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RED HILL HARD ROCK QUARRY
TOODYAY ROAD

GROUNDWATER MANAGEMENT

Prepared for: Hanson Construction Materials Pty Ltd

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RED HILL HARD ROCK QUARRY, TOODYAY ROAD

GROUNDWATER WATER MANAGEMENT

Document Status

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	Name	Position	Signature	Date
Originator:	Bradley van Blomestein	Senior Hydrogeologist		8/05/07
Reviewer:	Jeff Jolly	Principal Hydrogeologist		8/05/07

aquaterra
Aquaterra Consulting Pty Ltd
ABN 49 082 286 708
Suite 4, 125 Melville Parade
Como, Western Australia, 6152
Tel: (08) 9368 4044
Fax: (08) 9368 4055

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SECTION 1 - INTRODUCTION

1.1 GENERAL

Hanson Construction Materials Pty Ltd (Hanson) currently operates the Red Hill hard rock quarry and processing facilities located on Lot 11, Toodyay Road (Figure 1).

Hanson is proposing to continue to develop the Red Hill quarry pit to the north and north-west of the current quarry pit, to increase the area available for hard rock extraction and to enable long-term continuation of quarry operations. Hanson also proposes to extend the area of the existing stockpile and dispatch area (Figure 2).

The proposed extension of the quarry operations has a footprint of approximately 78.3 ha (about 73.3 ha for the pit, and about 5 ha for the stockpile extension), which will allow quarrying to continue for around 100 years. The Environmental Protection Authority has set the level of assessment for this proposal as Public Environmental Review.

The Red Hill Quarry is located on the Darling Plateau and encroaches on the catchments of two stream systems. Susannah Brook is a relatively unmodified ephemeral stream (June to November) that runs to the north of the existing quarry and ultimately drains into the Swan River. Strelley Brook is the other main surface water feature in the project area, located to the south west of the quarry operations (see Figure 3).

1.2 SCOPE OF SERVICES

This report is a desktop groundwater study to determine if the proposed Red Hill Quarry operation will impact on groundwater resources in the vicinity of the project, in terms of flow volumes and water quality. Aquaterra has been commissioned by Hanson to address the following issues:

- Description of the hydrogeological characteristics of the area with particular attention to the identification of the location, geometry and key parameters of local aquifers and the potential impacts of the proposed quarrying operations.
- The depth to water table in the area and seasonal variations, which may have implications for future quarrying operations.
- Local groundwater users and the potential impacts of quarry operations on these users.
- Potential for downstream impacts such as groundwater dependant ecosystems and impacts on the aquifers of the Swan Coastal Plain.

SECTION 2 - PHYSICAL ENVIRONMENT

2.1 SITE DESCRIPTION

The proposed quarry site is located near the top of a catchment divide, in the south east corner of the Wooroloo Brook catchment. This catchment forms part of the larger Swan-Avon catchment. The site is also located in a proposed Priority 3 Drinking Water Source Area.

The local catchments (Susannah and Strelley Brooks) have been subject to a long history of anthropogenic influence since European settlement. The upper catchments of Susannah Brook, to the east of the Darling Plateau, have been utilised as pastoral lands. The lower and Strelley Brook catchments open onto the Swan Coastal Plain, where the soil characteristics have been suitable for vineyards and orchards. The middle catchment, which includes the Red Hill Quarry Area, has some tracts of remnant vegetation, State Forest and industrial sites.

2.2 CLIMATE

Western Australia (WA) has three broad climate divisions. The northern part is dry tropical and the south-west corner including Perth has a Mediterranean climate, with long hot summers and wet winters. The remainder is mostly arid land or desert climates.

The Perth Region is characterised by a subtropical climate surrounded by the temperate zone of the south west land division. The summer is distinctly dry and hot. Mean monthly maximum temperatures range from 32° in February, to 18° in July, while mean monthly minimum temperatures range from 17.4° in February to 8° in July (Figure 4).

2.3 RAINFALL AND EVAPORATION

The Perth Region (Perth Airport) has an annual average rainfall of about 767mm per annum and Perth Gardens (pre 1950) about 857mm pa. The Upper Swan Research Station (on the coastal plain) has 740mm average, and the suburb of Kalamunda in the hills 1069mm annual average.

Rainfall in the area falls during the winter months of April to October. The driest months are November to March. There are on average about 87 rain days each year (Figure 4). The mean annual pan evaporation rate is about 2000mm/yr, which exceeds annual rainfall by about 1200mm.

