Development of Models for Tasmanian Groundwater Resources

Conceptual Model Report for Swansea – Nine Mile Beach

Prepared for
DPIW Tasmania
GPO Box 44
Hobart TAS 7001

December 2008

Australian Government
National Water Commission

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Document Title

Conceptual Model Report for Swansea-Nine Mile Beach

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Document Status

Doc. No.		Approved for Issue		
Rev No.		**Name**	**Signature**	**Date**
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1 INTRODUCTION

1.1 Scope

The Tasmanian Department of Primary Industries and Water (DPIW) engaged the Tasmanian Groundwater Resources (TGR) Partnership comprising; Resource & Environmental Management Pty Ltd (REM); Aquaterra Consulting Pty Ltd (Aquaterra); Hydro Tasmania Consulting Pty Ltd and Sloane Geoscience (SGeo) to undertake the project *Development of Models for Tasmanian Groundwater Resources*.

Stage 1 of the project required the compilation of available data and reports, confirmation of the proposed catchment prioritisation and categorisation, and agreement on preferred modelling approaches. Meetings and a two day workshop were held in June 2007 with local experts, including current and retired geologists from both private and Government sectors, to facilitate the data collection tasks. These forums provided a wealth of useful background geological and hydrogeological information, enabling the assembly of schematic cross-sections, data inventory spreadsheets and a bibliography.

Stage 2 of the project developed preliminary conceptual models, which were originally presented in this report. This report now includes revisions to the conceptual models, including comments from expert peer reviewers and results from a field program conducted during Stage 3 of the project. A total of twenty conceptual model reports have been prepared for different study catchments, with this report representing the Swansea-Nine Mile Beach catchment.

1.2 Catchment Water Balance

In order to develop a conceptual model for a particular groundwater catchment[1], it is important to identify and characterise all relevant components of the water balance. These components are illustrated in **Figure 1**, and may include any or all of the following: rainfall, surface water runoff, evaporation, transpiration, groundwater recharge, aquifer throughflow, groundwater discharge to springs or streams, groundwater abstraction and lateral discharge to either down-gradient catchments or (ultimately) the sea.

[1] The term *groundwater catchment* is not as easy to define as *surface water catchment*. If a distinct region of groundwater was a catchment in the true sense of the word, then the boundaries of that region would represent locations across which there is no horizontal flow of groundwater. In reality, this rarely occurs and is very difficult to measure, so for the purpose of this project the basis for defining each catchment boundary will be reported.

2 FIELD PROGRAM

2.1 Groundwater Dating

Stage 3 of the project was some field investigations that were undertaken to improve the conceptual understanding the Swansea – Nine Mile Beach groundwater system, and to aid the development of a numerical model in Stage 4. In order to establish groundwater recharge rates, groundwater was sampled from selected wells to determine groundwater age via CFC (chlorofluorocarbon) analysis. Groundwater monitoring wells screened in Quaternary sediments were sampled over 19-20 March 2008, using standard sampling and laboratory protocols.

3 BACKGROUND

3.1 Study Area

The Swansea-Nine Mile Beach catchment is a 15 kilometre long spit, covering an area of around 23 km^2 on the central east coast of Tasmania (**Figure 2**), near the outfall of the Swan River. This region has been the subject of hydrogeological investigations since the late 1970's, including trials of a spear point array that was intended to be used to supplement the town water supply. A detailed overview of the hydrogeology of the study area was compiled by Cromer (2003), which provides a guide to the capacity of the aquifer to meet the demand for potable water for local residential development.

3.2 Climate

Mean annual rainfall for the Swansea-Nine Mile Beach catchment is 582 mm/yr (Swansea Post Office). Historical rainfall data is presented in **Figure 3** and provides a long term pattern of annual rainfall, but unfortunately rainfall records are not available after 1991. The cumulative deviation in annual rainfall trend shown in **Figure 3** reveals several periods, each of typically 5-10 years duration, when rainfall was generally above average, followed by periods when rainfall was generally below average. There was a general decline in rainfall between the early 1970s and 1991.

Class A pan evaporation data is not available, although Cromer (2003) provides an estimate of evapotranspiration of 735 mm/yr.

3.3 Topography and Soils

The area is dominated by the Nine Mile Beach spit which lies between the ocean to the south, and the estuarine environment of the Swan River and Moulting Lagoon to the north.

Ground surface elevation ranges from sea level at the coast to approximately 9 mAHD on sand dunes that lie near to the beach (**Figure 4**). For the most part, the spit is covered by a series of sub-parallel beach ridges and swales.

Soil orders have been mapped using the Australian Soil Classification layer for Tasmania supplied by DPIW (**Figure 4**). This map reveals that the majority of the Swansea-Nine Mile Beach catchment is covered by Rudosols (i.e., sandy soils with rudimentary soil development) with Dermosols (structured B horizon) in the west. (Refer to the *Key to Soil Orders*[2] for further information about soil characteristics).

It should be noted however, that the layer presented in **Figure 4** was constructed from line work for Land Systems developed by the Tasmanian Department of Agriculture between 1978-1989 using geology, vegetation and climate data rather than soil surveys per se. Nevertheless, field observations in many areas have revealed that it is a reasonable representation of the actual conditions, particularly in the north and northwest of the State where many of this study's catchments are situated (pers. comm. Simon Lynch, DPIW 2007). There has also been observed

[2] Key to Soil Orders can be found at http://www.clw.csiro.au/aclep/asc_re_on_line/soilkey.htm

agreement between this layer and the more spatially confined Soils Reconnaissance map that was supplied originally by DPIW.

3.4 Land Use

Figure 5 presents the current range of land uses in the Swansea-Nine Mile Beach catchment. Irrigated agriculture accounts for only a small part of the catchment area (1.8 km^2), while the remainder is predominantly classified as either remnant native cover/environmental or rural residential (6 km^2 remnant native vegetation and 15 km^2 'built environs'). The rural residential area has not been extensively cleared.

3.5 Geology

The geology and hydrogeology of the Swansea-Nine Mile Beach area is well summarised by Cromer (2003). In broad terms, the area is a down-faulted basin (graben), which is flanked by uplifted basement rocks and filled with unconsolidated sediments that have been deposited since the Tertiary period. The basin is up to 20 km wide in places, extending from Bicheno in the north to Maria Island in the south. The Nine Mile Beach spit extends east-west across the full width of the basin and is composed of Quaternary and Tertiary sediments, estimated to be 100m thick. The spit is thought to have formed during the Holocene Epoch (Thom *et al.*, 1981).

The surface geology is dominated by Quaternary sediments (**Figure 6**). The small outcrops of Jurassic dolerite and Tertiary sediments at the western edge of the spit indicate the edge of the basin. Within a short distance towards the east, the sediments thicken to about 200 m (Leaman, 1981).

The general stratigraphy of Nine Mile Beach is depicted in section B-B (**Figure 7**), which was developed by Cromer (2003) using drill logs. The deepest unit in the sequence (Unit 1) is a stiff, dark coloured, high plasticity clay. Unit 2 is the lowermost sandy deposit, which is poorly sorted and mainly very fine grained. Lenses of fine quartzite gravel, fragments of sandstone to 10mm, and patches of carbonate cemented sand contribute to the poor sorting. Unit 3 is a fine to medium grained, well sorted sand and shelly sand, which is capped by a thin layer (~0.5 m) of finer-grained, shell-free sand. Unit 4 is comprised of shell-free clay, sandy clay and clayey sand beneath the backbarrier at the rear (north) of the spit. The materials are stiff to very stiff. The clays are of high plasticity.

3.6 Hydrogeological Units

The primary aquifer in the Swansea-Nine Mile Beach catchment, the Dolphin Sands aquifer, comprises Units 2 and 3 of the Holocene sediments along the Nine Mile Beach spit (**Figure 7**). The very low permeability of the clay in Unit 1 allows relatively fresh water to accumulate above it and limits the exchange of water with deeper Quaternary sediments below. The clays in Unit 4 are also of low permeability, which limits the exchange of water between the main aquifer and the more saline waters in swamp / marshlands behind the beach-ridge system in the west of the catchment.

The aquifer in Units 2 and 3 is unconfined and extends the full length (15 km) and width (1 km) of the spit, with an average thickness of approximately 7 m (ranging from 4 to 12 metres refer **Figure 8**). It is bounded to the south by seawater along the beach, on the eastern and northern side by the Swan River estuary, and on the western side by Unit 4. The western boundary is the low-lying drainage line that coincides with the boundary of the Tertiary sediments and Jurassic dolerite. A 21-day pump test in 1979 using spear wells located near the centre of the spit recorded an aquifer transmissivity of 250 m^2/day, permeabilities in the range of 5-30 m/day and a specific yield in the range of 0.17-0.2. Individual well yields of 1 L/sec are attainable, depending on bore construction and installation depth.

A summary of recorded groundwater salinities are provided in **Figure 5**. Only 2 wells show high salinities and these occur outside of the main aquifer in the Unit 4 estuarine materials. Otherwise, analyses show a small range of salinities: 250-600 mg/L. The lower salinity groundwater extends below mean sea level to the top of the Unit 1 clays. There is no clear evidence that deeper parts of the aquifer at Nine Mile Beach are more saline, but this has been noted in other coastal sand aquifers in Tasmania.

3.7 Surface Water – Groundwater Interaction

There are no major surface water systems within the catchment.

The primary 'surface water' interaction is potentially associated with sea water intrusion which has been investigated by Cromer (2003). Sea water intrusion to Units 2 and 3 was judged to be unlikely given that the aquifer is thin, and the elevation of the watertable is sufficient to support a large column of fresh water.

