localised. Ironstone appears to occur as a relatively continuous layer beneath the Scott Coastal Plain. The numerous farm soaks inspected on the Scott Coastal Plain all penetrate the ironstone. Rockwater (2004) notes the "coffee rock" (ironstone) to be discontinuous on the eastern Scott Coastal Plain. This is supported by the geological records in Mohsenzadeh (1999), in which "coffee rock" to about 2m thickness was observed in most, but not all, drill-holes.

The ironstone, when inspected on an undisturbed site, appears to be relatively impermeable (*Plate C1, Appendix C).* However, where it is exposed (such as by excavation at Tutunup, core drilling at Ruabon Road, and in farm soaks at the Scott Coastal Plain), the cavities that penetrate the ironstone are evident *(Plates C2 to C7).* It is likely that areas that are relatively devoid of larger plants (for example, parts of Ruabon Road) have fewer or smaller cavities, as these cavities would be utilised by plant roots to access the groundwater within and beneath the ironstone. The origin of the cavities is not known, but it is possible that they represent existing plant roots around which the ironstone was deposited.

The presence of ironstone adjacent to the Blackwood Plateau, where the groundwater level is elevated above the coastal plains, is depicted on the hydrogeological cross-section in *Figure 4 (Appendix A).* It is possible that movement of iron-rich groundwater from the older sediments beneath the Blackwood Plateau is responsible for the distribution of the ironstones. Further investigation is probably not warranted as there are no implications for management.

3.3 GROUNDWATER

The groundwater table is hosted in the superficial formations, and may be in sand or clay, depending on the location and the current groundwater level (which varies seasonally).

3.3.1 *Levels, Recharge, Flow and Discharge*

The regional groundwater table beneath the coastal plains is shown as contours in *Figure 5 (Appendix A)*. The groundwater levels are high at the inland margin of each coastal plain, and groundwater flows towards the coast. The various rivers receive groundwater and locally control groundwater flow directions. Under high runoff conditions, surface water may recharge the aquifer.

Hydrographs for selected regional monitoring bores are included in *Appendix D* and monitoring bore locations shown on *Figure 2, Appendix A*. Groundwater levels at the water table rise and fall in response to rainfall-recharge events, and drainage towards the coast and rivers. Local groundwater use, drains and natural wetlands all affect groundwater flow patterns. Several stormwater runoff detention structures have recently been constructed on the Swan Coastal Plain and these have some potential to affect local groundwater levels when inundated.

Groundwater can be observed in relation to the ironstone layer in various soaks on both coastal plains. *Plates C4, C5 and C7 (Appendix C)* show excavated soaks, where the groundwater level is visible at about the seasonal low. Seasonal high water level is visible at some locations as a stain. Groundwater occurs at shallow depths beneath each of the observed occurrences. Winter groundwater levels are above ground, and the shallow groundwater level is the cause of the inundation – the incident rainfall cannot infiltrate into the saturated ground.

Groundwater levels in the superficial formations fluctuate between 1 and 2m seasonally. At this depth, it is clear that the resident plant communities can still access the water, although there is sometimes evidence of water stress in some plants in late summer, under natural conditions. Historical water table variations (recorded or inferred) can be used as a guide to establish acceptable drawdown impacts.

3.3.2 *Quality*

Salinity

Groundwater salinity in the superficial formations beneath the Scott Coastal Plain is fresh, ranging from 60 to 690mg/L Total Dissolved Solids, with most falling between 200 and 500mg/L TDS (Baddock, 1995). Mohsenzadeh (1999) found, in a network of newly installed monitoring bores, groundwater salinities ranging between 20 and 1,000mg/L TDS, and one sample returned a salinity of 2,400 mg/L TDS. The higher salinities were recorded where evaporative concentration of salts occurs. Salinities for the Swan Coastal Plain are similar, ranging from below 500mg/L near the Whicher Scarp to about 7,000mg/L at the coast (Cable Sands 2001), and salinities near the Tutunup mine were between 160 and 450mg/L TDS.

Land clearing records were not reviewed, however it is expected that large tracts of land have been cleared for 50 to 100 years on the Swan Coastal Plain, and for perhaps shorter periods (40-60 years) on the Scott Coastal Plain. There is no indication in the available groundwater monitoring record of significant salinisation due to land clearing or rising groundwater levels. Locally elevated salinity may occur.

Nutrients

Several studies on nutrients in the Scott River (and the Scott Coastal Plain) have been undertaken (Gerritse 1994, Hiskotis 2004). The studies indicate elevated nutrients in groundwater (mean 8.5mg/L N, maximum 135mg/L N – Mohsenzadeh and Diamond, 2000) at various locations, due to agricultural use of fertilisers, and stock raising. The low intensity of the existing land-uses is probably not cause for concern, however new ventures with high nutrient demands up-gradient of a community would require assessment and perhaps control measures.

Acidity

Acidic groundwater conditions can occur due to lowering of the groundwater table, where there is pyrite in the soil profile. Pyrite occurs commonly in peat. Although significant peat deposits were not observed, the potential for falling groundwater levels to induce acidic groundwater conditions should be considered. The Swan Coastal Plain has been mapped (WAPC, 2003) at a reconnaissance scale for actual and potential acid sulphate soils, and the region in which the ironstone communities occur is mapped at either moderate to low, or low to negligible risk, for soils at greater than 3m depth. This would be best managed by assessing any occurrence if there was a specific threat.

The Beenup mineral sands mine (on the Scott Coastal Plain) was closed due to difficulties in managing acidic leachate in the tailings.

Neither the presence nor risk of acid-sulphate soils has been addressed as part of this study.

3.3.3 *Groundwater Use*

Groundwater resources in the region are used for stock and domestic water supplies, as well as for large scale fodder and vegetable crop irrigation, mineral processing and town water supplies. The Water Corporation is investigating the resources of the Yarragadee Formation beneath the Blackwood Plateau to supply groundwater for Perth's domestic consumption.

Figure 2 (Appendix A) shows the licensed groundwater users in the region, with the annual allocations coded to show the production aquifer. Note that there may be differences between the allocation and actual use.

The greatest potential impact on the ironstone communities from groundwater use is from direct abstraction from the superficial formations. Lesser impacts are associated with drawdown induced in the superficial formations by leakage into the deeper aquifer systems when they are pumped.

In terms of direct abstraction from the superficial aquifer system, the greatest impact to date on the ironstone communities has been through mine dewatering of the superficial formations at the Tutunup minesite. This is addressed in *Section 3.4*.

The increasing regional use from the deeper aquifer systems - Leederville, Yarragadee and Lesueur - are evident in the local hydrographs. Induced drawdown in the few overlying superficial formations monitoring bores has been negligible to date. For example, the impact of abstraction from the Yarragadee Formation by the pivot irrigator shown on *Figure 2b* is evident in the hydrograph of the Yarragadee monitoring bore BUS22D in the Tutunup study area. However, the drawdown has not propagated to the adjacent superficial formations monitoring bore BUS22S *(Appendix D)*.

On the Scott Coastal Plain, the Beenup Minesite operated to the west of the Scott River Ironstone communities in the mid- to late- 90s. Groundwater was abstracted from the Lesueur Sandstone for processing and the drawdown is evident in the local monitoring bores particularly during 1997 and 1998 (SC5A and SC15A, B). Drawdown propagated to the overlying Leederville formation (SC5B) but is not evident in hydrograph for the superficial formations (SC5C). Since the mine was closed, the production bores were transferred to a local farmer for irrigation supply. The pivot irrigation area is shown on the aerial photograph *(Figure 2c, Appendix A)*. The hydrograph for the nearest regional monitoring bore SC15A, screened over the Lesueur Sandstone, shows decreasing seasonal low groundwater levels with increasing use over summer, but a return to relatively constant seasonal high groundwater levels following reduced use over winter.

3.4 TUTUNUP EVENT 2004

Cable Sands excavated mineral sands ore from an orebody located to the north of the Williamson Road TEC (occurrence numbers 7 and 8, *Appendix B*). Groundwater level monitoring data for bores, installed and monitored by Cable Sands, were provided to Groundwater Consulting Services by the Department of Environment and Conservation. A plan showing the locations of the bores was available from the Public Environmental Review (PER 2001). During excavation of the orebody, part of which was below the local water table, groundwater drained into the excavation and was pumped out to maintain working conditions in the pit. This drainage resulted in lowering of the local groundwater levels, much the same as pumping from a bore. The network of groundwater monitoring bores, installed at various depths, enabled the effects of the dewatering drainage on the aquifer to be assessed.

Between approximately March 2004 and March 2005, groundwater levels in the bores adjacent to the Williamson Road community were lowered by up to four metres (hydrographs are provided in *Appendix D*). The lowest water levels were observed between about September and December 2004. The drawdown was greatest in the deeper monitoring bores, and less in the shallower bores.

Table 3.1 shows a summary of the groundwater level changes, based on background data provides in the PER (Cable Sands 2001) and data supplied by CALM. It is recognised that only an incomplete record of water levels is available, and that the analysis is somewhat compromised. Nevertheless, the following statements can be made:

- The seasonal water level variation is about 1.25 to 1.5m, with a high in September/October and a low in April/May.

- The natural groundwater levels trend steeply upwards at the start of winter (about May or June), due to rainfall recharge, and a subsequent gradual decline commencing from about October, due to dry conditions in summer.

- The drainage of groundwater towards the mine excavation appears to have induced drawdown in the monitoring bores (other influences may have also contributed to changes in groundwater levels).

- The drawdown was greatest in the deeper bores, and was greatest in the bores nearer the excavation (MB2 and MB4).

- The change in the water table elevation was mostly subtle (less than 0.3m), although the greatest recorded change was 1.2m, at MB4, which was nearest the excavation (records from MB1 are incomplete). MB4 is located near the area of vegetation deaths.

- Water levels recovered to pre-mining levels within about a year of the cessation of dewatering.

The drawdown induced at the water table may have resulted in desiccation of the soil around the root-zone of the plant community (soil type affects the retention of water in the zone above the water table, but was not assessed). Multiple vegetation deaths occurred around late 2004, although the timing of the deaths is not well understood. There appears to be a close relationship between the dewatering-induced groundwater level changes and the vegetation deaths.

It is understood that a surface irrigation system was initially proposed by Cable Sands (the mine operator) to minimise the risk of dewatering impact on the community, but was not approved by the Department of Environment and Conservation due to the risk of physical damage to the vegetation community and spread of phytophthera (die-back fungus). An artificial recharge system comprising a gravel-filled trench that was to be flooded with water during mining, to support the shallow groundwater levels, was installed, but vegetation deaths were not prevented. It is not known whether the system was operated reliably, but the groundwater monitoring data show that groundwater levels fell despite the system. Groundwater level data show that the target water levels for various parts of the trench (Cable Sands 2001, refer *Table 3.1*) were not maintained.

The experience at Tutunup helps us to understand that:

- The vegetation communities appear to be highly dependent on the shallow groundwater during summer,
- The decline in seasonal minima of about 0.3m at the water table was sufficient to kill some plants – the rate of onset and the actual decline at the plants is not known. '
- Some plants have recovered since water levels recovered, and other than the individual plant deaths, there were no long-term consequences.

Although quantitative limits cannot be drawn from the experience at Tutunup, it is likely that the community would have survived (or the number of deaths reduced), if any, or a combination, of the following had occurred:

- The water table drawdown at the community had been limited to less than about 0.3m;
- The drawdown had been induced gradually over several seasons, to encourage deeper root growth (the opinion of a botanist should be sought, and some trials mey be necessary)

It is likely that different plant species have different tolerances to the various changes in groundwater conditions. Differences in local hydrogeology may also result in differing normal seasonal groundwater level variations.

Further details on the design and operation of the artificial recharge system are available in the PER (Cable Sands, 2001).

Table 3.1 – Records of Groundwater Levels near Williamson Road Community (Tutunup Mine)

Bore Site	Bore ID	Trench Water Level Target	Background December 2001	Active Mining December 2004	Change in Dec 01 to Dec 04
MB2	**A**	**43.5**	**43.3**	**43.0**	**0.3**
	B		43.3	40.5	2.8.
	C		43.3	40.2	2.1
	D		43.3	40.2	2.1
MB3	**A**	**44.0/44.5**	**44.6**	**44.5**	**0.1**
	B		44.7	43.2	1.5
	C		44.4	42.0	2.4
	D		44.3	41.5	2.8
MB4	**A**	**43.0/43.5**	**43.5**	**42.3**	**1.2**
	B		43.1	39.5	3.6
	C		43.1	39.2	3.9
	D		43.0	39.2	3.8
MB5	**A**	**(45.0)**	**46.2**	**46.2**	**0**
	B		46.2	44.7	1.5
MB6	B	n/a	47.9	47.4	0.5
MB7	**A, B**	**44.0**	**44.4**	**43.8**	**0.6**
MB8	B	n/a	46.6	45.5	1.1

- A - shallowest bore, D – deepest bore – water table bores shown in **BOLD** typeface
- Target depths from PER (Cable Sands 2001) for adjacent sections of the recharge trench
- Water levels read from charts – numerical data not available
- Positive change means a deeper groundwater level
- Data from MB1, MB6A, MB8A not suitable for analysis

3.5 VEGETATION

The ecological value of the ironstone communities includes not just the individual species, but the assemblages of species. Assemblage details are available in the Interim Recovery Plans. For the purposes of this report, it is sufficient to note that not all communities have the same assemblages. Minor variations in soil type, climate, surrounding vegetation, and groundwater/surface water conditions are likely to affect the assemblage composition (supported by Gibson *et al* 2000)

It is inferred that the plant species that dominate the ironstone communities have the following characteristics:

- Tolerance to seasonal inundation for periods of several months.
- Reliance on the low salinity groundwater that occurs beneath or within the ironstone, during summer and autumn when surficial soil moisture is likely to be exhausted.

Where the ironstone is absent, or where a significant thickness of sand overlies the ironstone (in excess of perhaps 0.5-1m), a vegetation community more typical of areas not on ironstone is able to develop.

The communities are considered to be highly dependent on groundwater in summer and autumn. Their dependence on groundwater probably reduces significantly in winter and spring when there is a wetter shallow soil profile (in and just beneath the ironstones) and regular rainfall.

Although the ironstone appears impenetrable, closer inspection reveals common cavities and vertical holes through which plants can access the underlying soil. There may be areas where particular species are dominant due to their ability to extend their roots into the less penetrable sections of ironstone, however this is considered to be the exception. No flora investigations were conducted – this is based on geological observations only.

4. WATER AND IRONSTONES

The presence of shallow groundwater, and ephemeral surface water, both resulted in creation of the ironstone itself, and the unique flora communities. Where the surface water and groundwater conditions are different, the communities do not exist. Likewise, changes to the conditions are likely to result in significant changes to the communities.

Figure 4 (Appendix A) provides a pictorial depiction of the major geological and hydrogeological features and processes that control the occurrence of the ironstones, and support the vegetation communities.

The major features are summarised below:

Formation of Ironstones

- Seasonal fluctuations of the water table which precipitate iron as various oxide minerals, from iron-containing groundwater, over a long period of time – the iron oxides have cemented the original sediment, into a semicontinuous to discontinuous layer

Groundwater and Surface Water

- Both deposited the iron oxide (as above), and supports the vegetation during summer and autumn. The shallow groundwater levels prevent vertical drainage of rainfall and runoff, resulting in ponding at lowlying areas during the winter months.
- The standing water prevents flooding-sensitive plants from becoming established

Vegetation

- Is tolerant of periodic inundation.
- Relies on the groundwater at relatively shallow depth (1-2m below ground – specific to each community) in summer and autumn.
- The rare species and assemblages dominate in the particular conditions at the ironstones.
- Some plant species are sensitive to rapid groundwater level decline and deaths have occurred.