In general, the south west land division of Western Australia is experiencing the effects of a drying climate with below average rainfall over the last 20 years.

3.1 GEOLOGY AND SOILS

3.1.1 Geology

The project area is located on the Darling Plateau, to the east of the Darling Scarp. The Darling Plateau has an average elevation of 240m above sea level. The geology of the project area is typical of the edge of the Darling Scarp – lateritic plateau on the ridges, and Yilgarn Craton granite-gneiss rock, with bands of dolerite rock, in various stages of erosion on the Scarp face. Bands of diorite rock strike through the granite gneiss, varying between 2-30m wide. Pegmatite and quartz veins also occur as bands from a few centimetres to 5-10m wide and penetrate through the gneiss and diorite. Duplex soils consisting of Ferruginous and Lateritic gravels, underlain by white and cream clays with saprolite grits cap the higher hill areas of the quarry area. Ages of the granites-gneisses vary from 3100-2200 million years old. The dolerites are considerably younger, between 750 and 450 million years old. The laterites are late Tertiary to Pleistocene.

3.1.2 Structural Geology

The quarry lies approximately 2.5km east of the Darling fault.

The granite mass is cut by a series of vertical and near vertical dolerite dykes, up to 50m wide which generally trend in a northerly direction (Plate 1). A number of vertical shears intersect across the area (Plate 2). The structures can be divided into three dominant sets; northerly, south-west to north-east and east to west-north-west. The relationships between these sets of structures are unclear although they are believed to be of different ages.

Dolerite dykes post date most fault and fracture structures and have generally intruded along the sheared fractured rock zones. In a few cases where faulting post dates the intrusion of the dolerite dykes, the faulting is thought to be associated with movement of the Darling Fault.

3.1.3 Soils

Soil formation in the project area is influenced by the laterite mantle on ridges and the plateau, while the variable soils in the valleys depends on the amount of local relief, degree of stripping of the weathered mantle and the geological nature of the substrate. The soils of the lateritic plateau are mostly silty clays and loams, with a high proportion of laterite pebbles. The soils on laterite uplands have formed from weathering of laterite duricrust, and have been transported down slope by colluvial action (scree and rock fragments) to the lower slopes of the Darling scarp and into the incised watercourses. Soil patterns on the valley slopes are variable and depend on the underlying rock slopes, slope, moisture and degree of weathering.

SECTION 4 - BASELINE HYDROGEOLOGICAL CONDITIONS

Aquaterra has reviewed existing geological and hydrogeological information from the Department of Water and the adjacent Red Hill Landfill Site, as well as conducting a site visit to the quarry area. Information was reviewed to determine the conceptual hydrogeology of the quarry area.

4.1 REGIONAL HYDROGEOLOGY

The area east of the Darling Fault, where the Red Hill Quarry occurs, is underlain principally by crystalline basement rocks of the Archaean Yilgarn Craton (over 2.5 billion years old).

In general, the crystalline rocks (which are mainly granite and gneiss) and the regolith (weathered zone) are not of great groundwater potential. Bore yields are generally low and highly variable, and the groundwater salinity is variable. Most exploration has been for stock water with a supply of 4.5 kL/ day – enough for a windpump - considered adequate for stock. Consequently, there is little information on larger yields. Anecdotal evidence of high bore yields has subsequently been shown to be erroneous. Caution should be applied in accepting bore yields based on short term airlift testing, as such yields are usually not sustainable.

Groundwater salinity varies widely, both laterally and with depth. Bores separated by only a few hundred metres may have widely differing groundwater salinity. Consequently, it is not possible to map groundwater salinity in many areas, even at the broad scale, with current data.

West of the Darling Fault is the Swan Coastal Plain. Groundwater is widespread throughout this area and occurs in the primary superficial aquifers of the Yoganup Formation and the Guildford Clays. In general to the West of the project area the salinity of the groundwater is in the range of 1500-3000mg/L and groundwater is 18mAHD immediately west of the Darling fault. The base of the superficial aquifer to the West of the Darling Fault is approximately 10mAHD which means in general the superficial aquifer is relatively poorly developed and thin. This aquifer thickens rapidly further to the west as one moves away from the Darling fault.

4.2 LOCAL HYDROGEOLOGY

There are no groundwater bores in the quarry area so information has been extrapolated from the adjacent Red Hill Waste Site, from the DOW database of groundwater sources and from a site visit to the quarry.