If the groundwater level were to drop due to excessive groundwater extraction, it is possible for sea water intrusion to occur. However analysis of pump test data by Cromer (2003) revealed that the radius of influence for current domestic spear bores is small and thus unlikely to extend to the necessary distance to provoke sea water intrusion.

3.8 Water Use and Management Issues

Groundwater is currently used for domestic supplies within the nearby residential areas. The total groundwater extraction is not known, but is estimated to be 50 ML/year (Cromer, 2003). There will also be a small volume used for irrigation.

It is considered that there is potential for further development of the local aquifer (pers comm., Bill Cromer 2007).

3.9 Groundwater Monitoring

The statewide groundwater monitoring network currently has no groundwater observation wells in the Swansea-Nine Mile Beach catchment (Ezzy, 2006). There are however, six new wells that have recently been installed by DPIW and will be regularly monitored in the future (**Figure 9**).

There are water level measurements from 1979 and 1980 (including a well equipped with an automatic water level recorder for a 161 day period), but water levels have not been measured since at surveyed sites.

4 GROUNDWATER INFLOWS

4.1 Diffuse Recharge

Groundwater recharge through rainfall infiltration is assumed to occur throughout the Swansea-Nine Mile Beach catchment.

One method of calculating diffuse (rainfall) recharge is to analyse watertable fluctuations in response to rainfall. Cromer (2003) performed such an analysis using data from a water-level logger that was installed in an observation well over a 161 day period between September 1979 and October 1980 (**Figure 10**). The 50 mm of rain that fell between 26 September and 15 October raised the watertable by approximately 20 mm, which equates to 5 mm or 10 % of the rainfall when aquifer porosity (assumed to be 0.25) is taken into account. Rainfall events less than 2 mm had no measurable effect on the watertable and were deemed to be ineffective. Cumulatively, these low rainfall events accounted for 30 % of the total rainfall during the period. Thus only 70% of actual rain was categorised by Cromer (2003) as effective. Multiplying this factor by the recharge evident in the 50 mm sequence, gave a recharge estimate of 7 % of average annual rainfall, or 41 mm/yr.

The extrapolation from a single recharge event to annual totals is likely to provide estimates of lower reliability. In reality, the relationship between rainfall and fluctuations in groundwater levels will depend on the timing of rainfall events and antecedent conditions within the catchment.

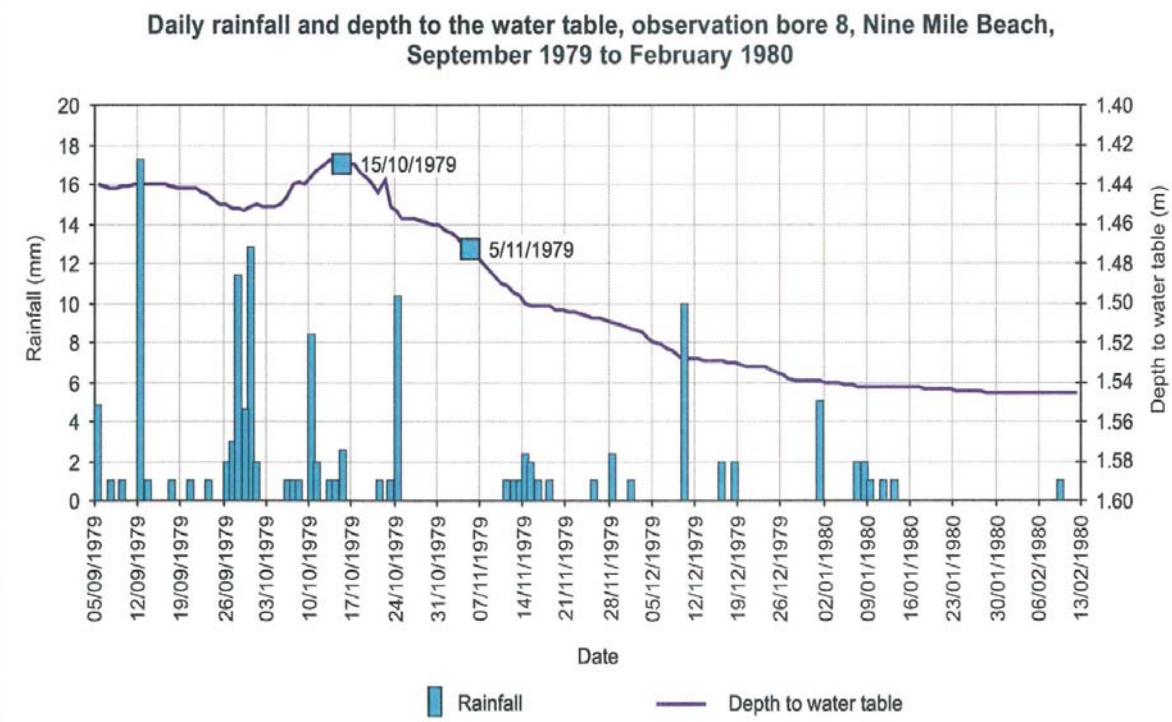

Figure 10. Daily rainfall and watertable fluctuations at Swansea Nine Mile Beach, 1979/80. (Source: Cromer, 2003)

The current project has also used three other methods to estimate recharge. The first is known as the steady state Chloride Mass Balance (CMB), which has been applied successfully to a range of climatic and hydrogeological settings around the world over the last 40 years. The method, which assumes the chloride ion behaves conservatively in the sub-surface environment[3], is based upon conservation of mass between the chloride deposited at the land surface in rainfall, and the chloride reaching the water table as groundwater recharge. This mass balance can be expressed as follows:

Recharge rate x [Cl] in recharge = Precipitation rate x [Cl] in precipitation (3)

Cromer (2003) reports groundwater chloride concentrations ranging from 25 to 76 mg/L with an average of 55 mg/L. Adopting this range of values for the Cl concentration in recharge water, and a mean annual rainfall of 582 mm/yr, the Cl concentration in precipitation is the only variable required to obtain an estimate of recharge rate. In the absence of chemical analyses for local rainfall samples (no reports found), the Cl concentration in precipitation must be estimated. Numerous previous studies of near-coastal aquifers on mainland Australia have measured rainfall Cl at 5 – 10 mg/L. Using this range of values, a range in recharge rates of 38 to 233 mm/yr can be derived.

Given that Swansea-Nile Mile Beach is a coastal catchment, it would appear appropriate to use a rainfall Cl value of 10 mg/L, which can be combined with the average Cl content of groundwater of 55 mg/L to provide a recharge estimate of 106 mm/yr (i.e.18 % of rainfall), which is higher than the estimate of Cromer (2003).

The second method employed by this project to estimate recharge utilises an empirical relationship derived by Zhang et al. (1999, 2001) for estimating evapotranspiration under different land use combinations and annual rainfall. The relationship, which has recently been calibrated for Australian catchments (**Table 1**), is:

$$ET = P\left(\frac{\left(1+\omega\left(E_0/P\right)\right)}{\left(1+\omega\left(E_0/P\right)+\left(P/E_0\right)\right)}\right) \qquad (4)$$

where ET is actual evapotranspiration, P is annual rainfall, E_0 is a rainfall scaling parameter, and ω is a parameter related to plant available water. This relationship is plotted in **Figure 11** using the parameters provided in **Table 2**.

Table 1 Calibration parameters for Australian catchments plotted on curves derived by Zhang et al. (1999, 2001).

Factor	Grass/Cleared	Trees
E_0 1400		1800
w 0.5		4

[3] Conservative behavior of chloride is usually a valid assumption as the chloride ion rarely participates in water-rock interactions, ex cept in situations w hen t he w ater is approaching, at or above saturation w ith respect to halite.

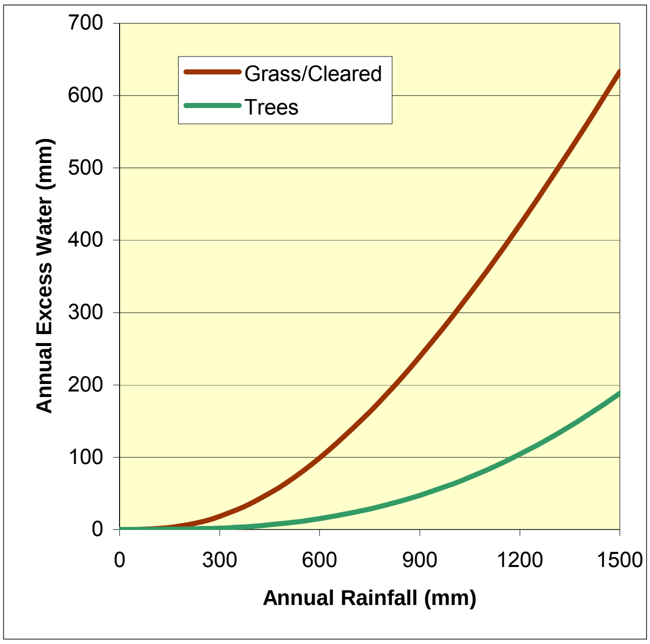

Figure 11 **Empirical curves derived by Zhang et al. (1999, 2001), plotted for Australian catchments using parameters from Table 2.**

"Excess water" can be defined as the difference between rainfall and evapotranspiration, or equally by assuming negligible change in groundwater storage, the sum of groundwater recharge and stream flow. Whilst only "grass/cleared" and "tree" curves are plotted in **Figure 11**, the excess water for any catchment containing a mix of these two extreme land uses can be estimated simply by linear scaling.