5. THREATS

Groundwater Consulting services considers that the major groundwater-related threats to the ironstone communities include:

- Pumping of groundwater that induces groundwater levels to fall in the aquifer beneath the ironstone.
- Changes in water quality (salinity or contaminants) in areas up-gradient from a community, such that poorer quality groundwater flows beneath the community.

5.1 GROUNDWATER LEVEL THREATS

Changes in the groundwater table elevation have demonstrably impacted the ironstone community at Tutunup. The groundwater table may be affected by pumping from the shallow aquifer in which it occurs, or from deeper aquifers, which may promote vertical leakage of groundwater.

Prediction of semi-quantitative of impacts of pumping is a relatively simple task for single-layer aquifers (such as when pumping from a shallow sand aquifer, and predicting the effect of pumping on the water table). When the water is pumped from deeper aquifers, vertical leakage can be difficult to predict. URS (2004) noted, based on hydrograph analysis, that water levels in the superficial aquifer were expected to be fully recharged despite smaller rainfalls. Rockwater (2004) also predicted that summer groundwater levels in the eastern Scott Coastal Plain may fall due to pumping from the Yarragadee Aquifer, in areas where an intervening clay layer was absent, but that winter groundwater levels would not be affected.

Groundwater levels in the Yarragadee Aquifer would be affected by pumping from the aquifer – larger scale pumping at distance may have a similar effect on water levels as smaller scale pumping nearer the point of measurement. As most of the communities do not directly overlie the Yarragadee Aquifer, it is considered that there is little threat.

Pumping from the Leseur aquifer using from the former Beenup mineral sands mine appears to result in increasing drawdown in the aquifer during summer (refer hydrographs for SC15A, *Appendix D*) . Propagation of the drawdown to the water table is possible and this should be regarded as a potential threat to ironstones within the zone influenced by pumping. Installation of suitable monitoring bores would be required to quantify the local groundwater levels and any changes.

The effect of pumping bores on a community should be assessed based on the drawdown measured at the water table. Any proponent should be required to make predictions of water table drawdowns in order to assist with assessment of the acceptability of a project. Development of suitable buffer distances is a case-specific exercise.

Production of timber in extensive tree-farms (such as the existing and proposed *Eucalyptus Globulus* (blue-gum) plantations), may result in both increased groundwater use and reduced rainfall recharge. Localised lowering of the groundwater table is likely to occur within and down-gradient of established plantations. The effects are unlikely to extend up-gradient by more than 100m or so at most, but local assessment is required.

Note that groundwater levels are recorded bi-annually at SC9B (water table). The monitoring frequency is insufficient to demonstrate that seasonal low or high water levels have been adequately captured. Superficial assessment of the hydrograph indicates that the seasonal low groundwater levels may have varied by about 0.3m since 2001 (establishment of an adjacent bluegum plantation, including an apparent rise to pre-2001 levels since 2005. The full recovery of the water table during winter indicates that the drawdown is not related to rainfall variability. The small change in the water table is not considered a threat, and in any case the data are insufficient to properly assess the impacts, and the apparent changes are likely due to recording of water levels at slightly different parts of the cycle of seasonal variation.

The ability to define a change in groundwater levels from their normal seasonal fluctuations depends on the ability to describe the normal fluctuations. Monitoring bore networks are present on both the Swan and Scott Coastal plain, and historical data are available at various frequencies. Apart from the Tutunup occurrence, there are no dedicated monitoring bores, nor regional monitoring bores, in locations suitable for assessment of specific threats.

Establishment of dedicated monitoring bores at the significant occurrences is seen as an important tool to enable any changes in groundwater conditions to be assessed. Linking short-term local groundwater monitoring data from any newly-installed monitoring bores to longer-term records from more distant bores will help to infer local groundwater level variations. This would form the basis of any assessment of impacts on local water table levels. The groundwater level at which plants will suffer cannot be determined at a general level, however experience at Tutunup indicates that reducing the seasonal low by less than 0.3m would be acceptable. The acceptability of greater reductions would depend on the aquifer grain-size (and subsequent capillary fringe thickness), plant species involved. Note that greater reductions in the groundwater pressure for parts of the aquifer beneath the water table may be acceptable, as long as the water table level is managed suitably. It is possible that laboratory trials with ironstone species would be required to assess the sensitivity to water level variations.

The ability of the plants to respond to gradually falling water levels is not known. Intuitively, if the groundwater level is to be lowered to a certain depth, then the more slowly the water level falls, the more able the plants are likely to be to extend their root systems to follow the groundwater. It is also likely that the vascular systems of some plants will have a limiting depth, below which they cannot draw groundwater, however this is outside the scope of work for this project.

Impacts on the communities from drawdown at the water table are likely to be controlled by the:

- seasons in which the drawdown occurs (most impact when there is no surface water);
- initial and maximum depth to the water table;
- rate of onset of the reduced groundwater level; and the
- duration of a reduced water level.

Any proposed intensive groundwater use (or groundwater-modifying activity, such as tree plantations) up-gradient or near a community should be considered as a threat.

Any groundwater use that has the potential to lower the summer low groundwater levels at the water table by more than 0.3m at a community should be considered a threat (larger drawdowns may be acceptable if they are developed slowly).

The guideline presented above should be used to increase the level of assessment and management of a proposed activity, but should not necessarily by used to prevent development.

For the purposes of identifying projects that may threaten local groundwater levels, a table of potential acitivities and interim buffer distances is provided below. The table should be used for initial identification of potential threats only, for guiding more detailed assessment, but not for allowance or disallowance of a proposal.

Table 5.1 – Nominated Distance for Further Attention

Scale	**Nominated Distance for Further Attention**
Superficial/Surficial aquifer	
stock/domestic	50m
irrigation (expect small scale, <200,000kL/annum)	200m
Leederville/Leseur/Yarragadee	
stock/domestic	100m
irrigation/mining/town water supply (<1GL/annum)	5,000m
irrigation/mining/town water supply (>1GL/annum)	10,000m or regional
Non-specific	
intensive silviculture	50m upgradient to ironstone or 500m downgradient to ironstone
point-source contamination threats	50m upgradient to ironstone or 1000m downgradient to ironstone

5.2 GROUNDWATER QUALITY THREATS

The sensitivity of the ironstone community plants to various water qualities was not assessed. Groundwater salinities are typically 100 to 500mg/L TDS on the inland parts of the Swan and Scott Coastal Plains, however salinities to 1,000mg/L are common and higher salinities occur naturally. Salinisation due to land clearing does not appear to be a threat to the communities in this study.

Surface water and groundwater can transmit excess nutrients and pesticides/herbicides from agricultural land (Gerritse 1996, Kitsios, 2004). Intensive landuse or chemical applications up-gradient of a community should be considered as a potential threat. Most contaminant concentrations in groundwater will reduce with distance from the source due to a combination of dilution, dispersion, adsorption and degradation. Therefore the distance between the activity and the community is important.

5.3 GROUNDWATER MONITORING NETWORK

There are various networks of monitoring bores over the general regions in which the communities lie. These range from deep stratigraphic investigation bores to shallow groundwater-table bores. The bores are spread over large areas and are mapped in *Figure 2*

(Appendix A). The only community at which useable monitoring bores exist is the Tutunup (Williamson Road) community, and these were installed by Cable Sands in response to the threat of impact on the Williamson Road community.

The current distribution is sufficient to monitor regional affects, such as climate or regional-scale groundwater pumping. The existing network is unsuitable to monitor threats to specific ironstone communities. Dedicated monitoring bore networks should be considered, with priority given to establishing monitoring networks in communities that are under the greatest perceived threat

Background monitoring at each community should comprise:

- Installation of three monitoring bore nests (each nest comprises three monitoring bores, each completed at a different depth) to enable horizontal groundwater flow directions and vertical groundwater pressure changes to be assessed and monitored.
- Installation of a staff gauge for measurement of surface water levels where appropriate;
- Monthly water level measurement (or more frequently using data loggers for remote sites) at each monitoring bore and at the surface water;
- Quarterly testing for electrical conductivity and pH; and,
- Annual testing for nutrients, pesticides or herbicides as appropriate for the local situation

If a specific threat is to be assessed in relation to a community, then changes to the appropriate monitoring programme

6. CONCLUSIONS

The following conclusions were drawn from this study.

- The ironstone communities are closely related to groundwater – their presence was caused by deposition of iron-oxides from groundwater, and the shallow groundwater level supports the communities
- The periodic inundation prevents the local typical locally occurring plant communities from growing, and results in the specialised community having dominance.
- Shallow groundwater levels fluctuate naturally due to seasonal conditions, and can be influenced by local groundwater use. Groundwater use from deeper aquifers is less likely to impact the communities due to the presence of confining layers between the aquifers and the water table.
- Natural groundwater flow can result in nutrients or contaminants moving towards a community in the groundwater.
- Existing groundwater monitoring networks are sparse and are only suited to monitoring regional trends. Specific monitoring, including historical background water level variations, is required at each community to understand the local hydrogeology and to monitor the impacts of any specific threats.

7. RECOMMENDATIONS

The following recommendations are subdivided to suit both long-term, regional impacts and short-term specific potential threats to the remaining ironstone communities on the Swan and Scott coastal plains.

Long Term

- Establish three nests of monitoring bores at each community, at depths to be evaluated for each site.
- Commence monthly monitoring of groundwater levels concurrently with site inspections.
- Conduct quarterly sampling and analysis for basic groundwater chemistry and perhaps annual analyses for potential contaminants (this may be site specific).
- Determine the ability of vegetation communities to respond to falling groundwater levels to establish the maximum rate of fall that can be matched by root growth, and the maximum depth from which the plants can draw water. These parameters may be used to set realistic maximum impacts on groundwater that could be tolerated near a community.

Short Term / Specific Threats

- Review the likely changes to the groundwater regime that may be induced by the threat.
- Establish groundwater monitoring bores both within and outside the community such that the pre-existing groundwater flow patterns and fluctuations can be recorded.
- Undertake water level and water quality monitoring to suit the perceived threat and to ensure that there is sufficient time to respond to the threat in a timely manner.
- Assess the tolerance of the ironstone plants to groundwater salinity in order to understand the threat posed by any change in groundwater salinity.

On behalf of Groundwater Consulting Services Pty Ltd,

Sam Burton
Director.

8. REFERENCES

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9. LIMITATIONS

Groundwater Consulting Services Pty Ltd prepared this report for the Department of Environment and Conservation in accordance with generally accepted groundwater consulting practice. The specific conditions of the contract and subsequent communications, including express or implied limitations on the scope of work or the budget, have had a bearing on the scope and detail of the project, and on the level of confidence in the findings.

Groundwater Consulting Services' confidence in the ability of a groundwater resource to support a nominated withdrawal of groundwater is subject to spatial and temporal variations in the aquifers, climate and land-use that may not be known or predictable. Conservative assumptions were used where-ever possible, however, estimates of bore and aquifer yield or predicted impacts of pumping can be inaccurate, especially when the conditions on which predictions were made have changed. Groundwater Consulting Services Pty Ltd's predictions are made on the basis that the client will contract Groundwater Consulting Services Pty Ltd to undertake regular reviews of operational data, and such reviews may lead to groundwater availability, quality or other predictions being re-estimated.

Groundwater Consulting Services Pty Ltd does not provide advice on water requirements, irrigation schedules, irrigation system design and other non-groundwater related areas. Groundwater Consulting Services Pty Ltd's advice on bore location, construction, operation or other factors must be considered by the client, after the client has obtained expert advice from other relevant disciplines.

This report must not be used by other parties without the prior express written consent of Groundwater Consulting Services Pty Ltd, with the exception of regulatory authorities. If this report is provided to third parties for reliance, then the client assumes all liability for the representations made in the report.

10. APPENDICES

Appendix A – Figures

Appendix B – Summary Table

Appendix C – Plates

Appendix D – Hydrographs

Appendix A

Figures

GCS Groundwater Consulting Services Pty Ltd

Department of Conservation and Land Management
THE HYDROGEOLOGY OF THE SOUTHERN AND SCOTT RIVER IRONSTONE COMMUNITIES

Figure 1

Project No. CALM011

REGIONAL LOCATION

Drawn: S. Burton
Date: 18 Dec 2006

SOUTHERN IRONSTONE COMMUNITIES (Busselton Area)

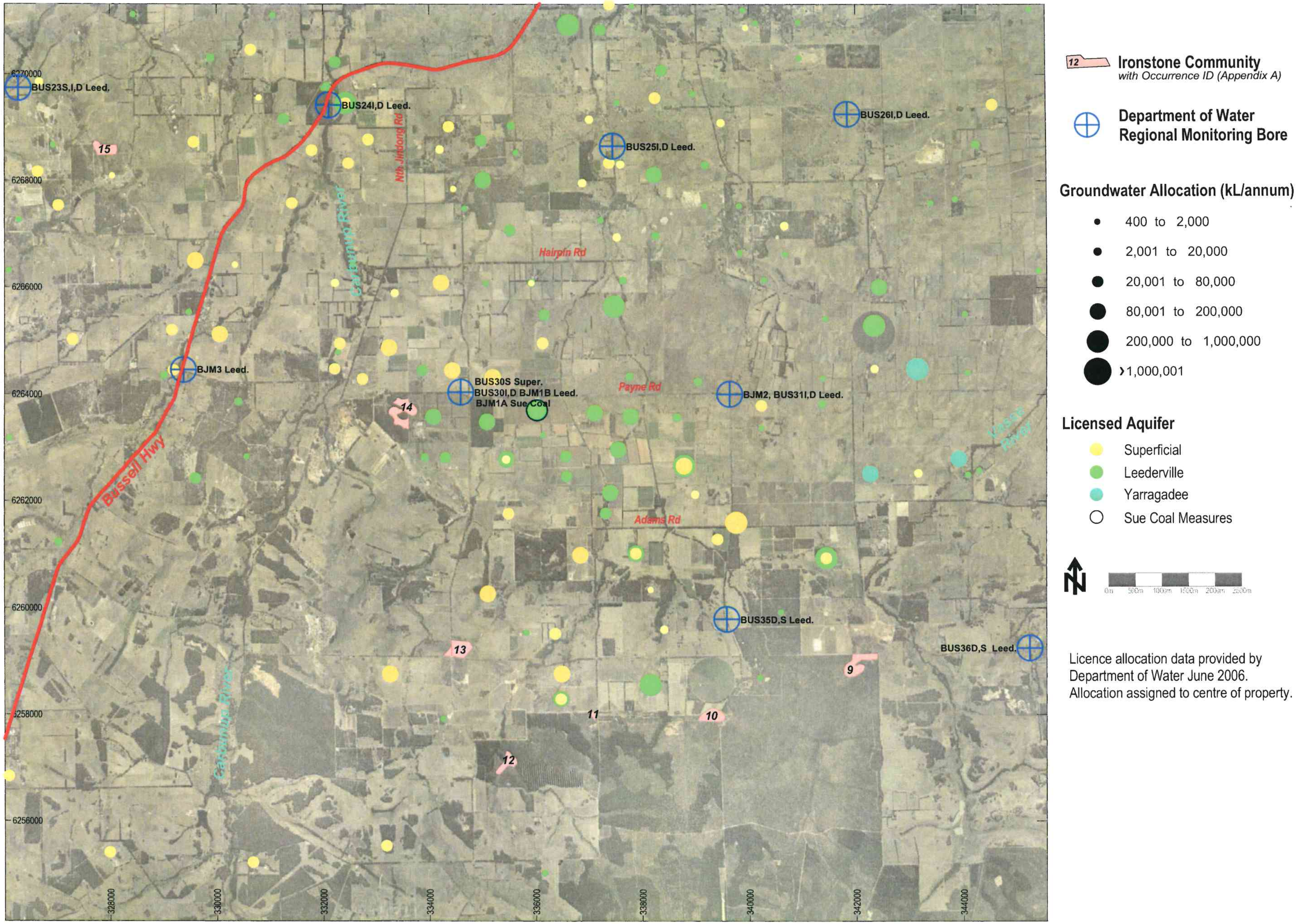
Figure 2a

Department of Conservation and Land Management
THE HYDROGEOLOGY OF THE SOUTHERN
AND SCOTT RIVER IRONSTONE COMMUNITIES