For the Swansea-Nine Mile Beach catchment, the long-term average rainfall value of 582 mm/yr (section 2.2) together with a land use mix of 40% grass/cleared and 60% trees (comprising remnant native vegetation and the rural/residential coverage that has not been extensively cleared, **Figure 5**) was used to estimate the annual excess water as being 45 mm/yr for the catchment. The annual excess water is assumed to be equal to rainfall recharge as there is expected to be little runoff on flat, sandy soils.

The third technique utilised by this project, to estimate rates of groundwater recharge to the aquifer, was based on the analysis of chlorofluorocarbons (CFC-11 and CFC-12) in groundwater. CFC-11 and CFC-12 concentrations in groundwater were compared to historic atmospheric concentrations to establish the year that water precipitated from the atmosphere and began recharging the groundwater system. The recharge rate (*R mm/yr*) is given by the following relationship:

$$R = \frac{z\theta}{T}$$

where *z* represents the height of the water column above the sampling point (screened interval of well) in millimetres, *θ* represents the porosity of the aquifer material (dimensionless fraction of volume of voids versus the total volume of the porous material) and *T* represents the apparent age of the groundwater in years. In the absence of actual porosity measurements, it has been assumed that the Quaternary sediments have a porosity of 0.2 (20%).

Three monitoring wells in the Swansea-9 Mile Beach catchment were sampled for CFCs in triplicate. The indicative groundwater ages for DS1, DS5 and DS3 were > 43, > 43 and 14 years respectively. Two of these wells were located in, or adjacent to areas covered by native vegetation (DS1 and DS5), and one was located in a more open sandy area (DS3) (**Figure 9**). Groundwater recharge rates in areas under native vegetation ranged from less than 4 ± 13 mm/yr on more clayey soils in the western catchment area (DS5), to less than 18 ± 5 mm/yr in the eastern catchment area on more sandy soils (DS1). In the central area of the catchment that had been cleared (DS3), the calculated recharge rate was higher (< 50 ± 16 mm/yr, from an indicative groundwater age of 14 years). These observations suggest that at Swansea – Nine Mile Beach, land use (in particular the presence or absence of deep rooted vegetation) and soil texture are significant factors controlling recharge.

The differences in recharge rates derived by CFC analysis at the three monitoring wells were supported by recent groundwater level data (**Appendix A**). A rainfall event on 6/2/08 led to a significant groundwater level rise at DS1 and DS3, but only a marginal rise was noted at DS5.

A summary of the recharge estimation methods and results for the Swansea-Nine Mile Beach catchment is presented in **Table 2**. The range in recharge estimates (18 - 106 mm/yr) reflects uncertainty in the parameters adopted for each method, as well as the scale of the area to which the method applies. Whilst the first of these two explanations (i.e., parameter uncertainty) is obvious, the second factor is often not considered when applying different recharge estimation techniques. Of the four methods applied in this catchment, the watertable fluctuation, CMB, and CFC techniques provide a point estimate, while the other method (Zhang, 1999 excess water) is a whole-of-catchment scale estimate. Furthermore, changes to land use (such as forestry or clearing) may affect the interpretation of the CMB since the method relies on the assumption that the loading of chloride from rainfall is in steady-state with the chloride loading to groundwater.

Table 2 Diffuse recharge estimates for the Swansea-Nine Mile Beach catchment.

Method (Source)	Recharge Rate (mm/yr)
Water table fluctuation (Cromer, 2003)	40
Steady-state Chloride Mass Balance (current project)	106
Annual excess water less stream flow (current project)	45
Chlorofluorocarbons (current project)	<4 to18 (vegetated areas) and < 50 in cleared areas
Assumed recharge for preliminary water budget	52

Diffuse recharge is likely to vary considerably over space and time, and this is reflected in the range of estimates presented in **Table 2**. However a single value is required to characterise recharge for a preliminary water budget. For Swansea – Nine Mile Beach, the average recharge rate of all the estimates (52 mm/yr) will be used.

4.2 Point Source Recharge

The main source of point source recharge is likely to be through downward percolation of excess irrigation water. This volume is likely to be very low given the small area of irrigated land (less than 2 km^2). Recharge from septic tanks is also likely to be occurring, but is probably insignificant volumetrically.

4.3 Recharge from Losing Streams

There are no major rivers within the region.

5 GROUNDWATER FLOW

5.1 Groundwater elevation data

Groundwater elevation data for 28 locations is available from Cromer (2003) and has been plotted in **Figure 9**. All but one of these wells is completed within the Quaternary Sands.

The groundwater elevation values suggest a relatively flat groundwater gradient that is difficult to represent with groundwater elevation contours. There is a poor correlation between groundwater elevation and the depth to groundwater across the whole of the dataset.

There is no data available to estimate the exchange of groundwater between the Unit 2/3 aquifer and the deeper Quaternary and Tertiary aquifers that lie below the confining layer (Unit 1), but given the low permeability of Unit 1, groundwater interaction between these units is highly unlikely.

5.2 Groundwater Flow Direction

Despite the uncertainty with the groundwater elevation data, the following features of the groundwater flow patterns within the Quaternary Sands are suggested:

- Groundwater flow at the local scale is likely to be towards discharge areas such as drains and swales where groundwater is lost through evaporation;
- Groundwater may be 'intercepted' where deep-rooted remnant native vegetation is able to access a shallow watertable; and
- Cromer (2003) suggests that groundwater movement is mainly towards the coast and towards the Swan river estuary. At the western end of the spit, groundwater flows to the low lying swampy ground at the rear of the spit and west to the Meredith River.

5.3 Flow rates

Cromer (2003) provides a calculation for the ground water flow rate along transect B-B (**Figure 7**), using data from 1979. The assumed parameters were an average watertable gradient of 0.001, a permeability of 30 m/day, and a porosity of 0.25, such that:

Rate of flow = 30 m/day x 0.001/0.25 = 0.12 m/day = 45 m/year

6 GROUNDWATER OUTFLOWS

6.1 Lateral Discharge

Palfreyman (2002) estimated a flow of 0.05 m^3/day/m of coastline, which converts to 475 ML/year (using an estimated coastline length of 26 km).

6.2 Groundwater Extraction

Whilst not metered, groundwater abstraction for domestic purposes in the Swansea-Nine Mile Beach catchment has been estimated at 50 ML/year (Cromer, 2003). Irrigation use is assumed to be negligible.

6.3 Evapotranspiration from Shallow Water Tables

ET is likely to be a significant component of the groundwater balance given that approximately two thirds of the measured groundwater depths are less than or equal to 2 m. In addition, the land use mapping indicates that about 6 km^2 of the spit area contains remnant native vegetation; although the total area covered by deep-rooted vegetation is likely be higher when sparsely cleared land from the rural/residential blocks are included.

The rate of ET from a shallow watertable is difficult to estimate as there are many influencing factors, however given the climatic conditions and soil type, a rate of ET from areas of shallow water tables of 50 to 100 mm/yr (0.5 to 1.0 ML/ha/yr) is considered reasonable for areas with deep rooted vegetation. The rate of ET in areas without deep rooted vegetation will be much lower (and remains unquantified).

An extinction depth of 5 m is considered reasonable where there is deep rooted native vegetation (i.e. the ET rate is estimated to be zero at depth of 5 metres or greater). The ET extinction depth in remaining areas is likely to be closer to 2 m.

6.4 Groundwater Discharge to Streams

There are no major rivers within the region, but groundwater discharge would occur to swamps and areas with enhanced drainage in the western part of the region. This flux remains unquantified.

7 CONCEPTUAL MODEL

7.1 Block Diagram

A three-dimensional conceptual model of the Swansea-Nine Mile Beach catchment has been built (**Figure 12**) using a Digital Elevation Model (DEM) for the topographic surface. This model will form the initial framework for the numerical groundwater flow model that is to be developed for the catchment during Stage 4 of the project. Key features of the conceptual model are:

- An unconfined aquifer 4 to 12 metres thick extending across the 15 km long sand spit;
- The unconfined aquifer is likely to be hydraulically separated from the deeper confined Quaternary and Tertiary sediments by a clay confining layer of around 20 m thickness. Leakage between the unconfined and confined systems is estimated to be small, given the thickness and nature of the confining materials;
- Rainfall recharge to the unconfined aquifer; and
- Discharge through evapotranspiration from low lying areas and areas with remnant native vegetation (such as the areas along the northern edge of the spit). There is also likely to be groundwater discharge to the ocean and to the estuary.

7.2 Preliminary Water Budget

Figure 12 summarises preliminary estimates of the main components of the water balance. This data is also summarised as either groundwater inflows or outflows in **Figure 13** to establish a catchment groundwater balance. This budget is considered to be very approximate and should not be used for any purpose other than to inform the project team of where efforts should be focussed for the upcoming field program, and to provide a starting point in the model setup and calibration. Key aspects to the water budget are listed below:

- The largest component of the water budget is the rainfall recharge, which is largely balanced by lateral groundwater discharge and ET in areas of remnant vegetation;
- The groundwater budget appears to be close to balanced;
- The Swansea – Nile Beach catchment is considered to be under a relatively low level of threat, based on the small rate of the groundwater extraction relative to the rate of rainfall recharge.

7.3 Knowledge Gaps and Uncertainty

A summary of all data sources made available for the preparation of this conceptual model report is provided in the Data Inventory in **Appendix B**.

The above water budget is considered to be very approximate and should not be used for any purpose other than to provide a starting point for the numerical model setup and calibration. In particular, it should not be used for defining existing levels of use or the sustainable yield for management purposes.