GCS Groundwater Consulting Services Pty Ltd

Project No. CALM011

Date: December 2006



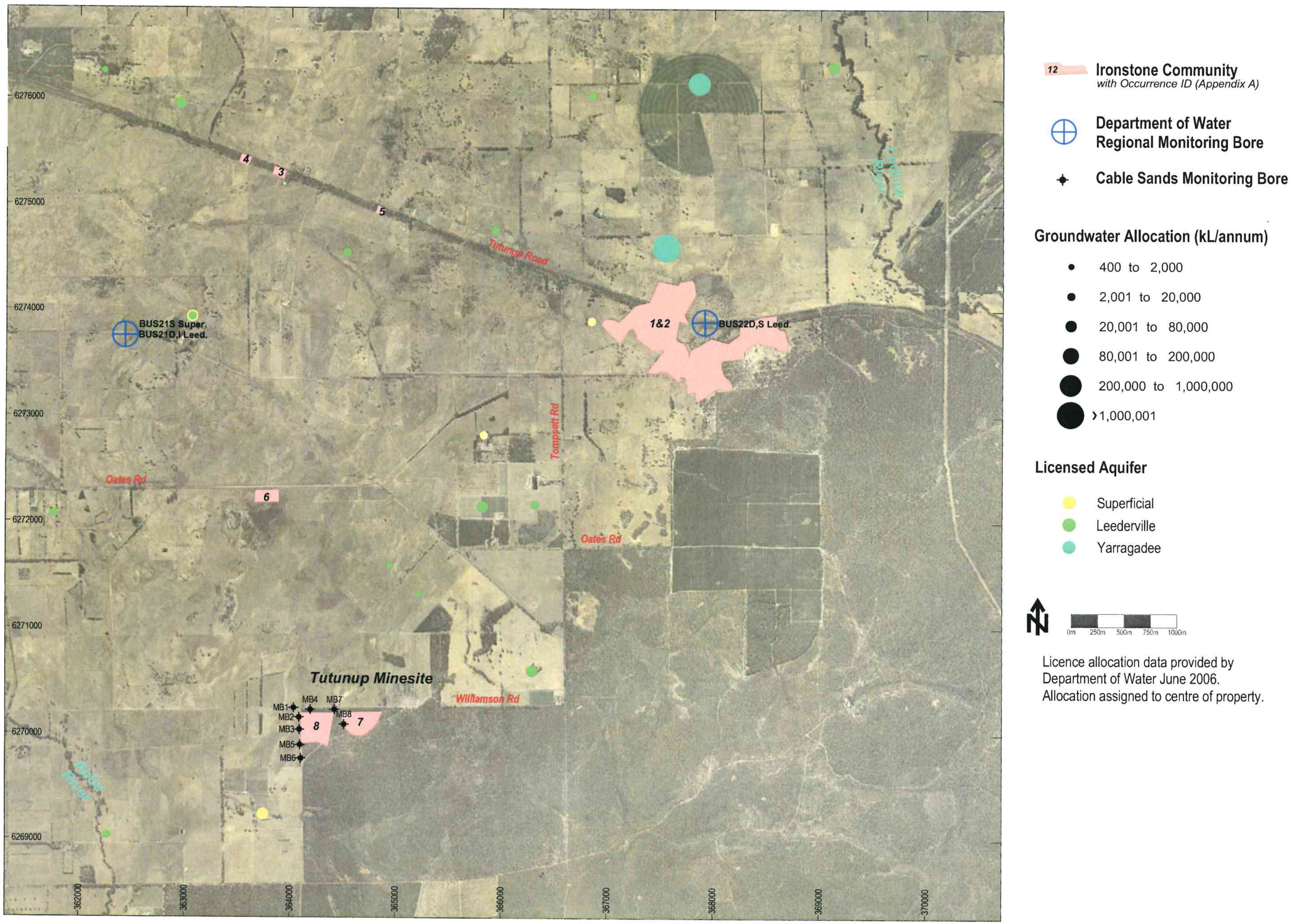


Figure 2b

SOUTHERN IRONSTONE COMMUNITIES (Tutunup Area)

Department of Conservation and Land Management
THE HYDROGEOLOGY OF THE SOUTHERN
AND SCOTT RIVER IRONSTONE COMMUNITIES

GCS Groundwater Consulting Services Pty Ltd

Project No. CALM011

Date: December 2006

Department of Conservation and Land Management
THE HYDROGEOLOGY OF THE SOUTHERN
AND SCOTT RIVER IRONSTONE COMMUNITIES

GCS Groundwater Consulting Services Pty Ltd

Project No. CALM011

SCOTT IRONSTONE COMMUNITIES

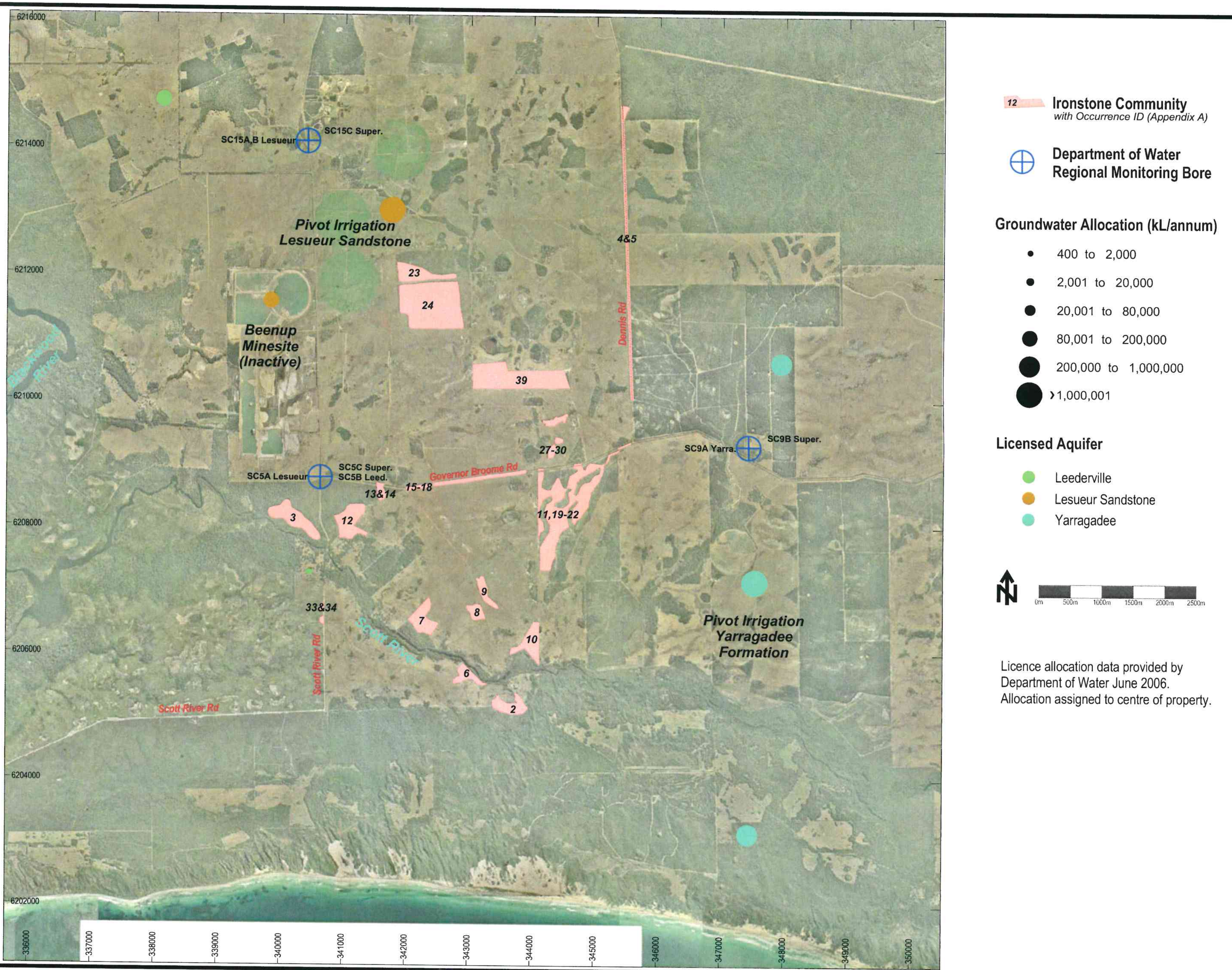
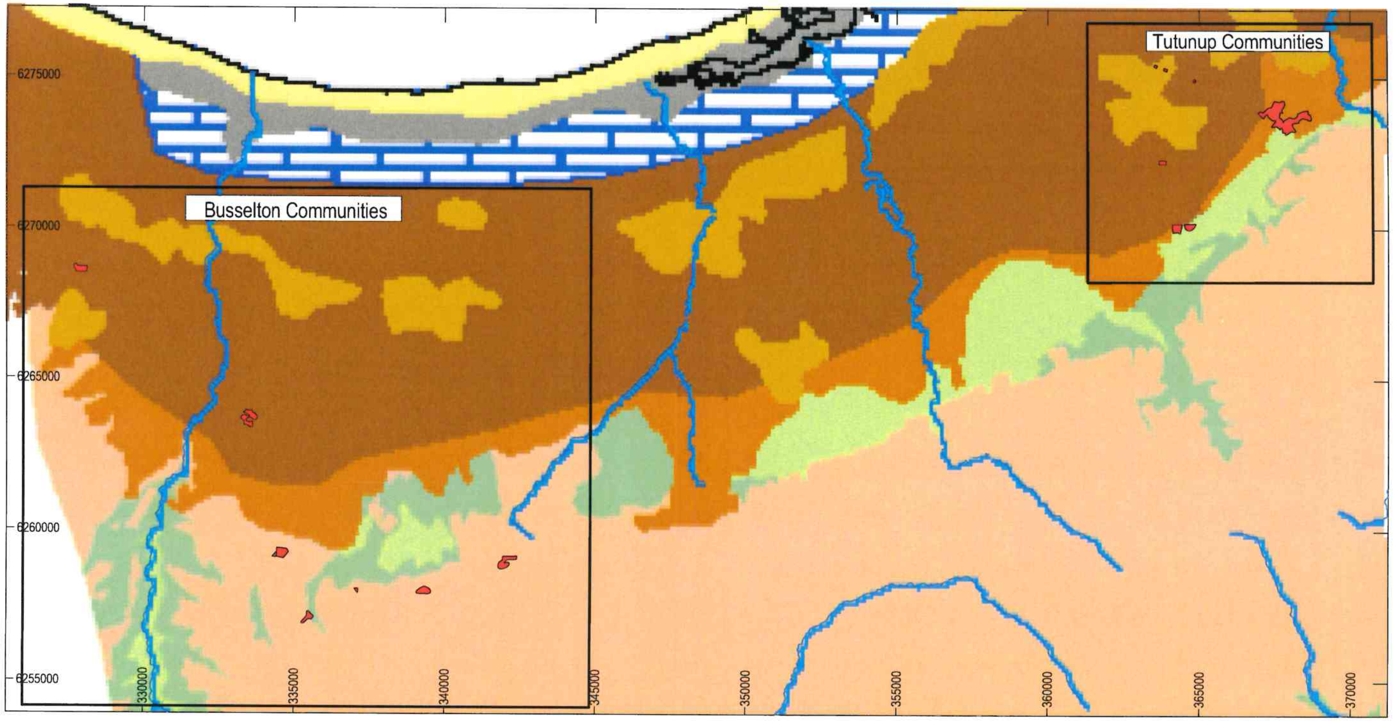


Figure 2c

Date: December 2006



Surface geology collated from:

Water Corporation (2005),
"South West Yarragadee Hydrogeological Investigations and Evaluation Southern Perth Basin"
Infrastructure Planning Branch,
Planning and Development Division.
IPB Project No. R302.

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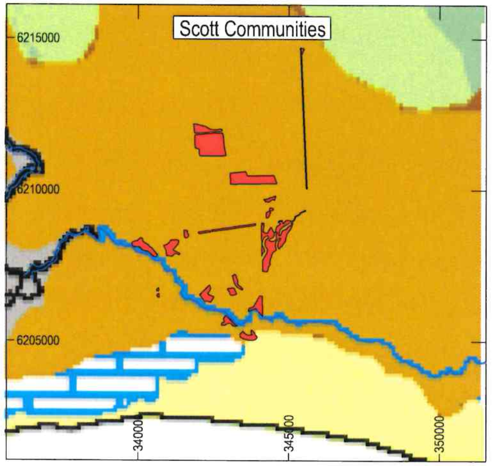

Ironstone Community

Surface Geology

superficial formations:
- Safety Bay Sand
- Alluvium, Estuarine Mud
- Tamala Limestone
- Bassendean Sand
- Guildford Formation
- Yoganup Formation

Leederville Formation:
- Quindalup Member
- Mowen Member
- Vasse Member

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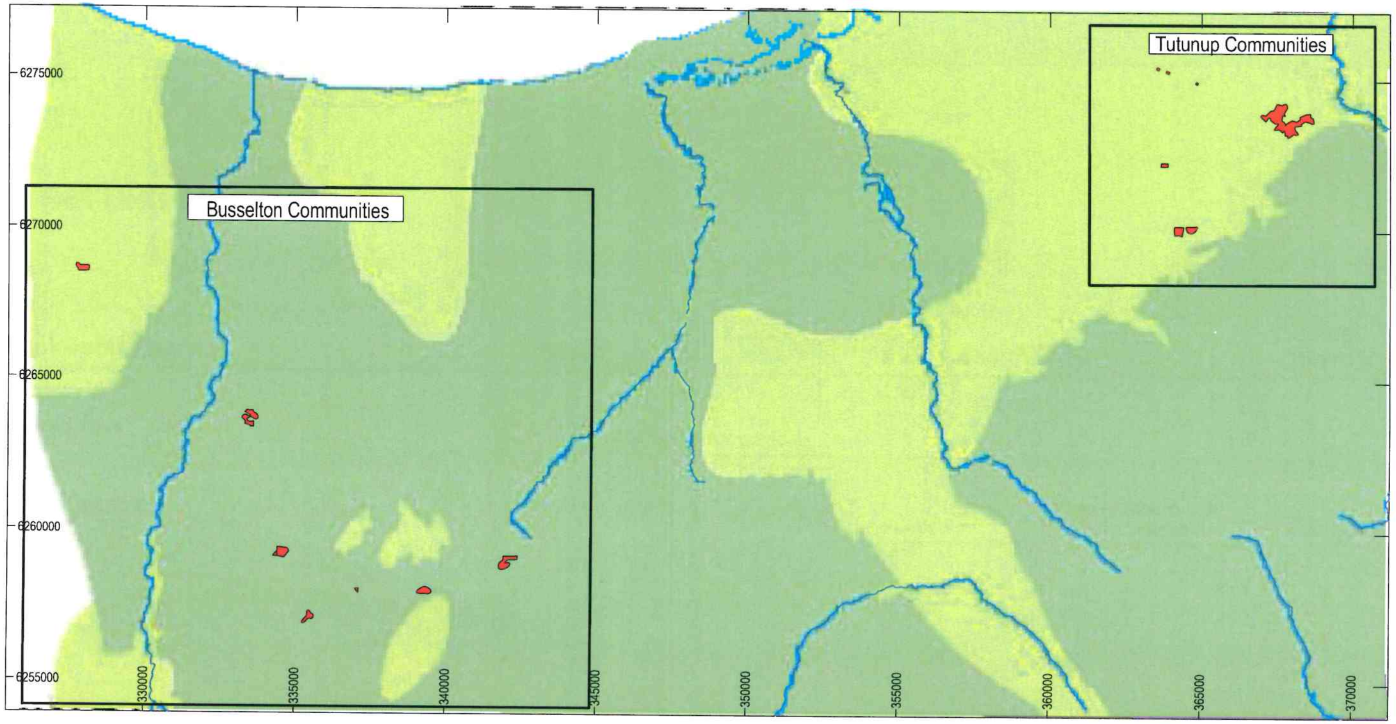
Department of Conservation and Land Management
THE HYDROGEOLOGY OF THE SOUTHERN
AND SCOTT RIVER IRONSTONE COMMUNITIES

SURFACE GEOLOGY

Figure 3a

Date: December 2006



Surface geology collated from:

Water Corporation (2005),
"South West Yarragadee Hydrogeological Investigations and Evaluation Southern Perth Basin"
Infrastructure Planning Branch,
Planning and Development Division.
IPB Project No. R302.

N

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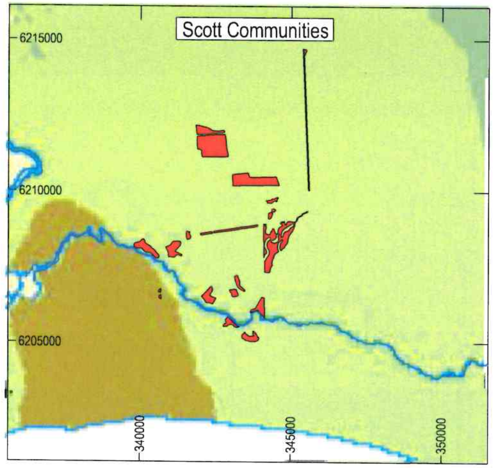

Ironstone Community

Leederville Aquifer Distribution

- Leederville Aquifer confined by Leederville Aquitard.
- Leederville Aquitard is absent. Leederville Aquifer overlain by Superficial Aquifer on the coastal plains.
- Leederville Aquifer is absent. Lesueur Sandstone overlain by Superficial Aquifer.

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Project No. CALM011

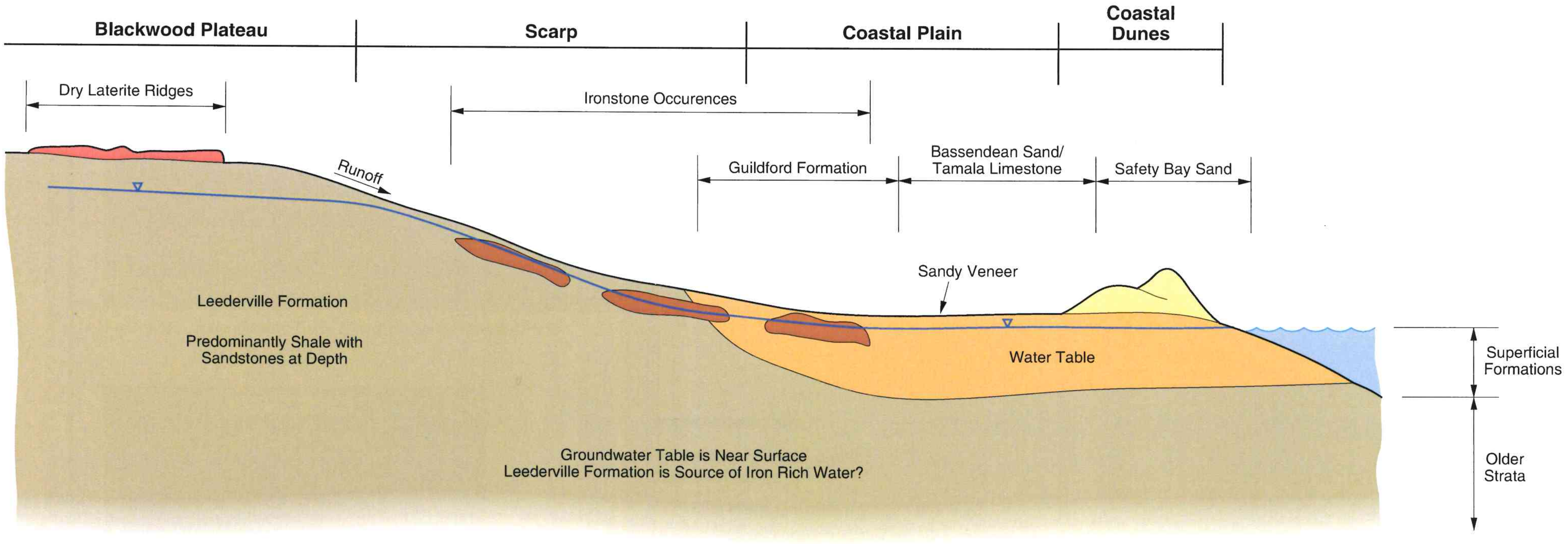
Department of Conservation and Land Management
THE HYDROGEOLOGY OF THE SOUTHERN AND SCOTT RIVER IRONSTONE COMMUNITIES

LEEDERVILLE AQUIFER DISTRIBUTION

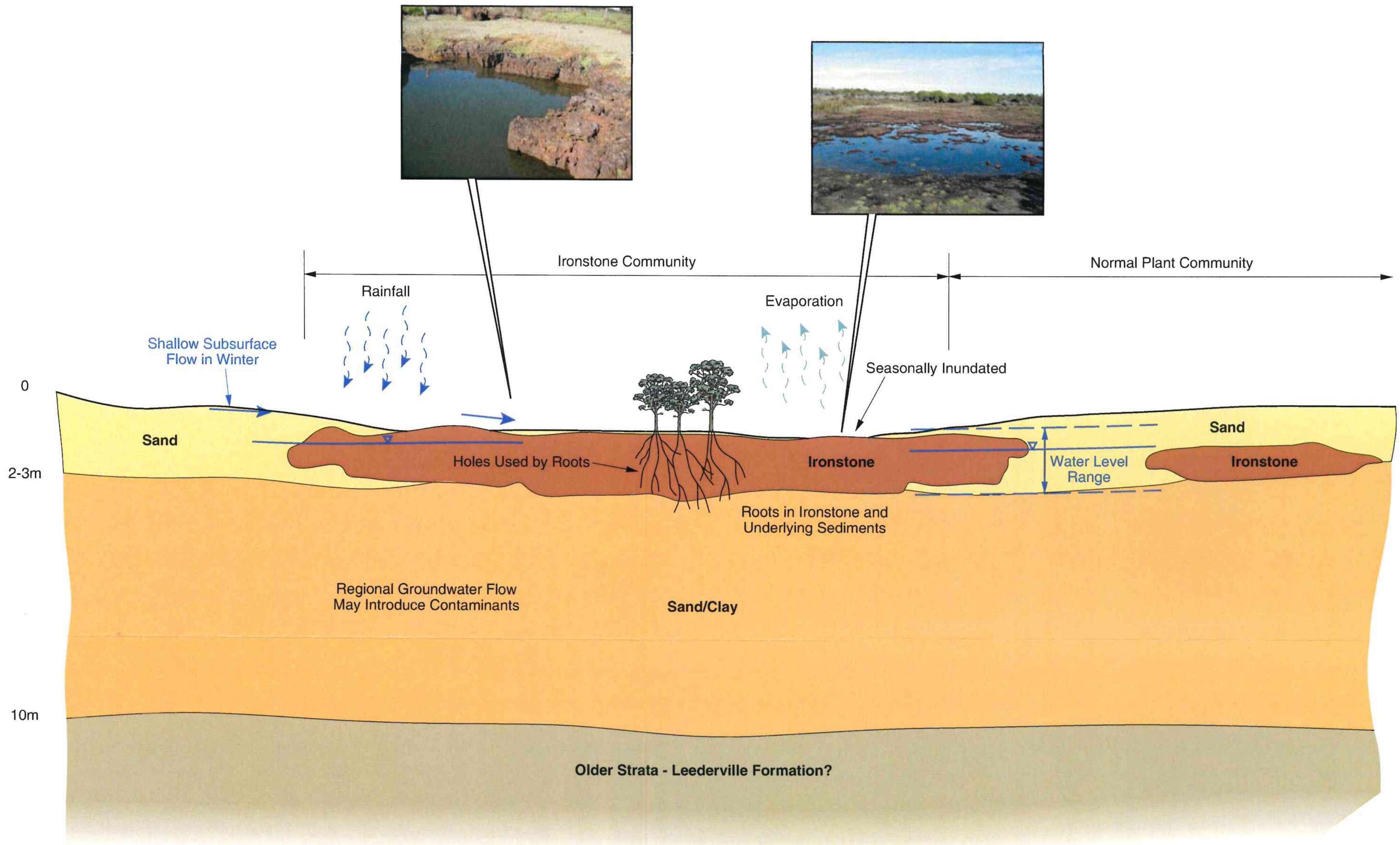
Figure 3b

Date: December 2006

REGIONAL SETTING SCHEMATIC



LOCAL SETTING SCHEMATIC



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Project No. CALM011

Department of Conservation and Land Management
THE HYDROGEOLOGY OF THE SOUTHERN AND SCOTT RIVER IRONSTONE COMMUNITIES

IRONSTONE HYDROGEOLOGICAL SETTING AND LOCAL IRONSTONE HYDRGEOLOGICAL SETTING

Figure 4

Drawn: S. Burton
Date: 18 Dec 2006

GCS Groundwater Consulting Services Pty Ltd

Department of Conservation and Land Management
THE HYDROGEOLOGY OF THE SOUTHERN
AND SCOTT RIVER IRONSTONE COMMUNITIES

GROUNDWATER TABLE ELEVATION

Project No. CALM011

Date: December 2006

Figure 5

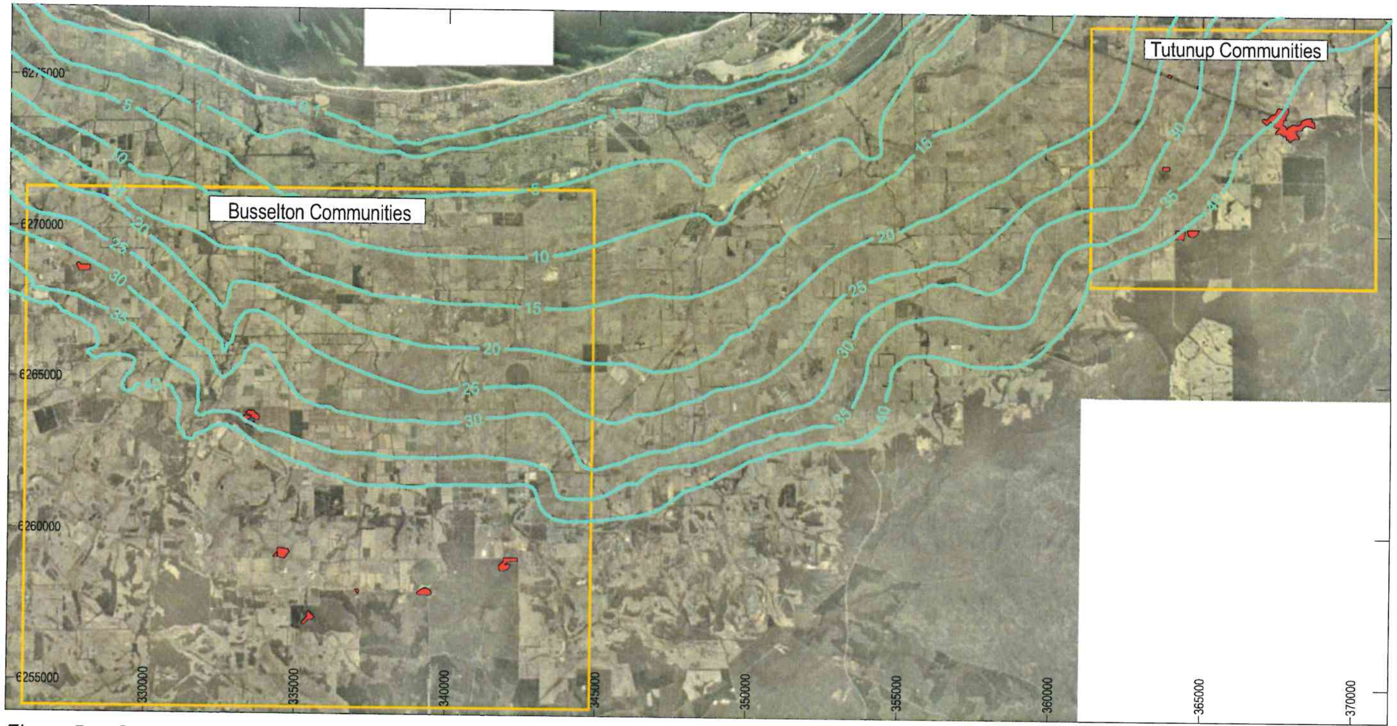

Figure 5a: Groundwater Table Elevation Swan Coastal Plain

Groundwater table elevation collated from:

Water Corporation (2005),
"South West Yarragadee Hydrogeological
Investigations and Evaluation Southern Perth Basin"
Infrastructure Planning Branch,
Planning and Development Division.
IPB Project No. R302.