The preliminary conceptual model (**Figure 12**) and groundwater budget (**Figure 13**) highlight at least two key components of the water balance that need to be better defined for the Swansea-Nine Mile Beach catchment. The first of these is evapotranspiration from shallow water tables. As discussed in Section 5.3, estimating this flux is not straight forward. It is recommended that the numerical model be used to simulate this process and thereby identify its likely magnitude and importance on the catchment groundwater balance. However, this will require a high quality DEM, which is currently unavailable.

There is insufficient data to enable the development of a full coverage of elevation and thickness contours of Unit 1 (confining layer). There is also no data available to determine the potential for vertical leakage across this confining layer.

7.4 Implications for Numerical Model Development

It is recommended that the Swansea-Nine Mile Beach catchment be modelled as a three layer system which represents the productive aquifer of Unit 2 and 3, a confining layer (Unit 1) and the deeper Quaternary sediments.

The lack of groundwater monitoring data means that the model will not be fully calibrated, although it may be possible to test the model against the 21-day extraction trial reported by Cromer (2003).

The lack of a high quality DEM will limit the capacity of the model to take into account ET.

8 RECOMMENDATIONS FOR FURTHER FIELD STUDIES

Based on the available data, the following field work is recommended for the Swansea-Nine Mile Beach catchment.

- Groundwater elevation survey across the entire catchment;
- Additional drilling to confirm the elevation and thickness of Unit 1; and
- Ongoing groundwater level and salinity monitoring.

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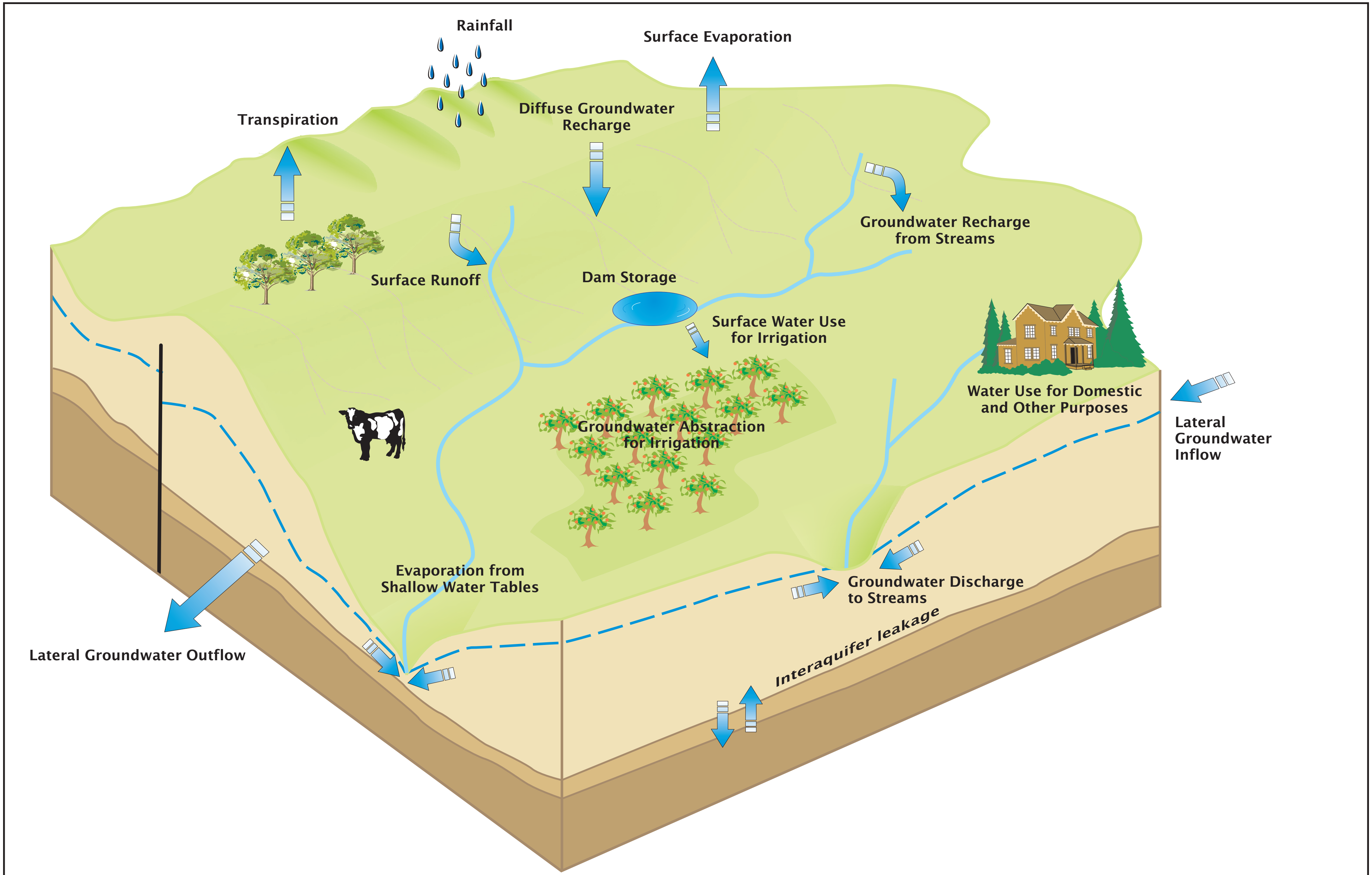

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Schematic diagram showing the main components of a catchment-scale groundwater balance

FIGURE
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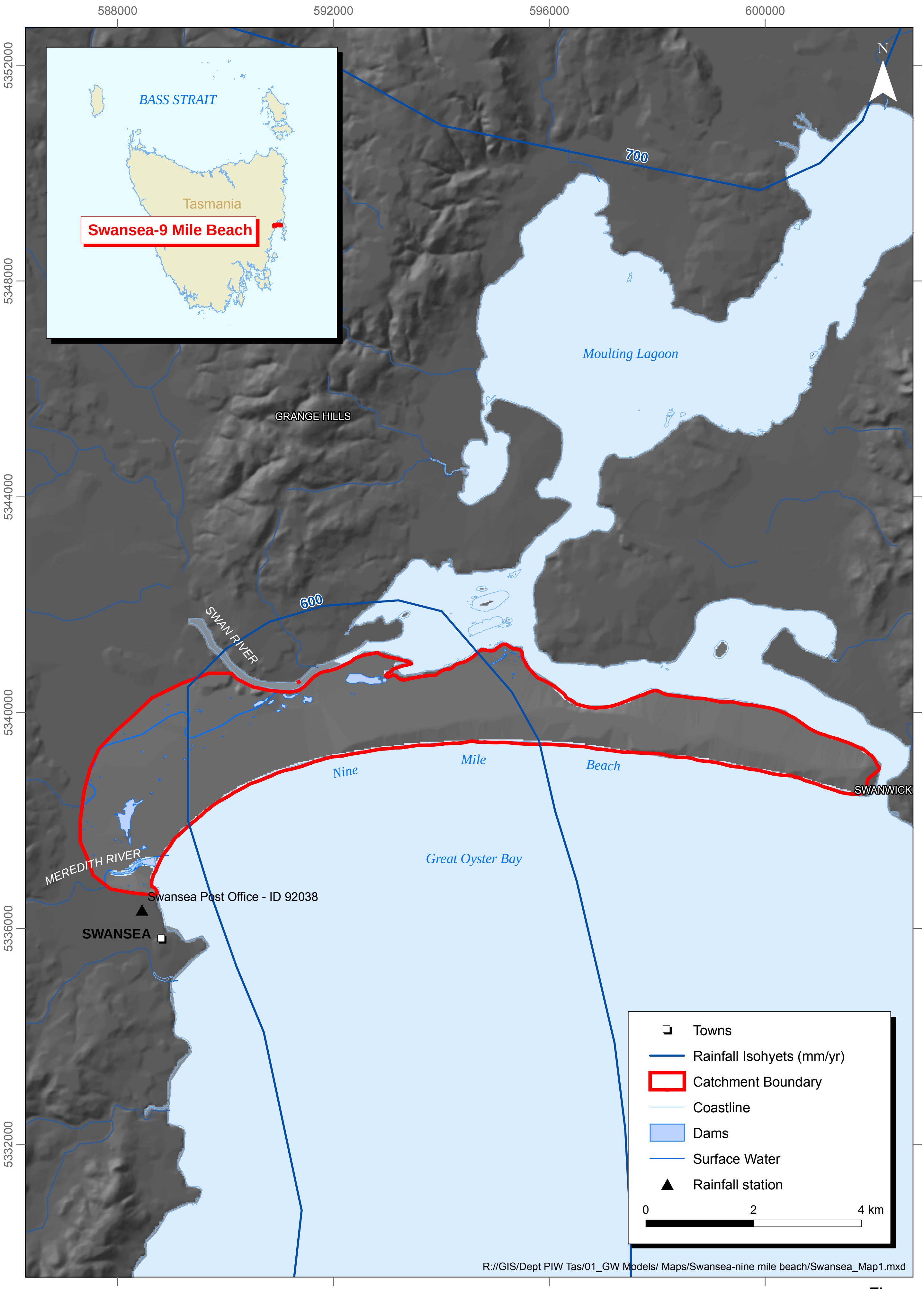