N

0m 2000m 4000m 6000m 8000m 10000m

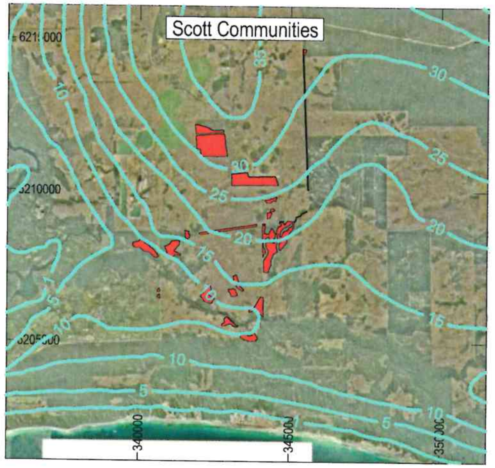

Figure 5b: Groundwater Table Elevation Scott Coastal Plain

Ironstone Community

30 **Grourndwater Elevation (mAHD)**
Superficial Aquifer

Appendix B

Summary Table

APPENDIX B : Extent and location of occurrences

Study Area	Occurrence Number	Location	Land Tenure	Estimated area
TUTUNUP	Occurrence 1 & 2	Ruabon – Tutunup Rd 2 (WONN03, 04)	Rail and road reserves, Nature Reserve and adjacent private land	65.9 ha
	Occurrence 3	Ruabon – Tutunup Rd 3 (WONNEW1)	Rail and road reserves	1.4 ha
	Occurrence 4	Ruabon – Tutunup Rd 4 (WONN06)	Rail and road reserves	3.8 ha
	Occurrence 5	Ruabon – Tutunup Rd 5 (WONN05)	Rail and road reserves	0.1 ha
	Occurrence 6	Oates Road verge (OATESIRON)	Road reserve and Nature Reserve	0.2 ha
	Occurrence 7	Williamson Road east (WIL01)	State Forest - Abba block	4.2 ha
	Occurrence 8	Williamson Road west (WIL03)	State Forest - Abba block	4.2 ha
BUSSELTON	Occurrence 9	Smith Road (SMITH01)	State Forest - Treeton block	9.4 ha
	Occurrence 10	Jacka Road (JACKA01)	State Forest - Treeton block and adjacent private land	7.8 ha
	Occurrence 11	Kolhagen Road (SMITH04)	State Forest - Treeton block, road reserve	0.3 ha
	Occurrence 12	Ironstone Gully (IRON01, 02)	State Forest - Treeton block	7.0 ha
	Occurrence 13	Sussex Location 5114 (YIRON) Corner of Jindong-Treeton & Gale Rds	Nature Reserve	12.5 ha
	Occurrence 14	Private land and Nature reserve Kaloorup (PAYNE02, 03, 04)	Nature Reserve and adjacent private land	14.2 ha
	Occurrence 15	Private land Carbanup River	Private land	7.7 ha
SCOTT	Occurrence 1	Gingilup Swamps Nature Reserve (NR) 30626 (GSNR8, GSNR9)	Nature Reserve	40 ha
	Occurrence 2	Mileanup Road Scott River (SCOTT02NTH)	Private Property and Unallocated Crown land	4.5 ha
	Occurrence 3	Scott NP A25373; Reserve A12951; Scott River banks NR C42942 (SR19, SRFE01, SRFE02)	National Park, Camping Reserve, Nature Reserve	19.25 ha
	Occurrence 4	Dennis Road Scott River (MYDENIS01)	Road Reserve	0.5 ha
	Occurrence 5	Dennis Road; Chester Forest Block (CHESTER01, MYDENIS02)	Road Reserve, State Forest	1.25 ha
	Occurrence 6	Private land Scott River (MY4155STH)	Private Property	7 ha
	Occurrence 7	Private land Scott River (MY4155WEST)	Private Property	14 ha
	Occurrence 8	Private land Scott River (MY4155CNTR)	Private Property	4 ha
	Occurrence 9	Private land Scott River (MY4155NTH)	Private Property	3 ha
	Occurrence 10	Private land Scott River (MY4155EAST)	Private Property	1.5 ha
	Occurrence 11	Private land Scott River; Governor Broome Road (MY4156)	Private Property and Road Reserve	73 ha
	Occurrence 12	Reserve A12951; Private land Scott River (MY12951SE)	Camping Reserve and Private Property	15 ha
	Occurrence 13	Reserve A12951; Governor Broome Road (SRFE03)	Camping Reserve and Road Reserve	2 ha
	Occurrence 14	Governor Broome Road (MYGVBMN1)	Road Reserve	0.06 ha
	Occurrence 15	Governor Broome Road (MYGVBMN2)	Road Reserve	0.4 ha
	Occurrence 16	Governor Broome Road (MYGVBMS2)	Road Reserve	0.4 ha

Study Area	Occurrence Number	Location	Land Tenure	Estimated area
SCOTT *cont.*	Occurrence 17	Governor Broome Road (SRFE04)	Road Reserve	1.5 ha
	Occurrence 18	Governor Broome Road (MYGVBMS3)	Road Reserve	1.5 ha
	Occurrence 19	Governor Broome Road (MYGVBMN4)	Road Reserve	0.1 ha
	Occurrence 20	Governor Broome Road; private land Scott River (MYGVBMN5)	Road Reserve; Private Property	0.6 ha
	Occurrence 21	Governor Broome Road; private land Scott River (MYGVBMN6)	Road Reserve; Private Property	2 ha
	Occurrence 22	Governor Broome Road (MYGVBMS6)	Road Reserve	0.15 ha
	Occurrence 23	Private land Scott River (MY4264NTH)	Private Property	15 ha
	Occurrence 24	Private land Scott River (MY4264STH)	Private Property	62 ha
	Occurrence 27	Private land Scott River (MY4262NTH)	Private Property	3.5 ha
	Occurrence 28	Private land Scott River (MY4262W)	Private Property	1 ha
	Occurrence 29	Private land Scott River (MY4262CN1)	Private Property	2 ha
	Occurrence 30	Private land Scott River (MY4262CN2)	Private Property	1.5 ha
	Occurrence 32	Private land Scott River (MY2973)	Private Property	4 ha
	Occurrence 33	Scott River Road (MYSCTRDW)	Road Reserve	1 ha
	Occurrence 34	Scott River Road (MYSCTRDE)	Road Reserve	0.3 ha
	Occurrence 38	Private land Scott River (MY4264W)	Private Property	1.5 ha
	Occurrence 39	Reserve C42377 (MY42377)	Nature Reserve	42 ha

References:

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"Scott River Ironstone Association Interim Recovery Plan 2004 – 2009". Department of Conservation and Land Management Species & Communities Branch (SCB) Unpublished report for CALM. Interim Recovery Plan 217.

Meissner R, English V (2005);

"Shrubland association on Southern Swan Coastal Plain Ironstone (Busselton Area) (Southern Ironstone Association) Interim Recovery Plan 2005-2010". Department of Conservation and Land Management Species & Communities Branch (SCB). Interim Recovery Plan 215.

Appendix C

Plates

Plate C1: Ruabon Road, Swan Coastal Plain, showing ironstone pavement in foreground and typical vegetation assemblage. 25/5/2006.

Plate C2: Ruabon Road, Swan Coastal Plain, discarded core sample in road reserve from mineral sand exploration drilling, shows concentric rings as iron-oxides have cemented the original soil. 25/5/2006.

Plate C3: Williamson Road, Swan Coastal Plain. View shows artificial recharge system, injection bores in middle ground and water distribution pipe. Excavated ironstone is visible at surface. Williamson Road community is on left side of fence. Mining area behind the photographer, looking south. 25/5/06.

Plate C4: Williamson Road, Swan Coastal Plain. Ironstone excavation. 25/5/06.

Plate C5: Soak on Scott Coastal Plain, showing ironstone, overlying sand, high and low water levels. 26/5/2006.

Plate C6: Vertical holes in ironstone at soak shown above. 26/5/2006.

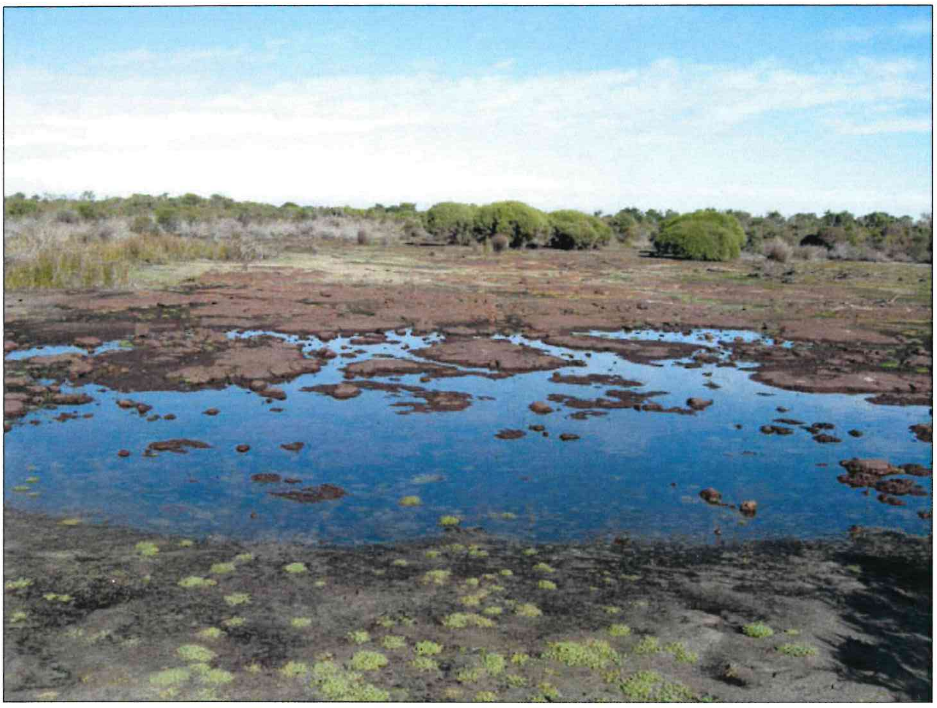
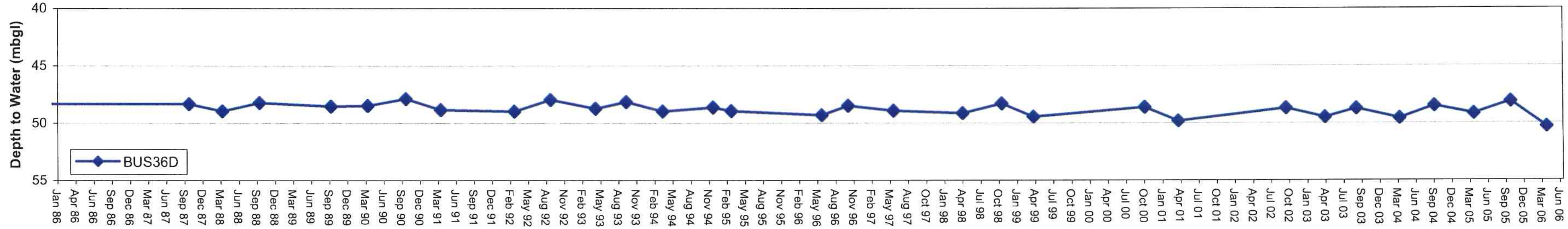


Plate C7: Dennis Road. Ironstone in foreground, shallow surface water and vegetation in background. 26/5/06.

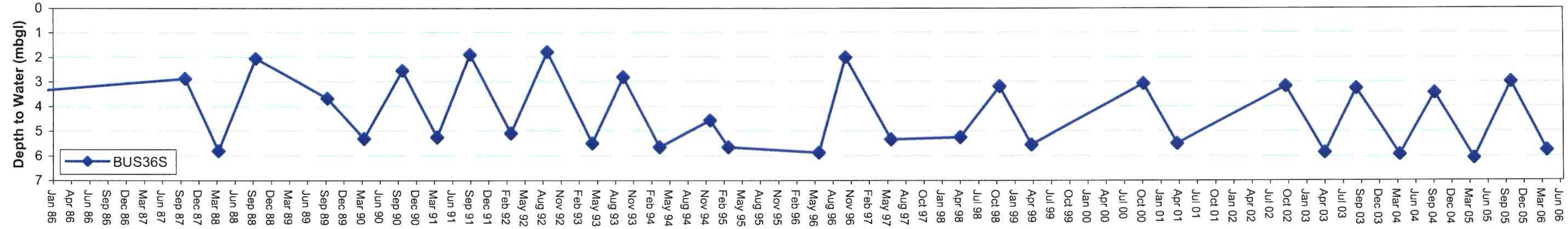
Appendix D

Hydrographs

BUS36D (Leederville)



BUS36S (Leederville)



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Busselton Shire Rainfall (1986-2006)

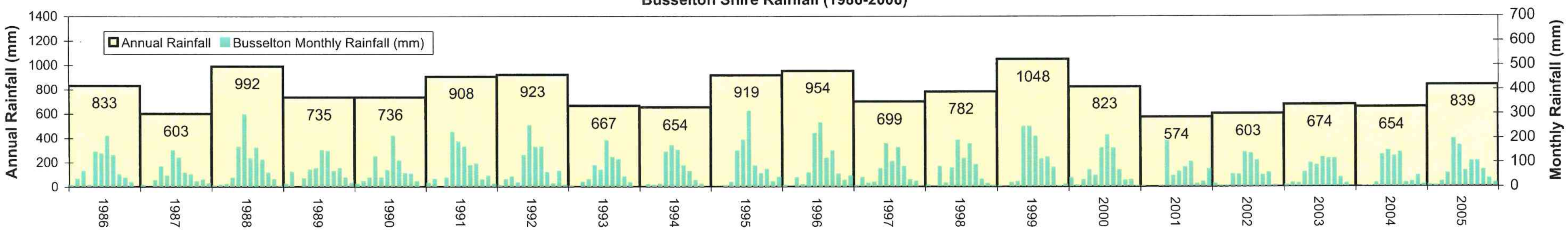

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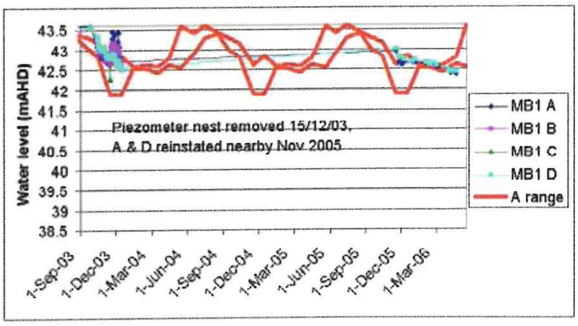
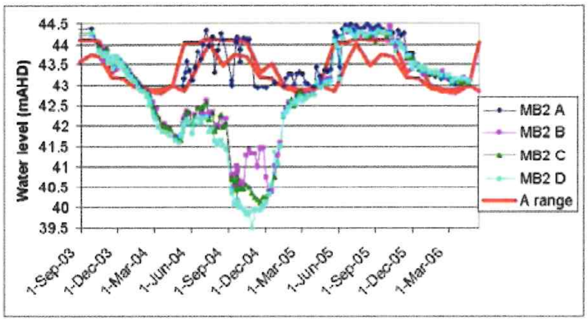
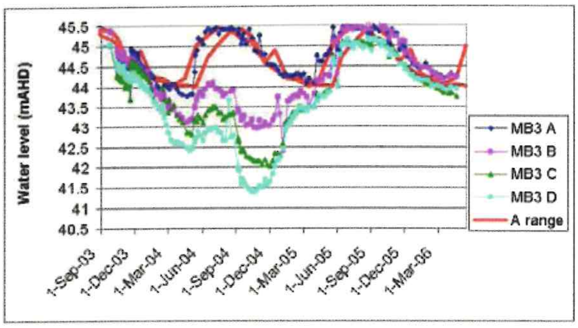
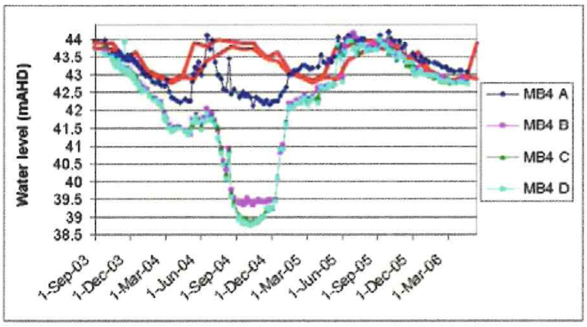
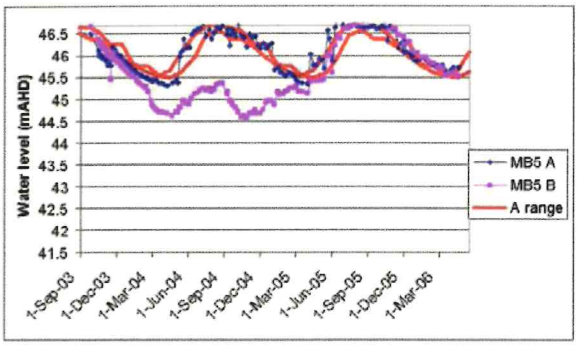
Figure D1:	***Depth to Water BUS36 - Busselton Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*

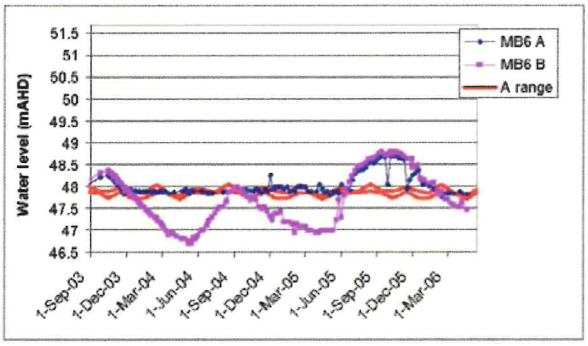


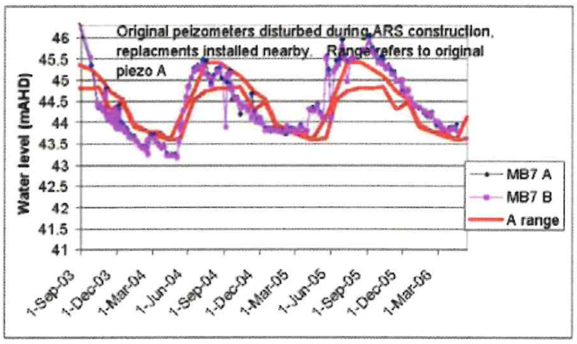


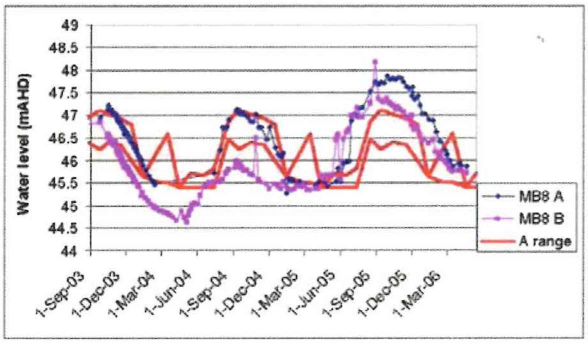


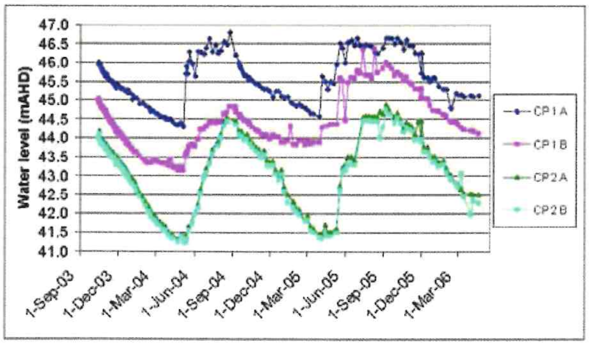












Hydrographs provided by CALM for report. Water level monitoring and reporting completed by Cable Sands.

GCS Groundwater Consulting Services Pty Ltd

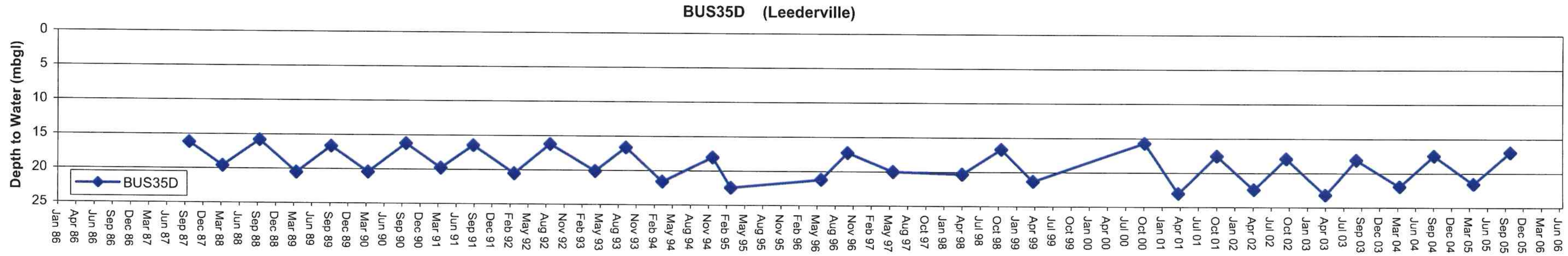
Department of Conservation and Land Management
THE HYDROGEOLOGY OF THE SOUTHERN AND SCOTT RIVER IRONSTONE COMMUNITIES

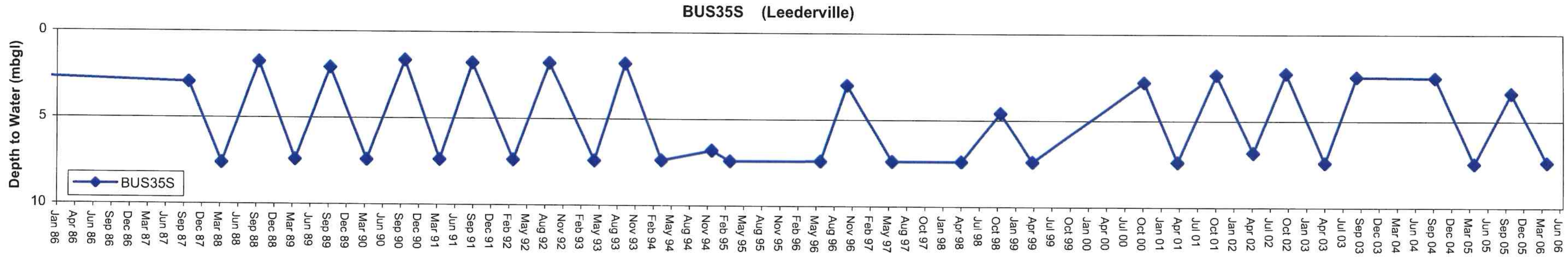
Figure D-12
Appendix D

Project No. CALM011

HYDROGRAPHS WILLIAMSON ROAD

Date: December 2006





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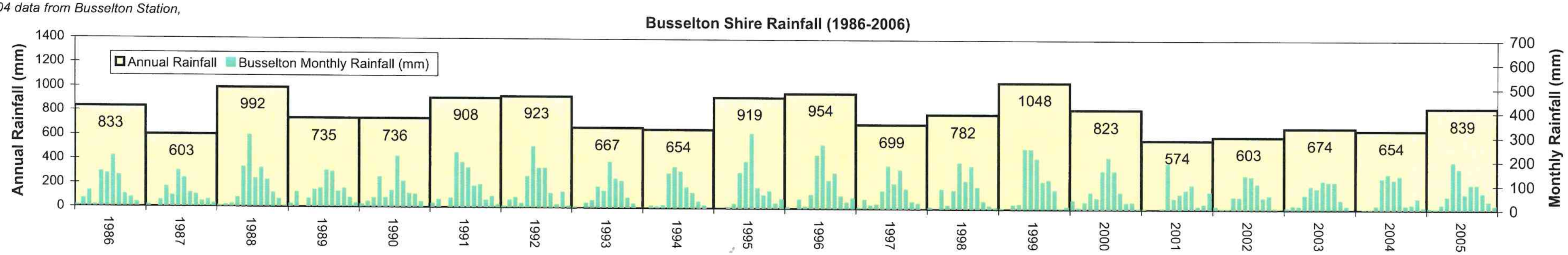
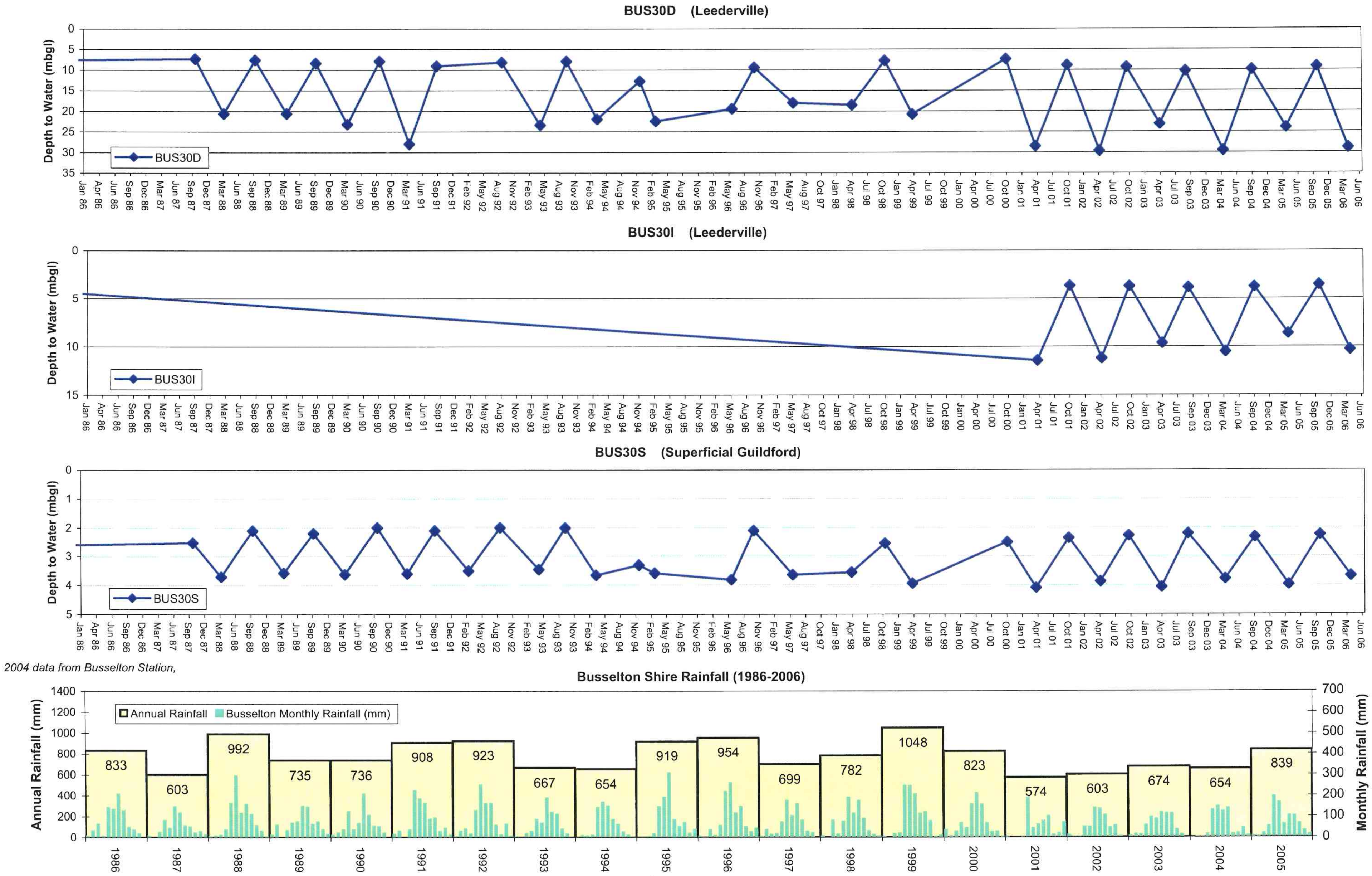


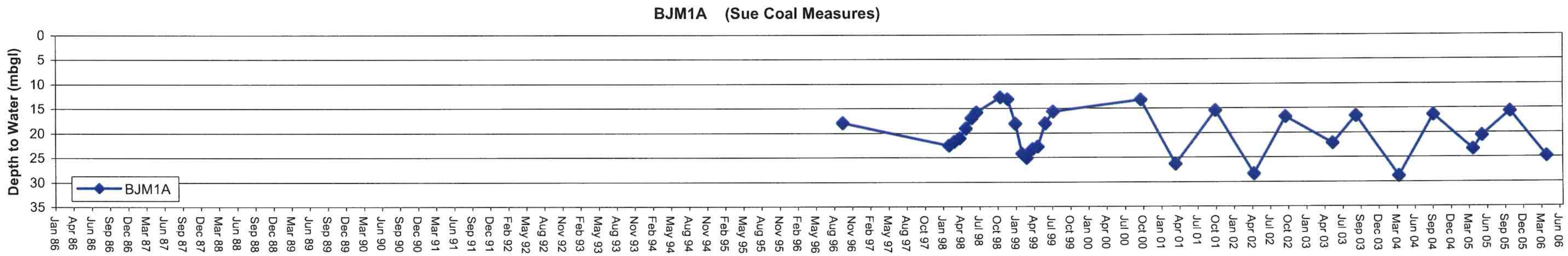
GCS Groundwater Consulting Services Pty Ltd

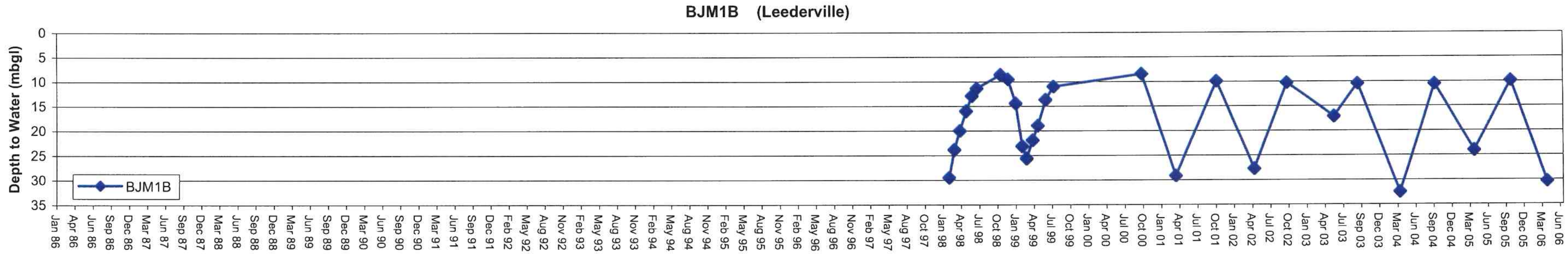
Figure D2:	***Depth to Water BUS35 - Busselton Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*



GCS Groundwater Consulting Services Pty Ltd

Figure D3:	***Depth to Water BUS30 - Busselton Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*