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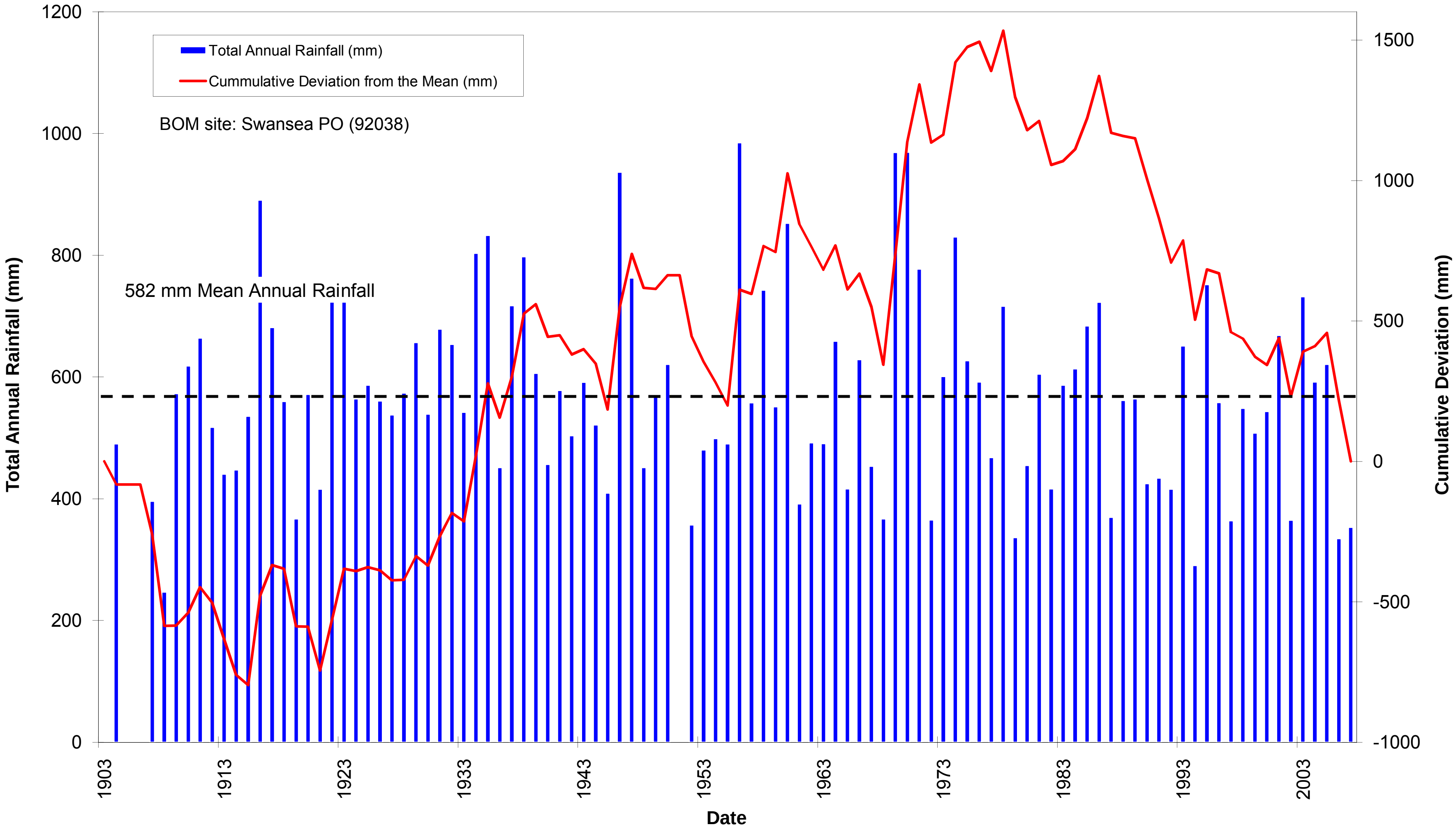
SWANSEA-9 MILE BEACH

Surface Water and Rainfall Isohyets

Project: FQ-01-1

Figure 2



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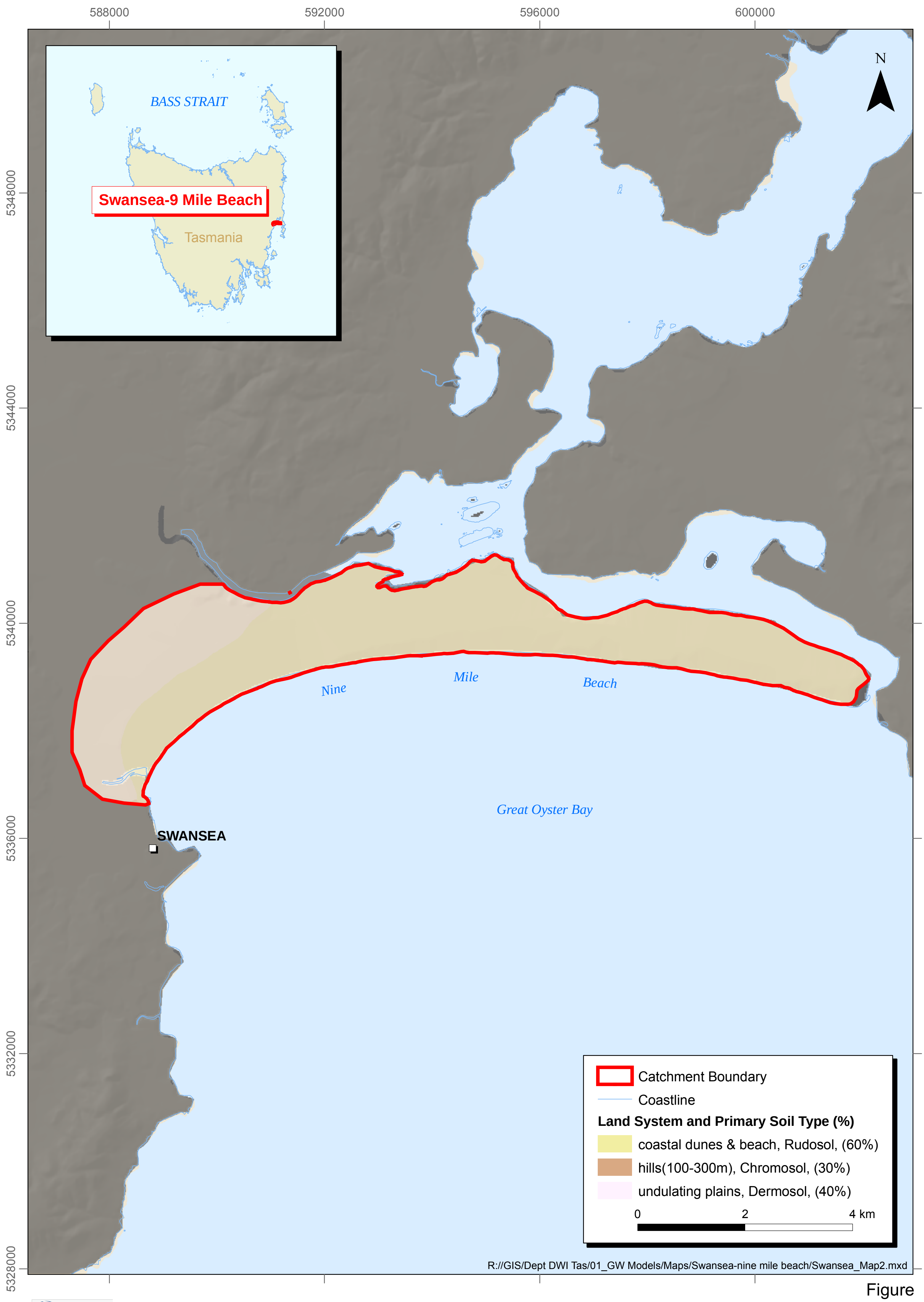
Total annual rainfall and cumulative deviation from mean annual rainfall for Swansea - Nine Mile Beach catchment

FIGURE 3

PROJECT FQ-01

September-07



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SWANSEA-9 MILE BEACH

Topography, Land System and Primary Soil Classification

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Figure 4

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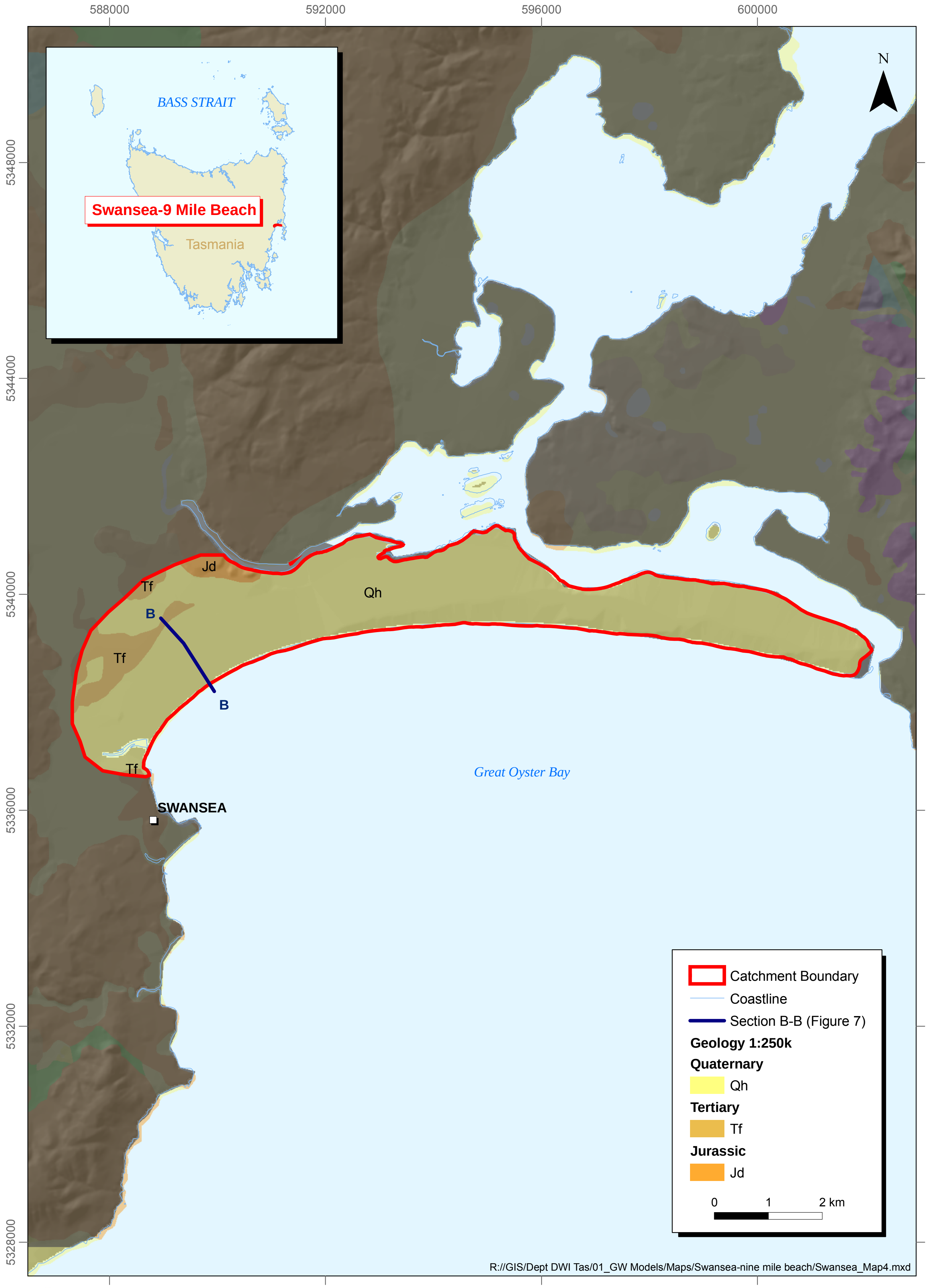
SWANSEA-9 MILE BEACH
Land Use and Groundwater Salinity

Project: FQ-01-1

Figure 5



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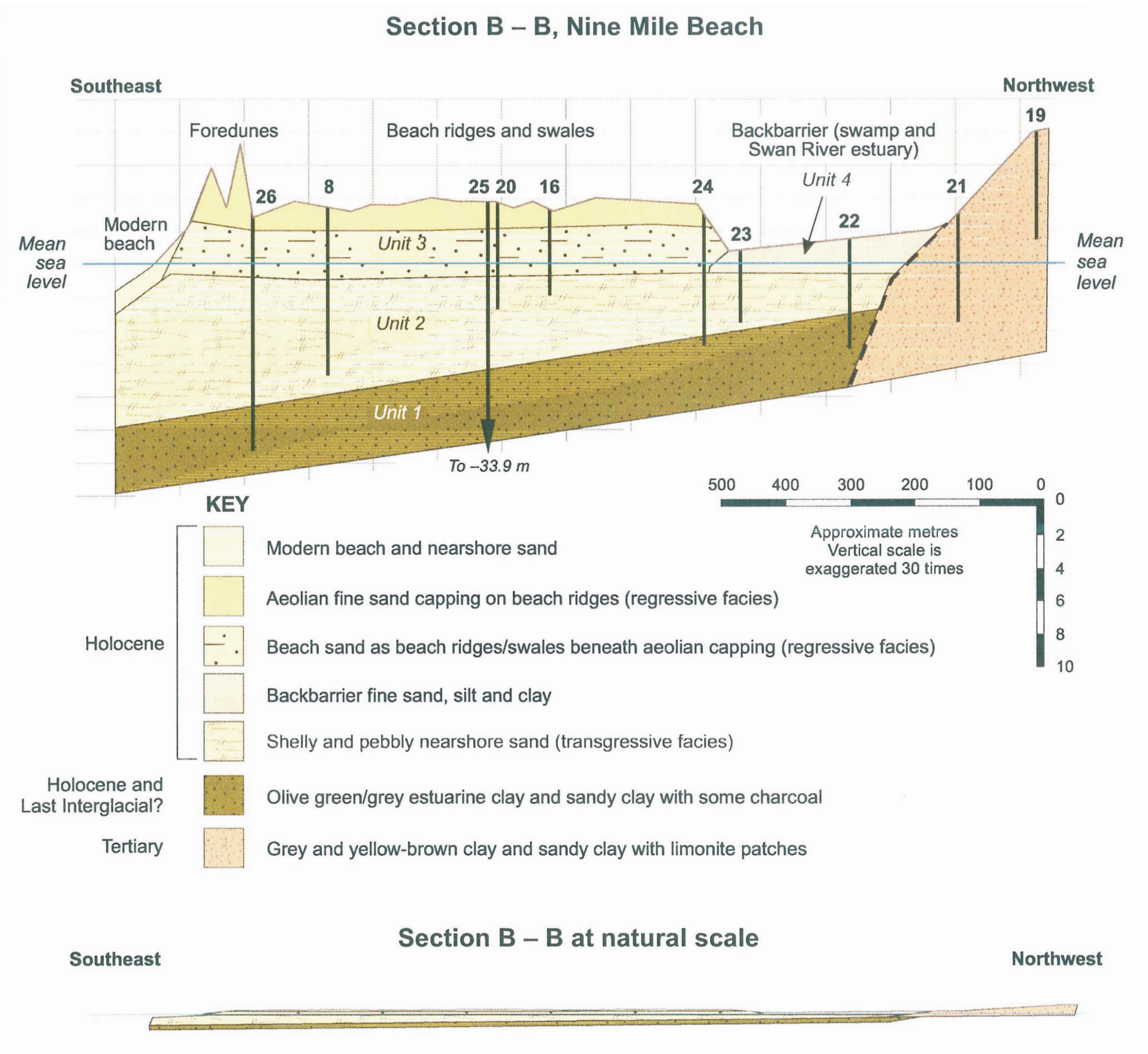
SWANSEA-9 MILE BEACH
Surface Geology
Project: FQ-01-1

Figure
6



courtesy of Tasmanian Geological Survey Record 2003/07
'The geology and groundwater resources of Nine Mile Beach, eastern Tasmania'

R:\GIS\Dept PIW Tas\01_GW Models\Maps\Swansea-ninemilebeach\schematic stratigraphy.cdr

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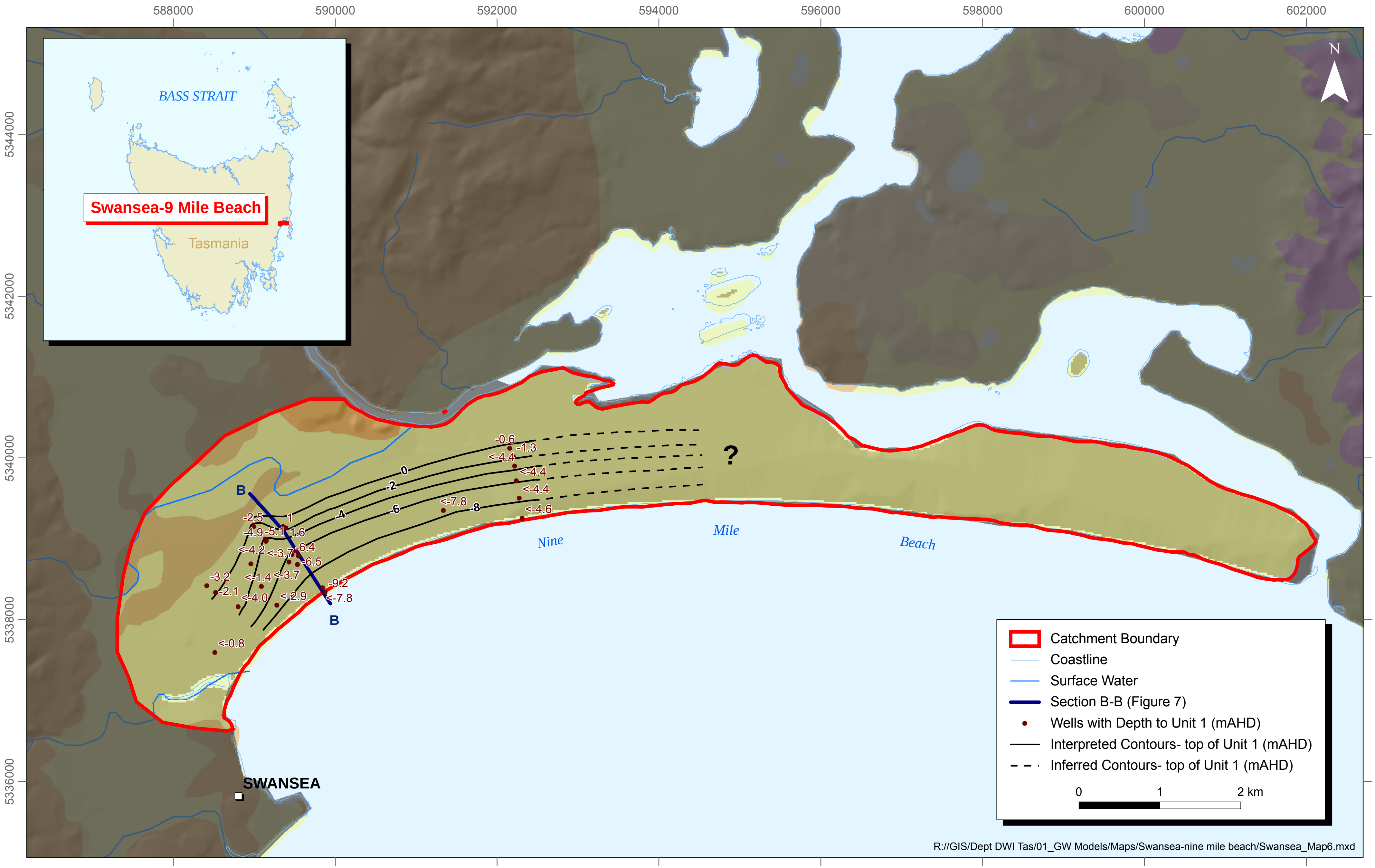
SWANSEA – NINE MILE BEACH
Schematic stratigraphy at transect B