2004 data from Busselton Station,

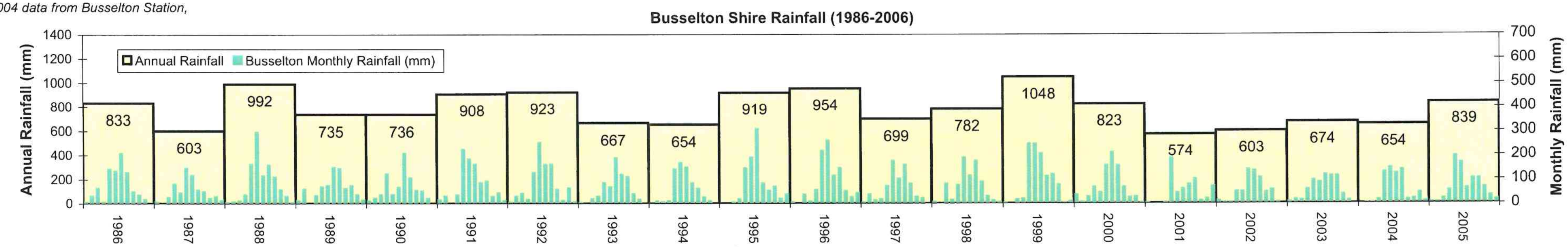


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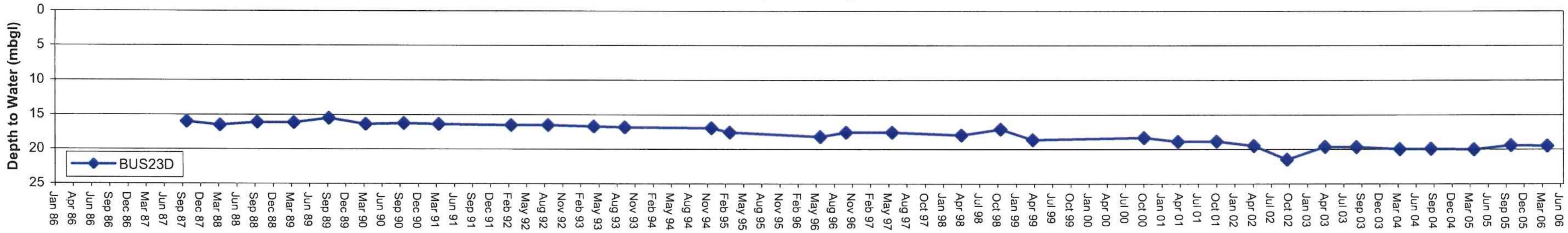
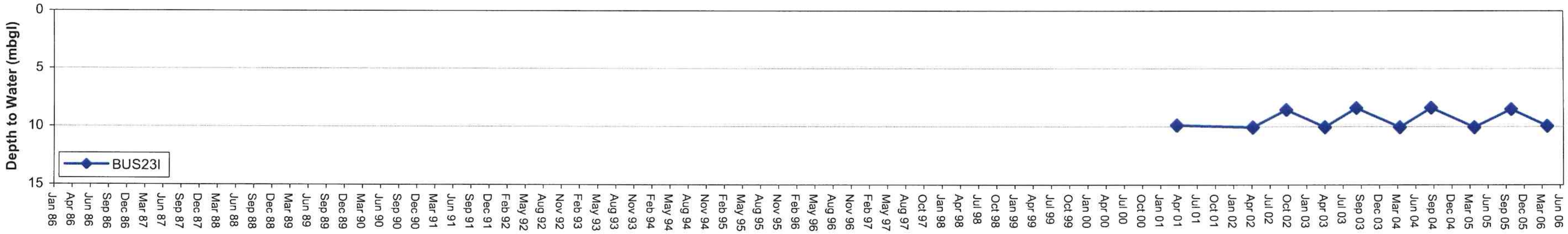
Figure D4:	***Depth to Water BJM1 - Busselton Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*

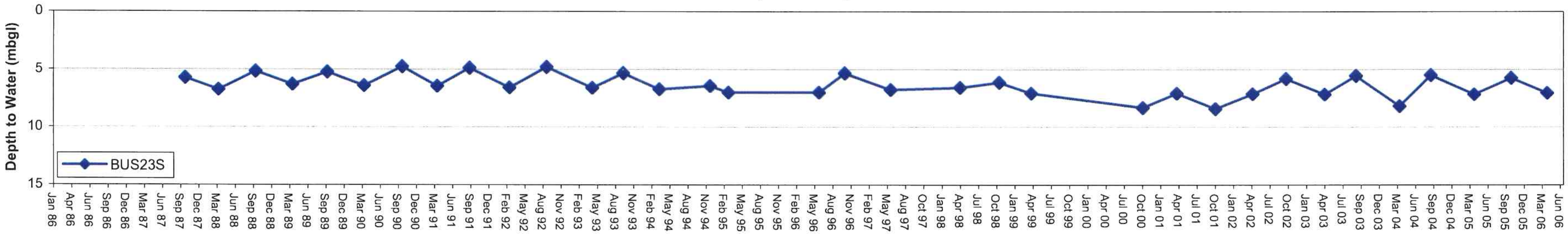
BUS23D (Leederville)



BUS23I (Leederville)



BUS23S (Leederville)



2004 data from Busselton Station,

Busselton Shire Rainfall (1986-2006)

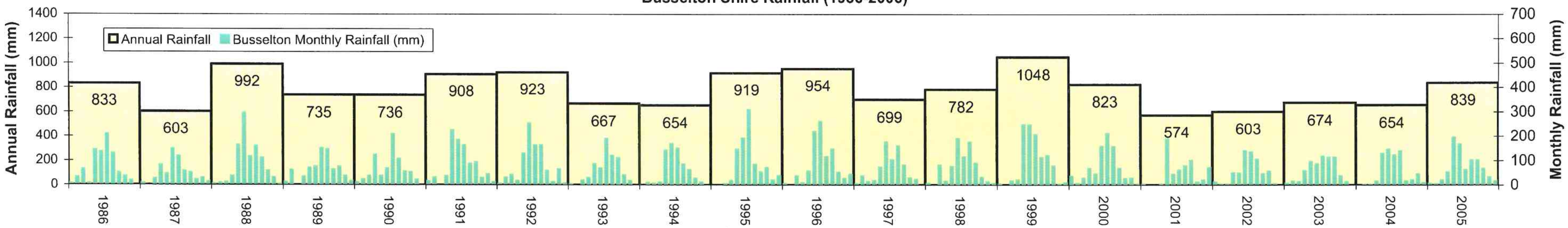


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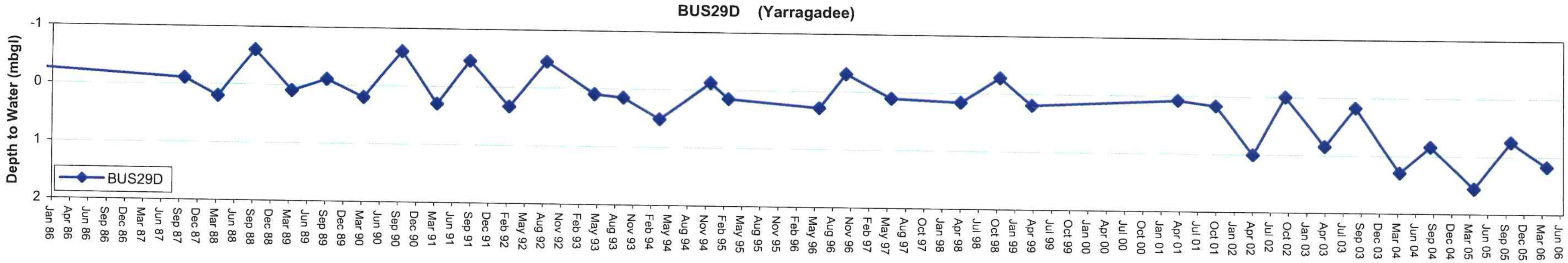
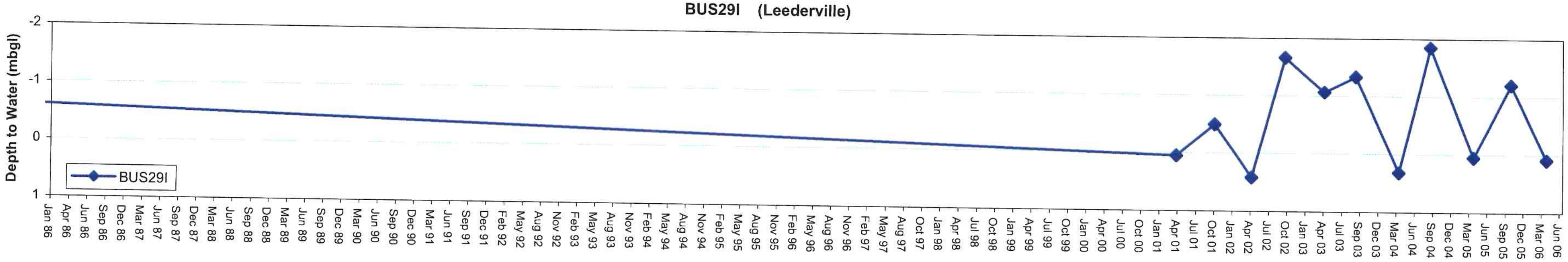
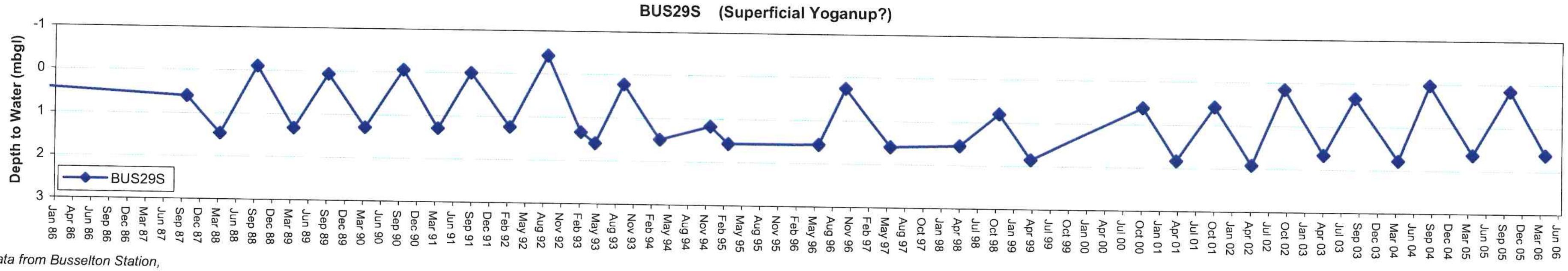
Figure D5:	***Depth to Water BUS23 - Busselton Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*







2004 data from Busselton Station,

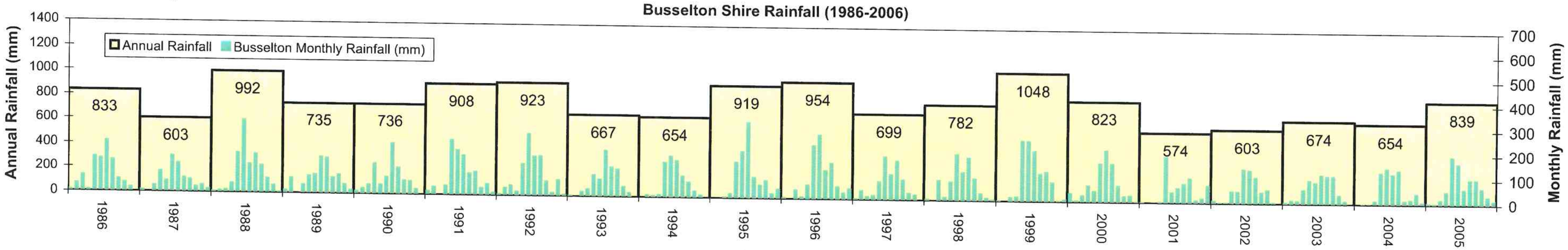


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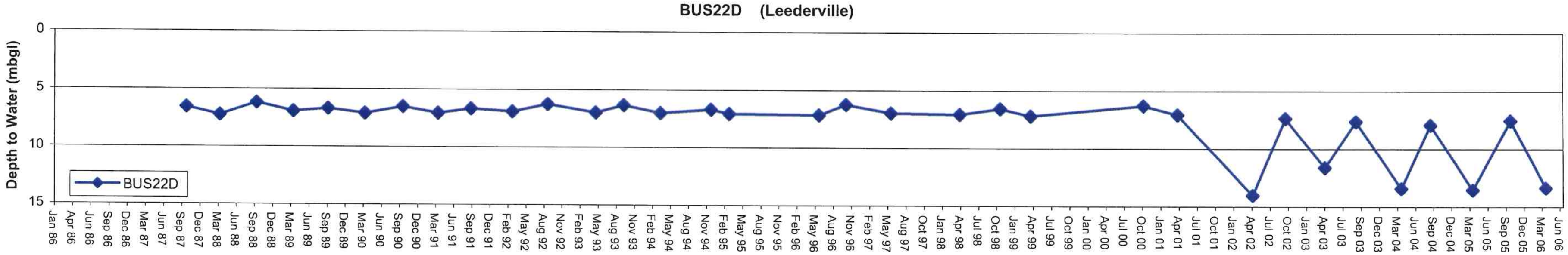
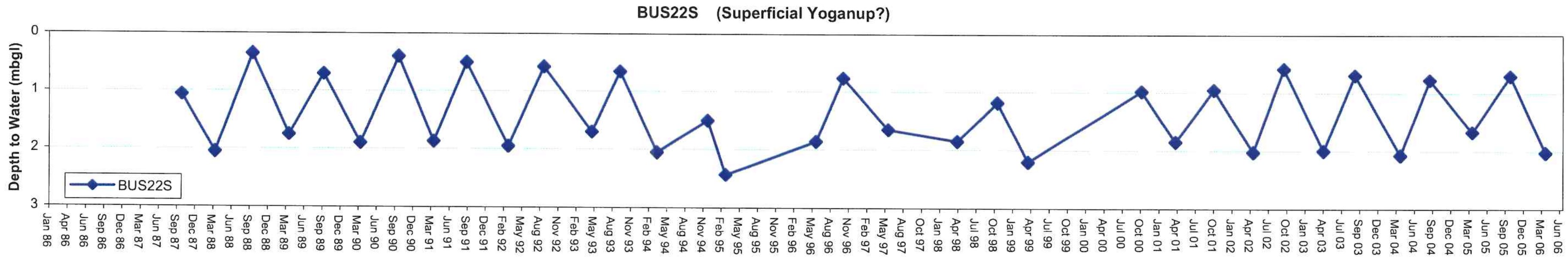
Figure D6:	***Depth to Water BUS29 - Tutunup Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*





2004 data from Busselton Station,

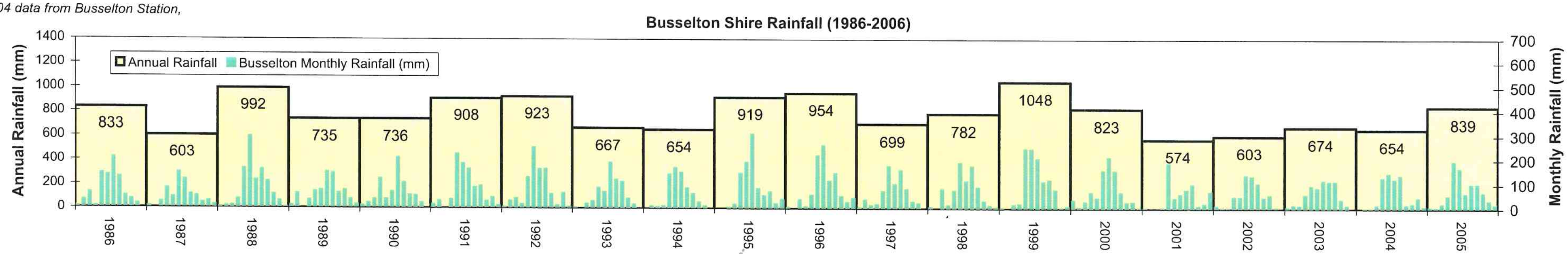


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Figure D7:	***Depth to Water BUS22 - Tutunup Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*

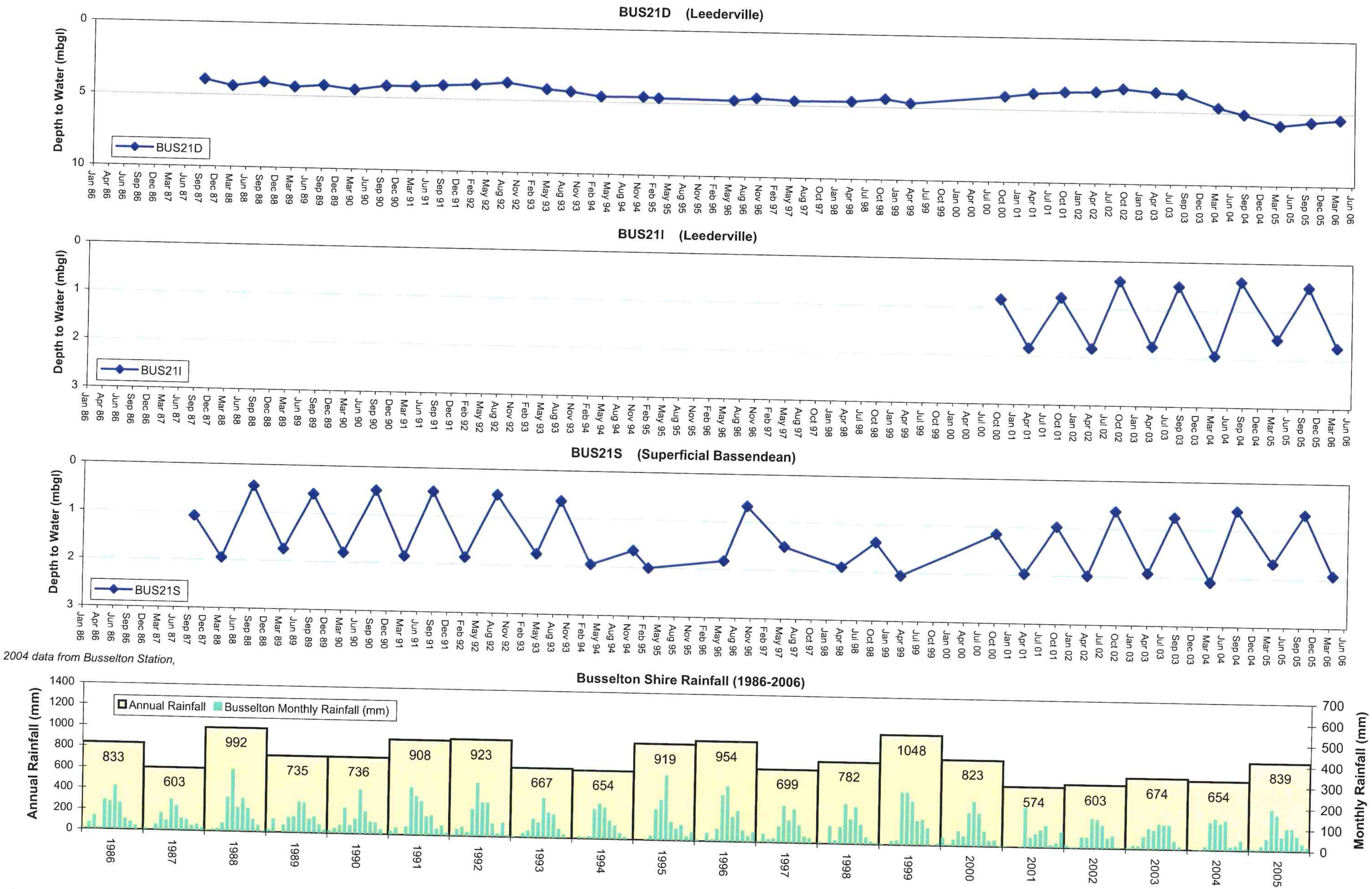

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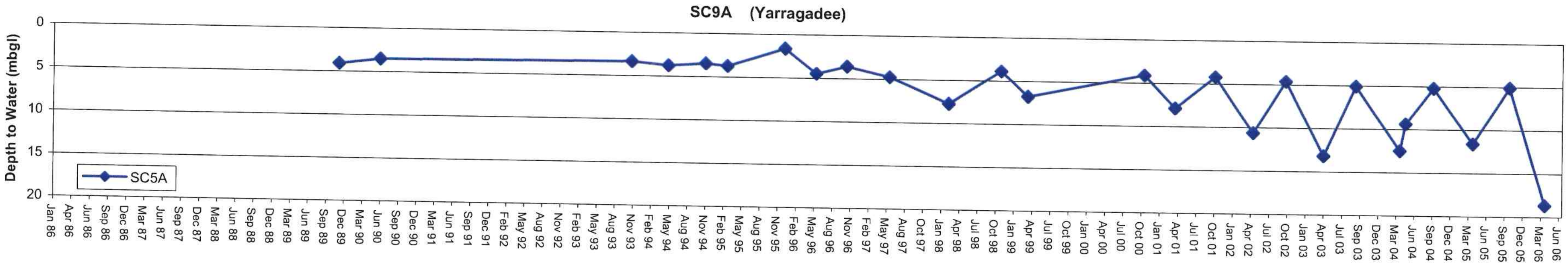
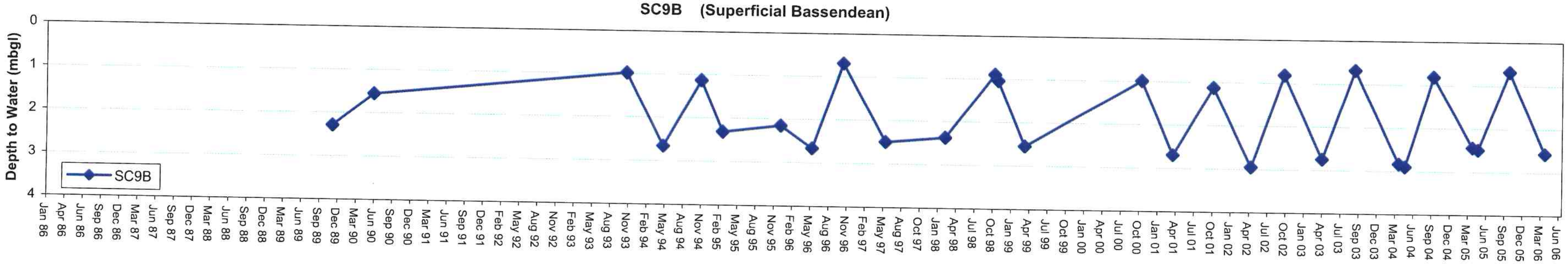
Figure D8:	***Depth to Water BUS21 - Tutunup Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*





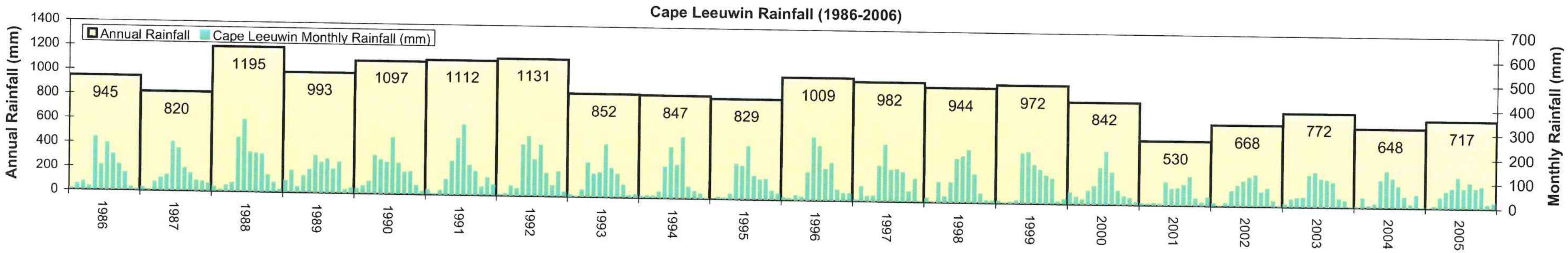


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Figure D9:	***Depth to Water SC9 - Scott Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*

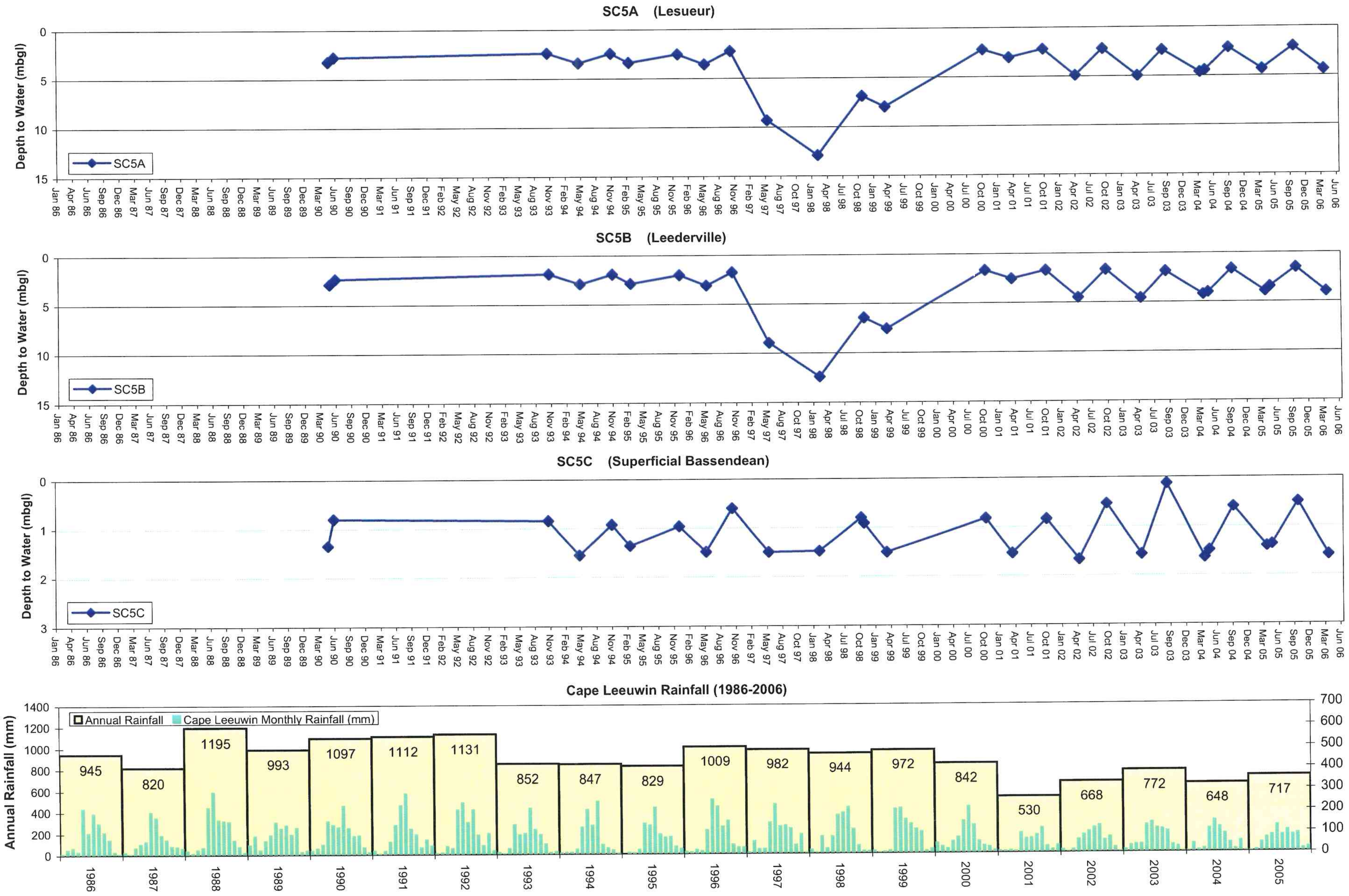

Figure D10: ***Depth to Water SC5 - Scott Study Area***

Project: *Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*

Client: *Department of Conservation and Land Management*

Project Number: *CALM011 June 2006*

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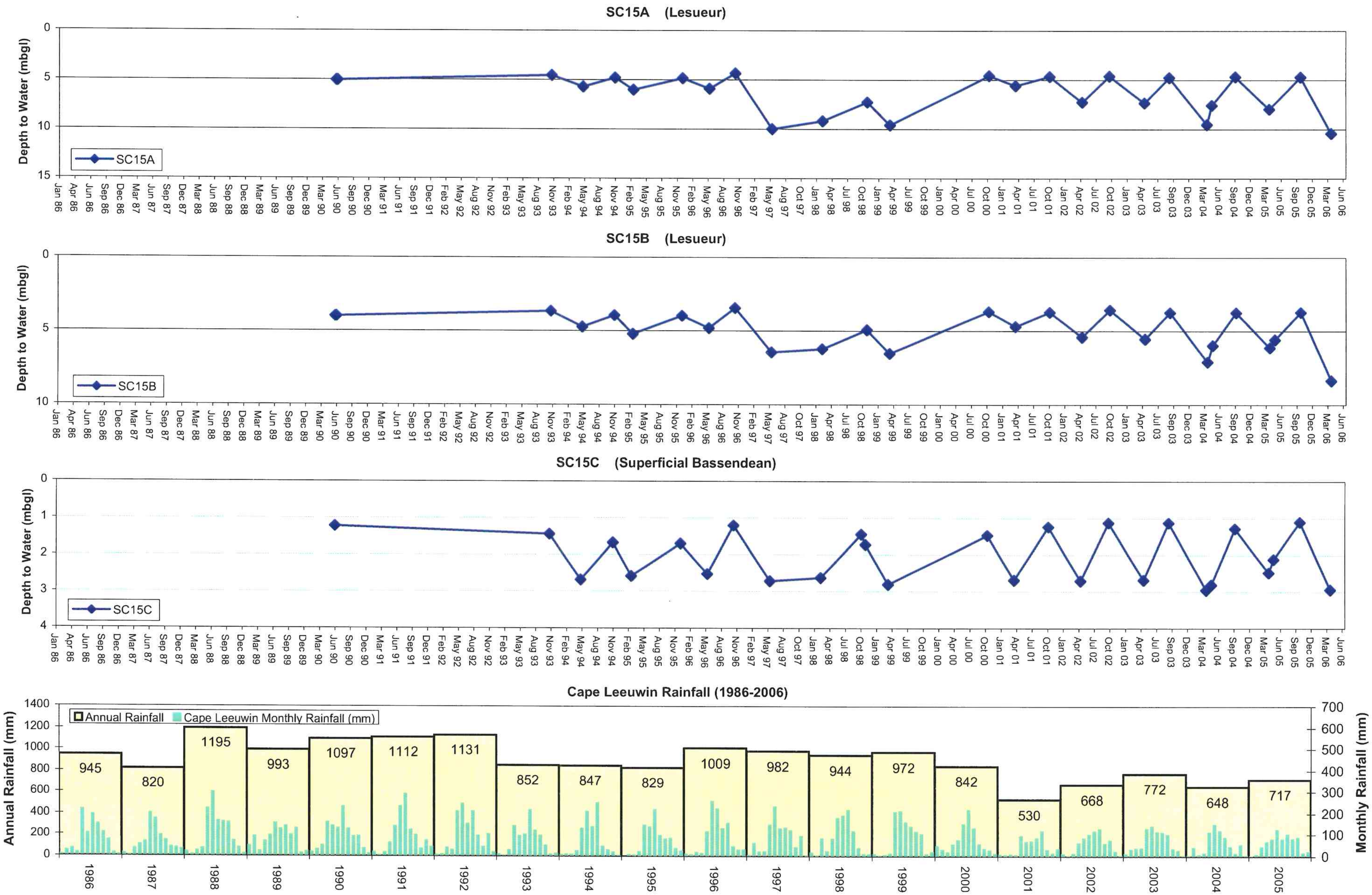

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Figure D11:	***Depth to Water SC15 - Scott Study Area***
Project:	*Groundwater Reliance Investigation - Busselton and Scott Ironstone Communities*
Client:	*Department of Conservation and Land Management*
Project Number:	*CALM011 June 2006*