FIGURE
7



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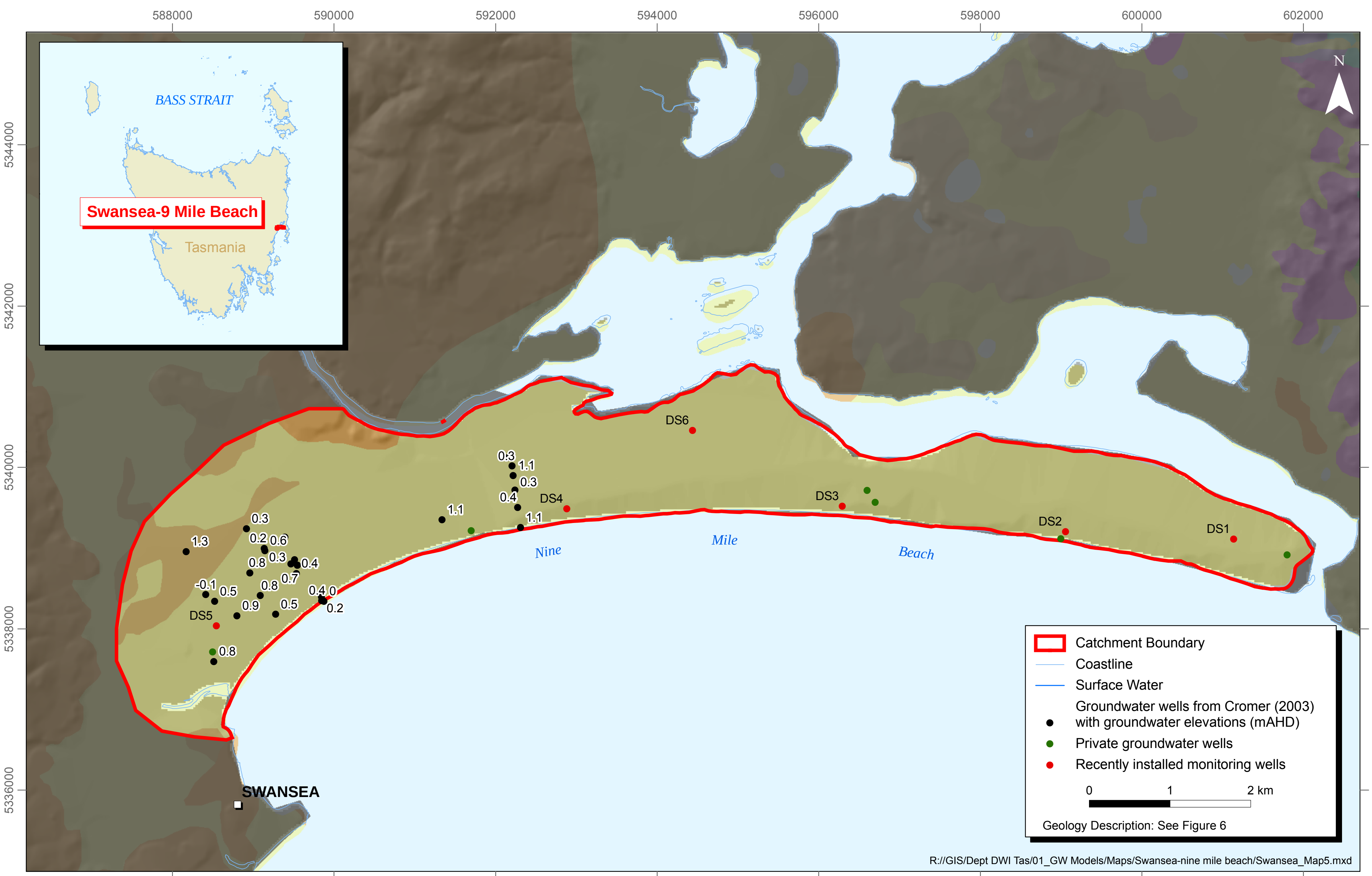
SWANSEA-9 MILE BEACH

Unit 1 Contours

Project: FQ-01-1

Figure

8



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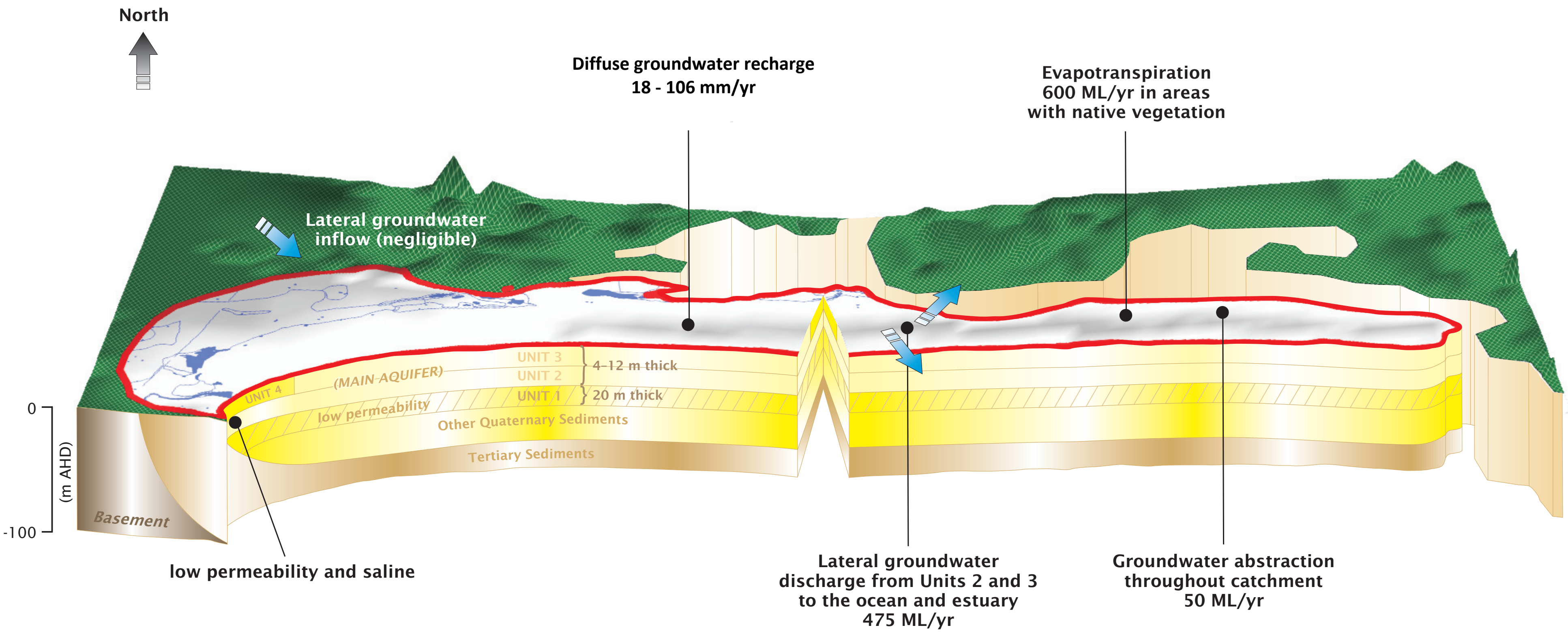
SWANSEA-9 MILE BEACH

Groundwater Elevations

Project: FQ-01-1

Figure

9



CATCHMENT AREA 23 km^2
MEAN ANNUAL RAINFALL 582 mm/yr

R:\GIS\Dept PIW Tas\01_GW Models\Maps\3D Block Diagrams\swansea-9 mile beach.cdr

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SWANSEA-NINE MILE BEACH
Conceptual Hydrogeological Model

FIGURE
12

CATCHMENT NAME: **Swansea Nine Mile Beach**

Area: **23 km^2**

Mean Annual Rainfall: **582 mm/yr**

Annual Average Surface Water Discharge: negligible **ML/yr**

comprising of

Annual Average Surface Runoff: **ML/yr**

Annual Average Baseflow: **ML/yr**

CONFIDENCE IN ESTIMATE
(1 = Very Low, 5 = Very High)

GROUNDWATER INFLOWS

			Confidence
Lateral Inflow:	negligible **ML/yr**		4
Recharge by:			
Diffuse Rainfall Recharge:	**1,196 ML/yr**	(18-106 mm/yr)	3
Point Source Infiltration:	negligible **ML/yr**		4
Stream Losses:	neglibible **ML/yr**		4
TOTAL INFLOWS =	**1,196 ML/yr**		

GROUNDWATER OUTFLOWS

			Confidence
Lateral Discharge:	**475 ML/yr**		2
Groundwater Abstraction:	**50 ML/yr**		2
Evapotranspiration:	**600 ML/yr**	in areas of native vegetation only	1
Discharge to Streams:	negligible **ML/yr**		4
TOTAL OUTFLOWS =	**1,125 ML/yr**		

GROUNDWATER BALANCE

CHANGE IN AQUIFER STORAGE:
ΣINFLOWS - ΣOUTFLOWS = **71 ML/yr**

Groundwater Threat Index

	Extraction/Recharge		
Extraction	0 - 25%	25 - 75%	>75%
< 5 GL/yr	**Swansea- 9 Mile Beach** (Low Threat)	Low Threat	Moderate Threat
5-10 GL/yr	Low Threat	Moderate Threat	High Threat
> 10 GL/yr	Moderate Threat	High Threat	High Threat

Low Threat
Moderate Threat
High Threat

PRELIMINARY
CATCHMENT WATER BALANCE
FOR SWANSEA- 9 MILE BEACH

FIGURE 13

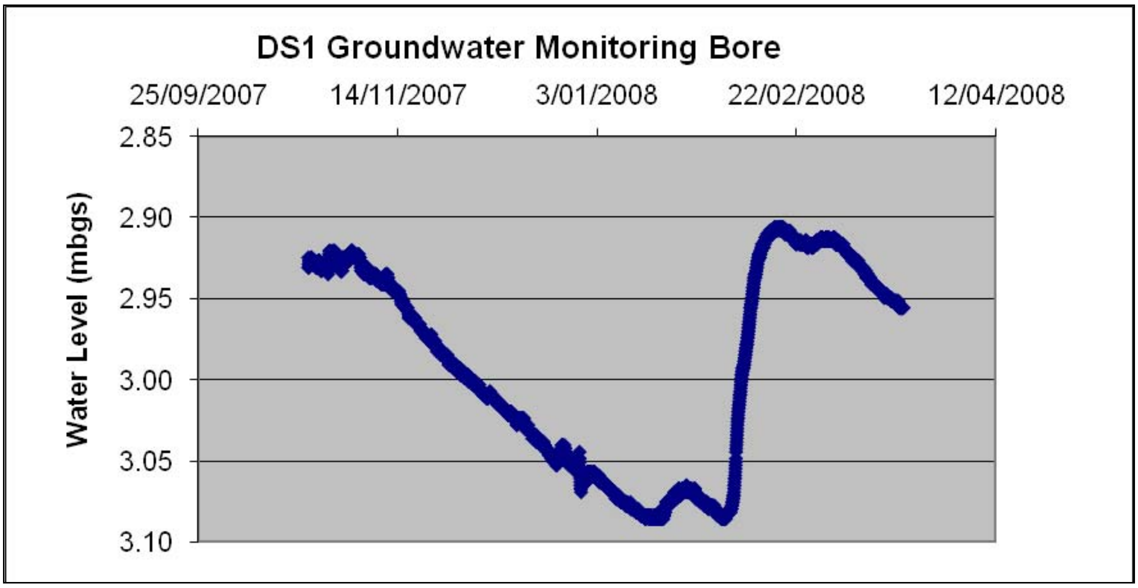
PROJECT FQ-01

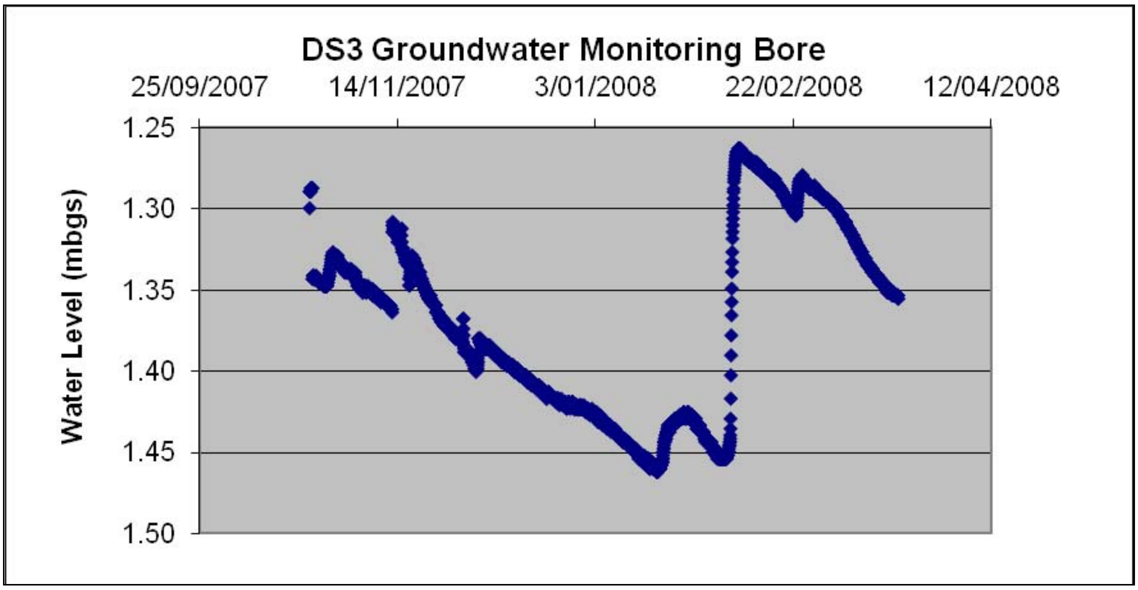
July-08

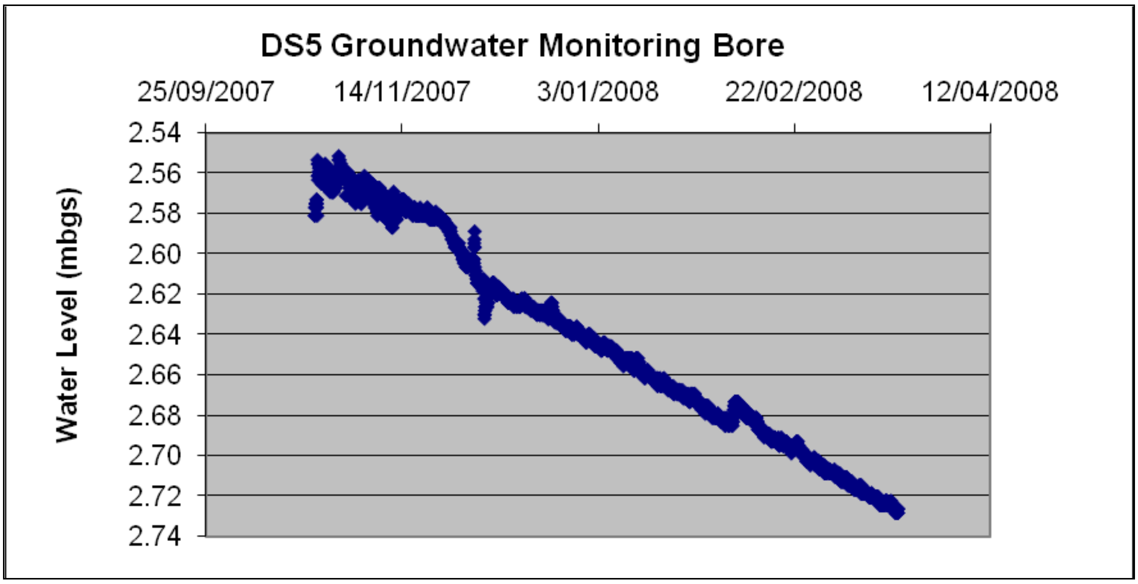
Appendix A

Recent groundwater level data

Recent groundwater level monitoring data at Swansea – Nine Mile Beach







Appendix B

Data Inventory for the Swansea – Nine Mile Beach Catchment

	Data Available	Source / Publications	Comments
Overview of Geology			
Age and depositional enviroments	Y	Cromer 2003/07	
post-depositional history (tectonics, metamorphism)			
Topography / Physiographic Setting			
DEM ***	Y	DPIW - electronic	
- contours	Y	DPIW - electronic	
- point heights	raster	DPIW - electronic	
soil type	Y	DPIW - electronic	Simon Lynch
land use (i.e., native vegetation vs. dry land farming vs. irrigation vs. plantation forestry)	Y	DPIW - electronic	Simon Lynch
Basic Hydrogeology			
stratigraphy - no. aquifers/aquitards	Y	Palfreyman, 2002; Cromer 2003/07	
thicknesses (reliable geological logs)	Y	Cromer 2003/07	
porosity/specific yield	Y	Cromer 2003/07	
hydraulic conductivity			
Groundwater Monitoring			
multilevel piezometers			
time series gw levels ***	Y/N	Cromer 2003/07	historical data only, new DPIW wells installed
time series gw chem			
Water table contours			
Groundwater flow – direction, rates?			
Surface water monitoring			
time series sw flows			
time series sw chem			
Surface water-groundwater interaction * **			
baseflow separation from sw monitoring	N		not for this catchment
gw monitoring responses			
Groundwater Recharge			
Rainfall seasonality/history			
Diffuse recharge	Y	Cromer 2003/07	7% mean annual rainfall
- relationship with soil/land use			
- rainfall-gw chemistry/salinity			
Localised recharge (e.g. flood or preferential)			
- flood extent and duration			
- bore hydrograph responses			
- gw quality maps			
Groundwater pumping (extraction) * **			
Irrigation type/efficiency			
Crop types/volumes applied			
History of use			
Bore density			
Drawdown/recovery responses			
Evapotranspiration			
depth to water table			
vegetation types/health			
evidence of salinisation			
Artificial Drainage			
network			
drain elevation cf. groundwater levels			
Groundwater Model - type, purpose and necessary features			

Appendix C

Geological description of features in Figure 6

Geological description for features in Figure 6

Symbol	Description
Qh	Sand gravel and mud of alluvial, lacustrine and littoral origin.
Tf	Ferricrete, silcrete, laterite and derived lag deposits.
Jd	Dolerite (tholeiitic) with locally developed granophyre.