It appears there are two potential types of aquifers which could occur in the quarry area, namely perched aquifers and fractured/weathered rock aquifers.

4.2.1 Perched Aquifer

The more permeable ferruginous lateritic soils which cap the quarry area appear to form a local perched system during the wet season, although the seepage along this zone dries up in summer. There is insufficient data from bore logs to assess the extent of any perched system, however data from the adjacent Redhill Landfill Site, suggest any aquifers would be isolated and at most have a local influence.

4.2.2 Fractured/Weathered Rock Aquifer

The fractured/weathered crystalline rocks (granites, diorites and dolerites) are likely to comprise a minor (local) aquifer in the quarry area.

Information from deeper bores was obtained for the adjacent Red Hill Landfill Site. A regional groundwater flow pattern was determined using groundwater levels from existing monitoring bores on site. Regional groundwater appears to occur within the weathered granitic basement rocks and in fractures in the relatively unweathered basement rocks.

Groundwater level contours broadly mimic topographic contours with groundwater levels being about 60m below surface level for the most elevated areas (295mAHD) at the adjacent Red Hill Landfill Site. Groundwater levels were taken at Red Hill Landfill Site at the end of the wet season (September 2005) and in April 2006 at the end of the dry season. Groundwater levels were approximately 1m higher in September which indicates a minor change to levels.

Herne Hill Quarry, to the south-west of the Red Hill Quarry Site is partially filled with water (Plates 3 and 4). Assuming that the regional groundwater level is approximately 60m below surface (as in the adjacent Red Hill Waste Site) then the water level in the Herne Hill Quarry which is excavated at least 60m below surface may be attributed to a combination of both groundwater infiltration rainfall runoff. However, as no active dewatering was required during the quarrying operation at Herne Hill, groundwater infiltration is likely to have been very minor and exceeded by annual evaporation.

At Herne Hill, two pits are separated by a dolerite dyke with a difference in pit water of about 4m between the two pits. This difference in water levels would suggest that groundwater flow may be compartmentalised with the dolerites acting as barriers to flow. If there is compartmentalisation of the groundwater, this could isolate effects of dewatering to certain areas along strike between sets of dolerite dykes.

The current quarry operation has not intercepted any significant groundwater resources even though the present level of the quarry is below the expected regional groundwater table. Some seepage does occur, typically being restricted to fractures within the granite basement. Plate 5 shows the existing Quarry with minor seepage. No dewatering is undertaken for the current operation (or was undertaken for the Herne Hill Quarry).

The GRM (2006) report for the adjacent Red Hill Landfill Site, cited in ATA Environmental (2007), indicates a range of transmissivity (T) values for the aquifer determined from pump tests, recovery tests and slug tests (Transmissivity is the rate at which water is transmitted through a unit width of aquifer under a unit head of hydraulic gradient). Average T values ranged from 0.37m²/day to 0.03m²/day, which are low and would mean that limited flow takes place along these aquifer zones. Average hydraulic gradients were measured to be about 0.1 (Hydraulic gradient is the change in elevation of a water table with respect to a change in distance over a given direction. It is a ratio rather than a measurement and therefore does not have a unit). Using a conservative average kinematic porosity of 0.2, the average groundwater flow rate would be between 0.0185 - 0.0015m/day (Kinematic porosity is the ratio of the volume of spaces through which water can travel in a rock divided by the total volume of the rock. It is a ratio and therefore does not have a unit). This would mean any flows to the pits would be extremely minor.

SECTION 5 - POTENTIAL IMPACTS AND MANAGEMENT GROUNDWATER

5.1 POTENTIAL IMPACTS OF QUARRY OPERATIONS ON LOCAL GROUNDWATER USERS, GROUNDWATER DEPENDANT ECOSYSTEMS AND AQUIFERS OF THE SWAN COASTAL PLAIN

The Department of Water (DOW) provided information on groundwater sites within a 5km radius of the Red Hill Quarry site. Three hundred and eight-nine sites were identified within 5km of the quarry site as illustrated in Figure 5. However, most of these sites are situated to the West of the Darling Fault along the Swan Coastal Plain in the Superficial Aquifers and are not comparable to the Achaean basement hydrogeological setting of the quarry site. The Swan Coastal Plain Aquifers are recharged through rainwater infiltration of the primary aquifers and are not dependant on the minor groundwater flow generated from the adjacent granite/dolerite secondary aquifer.

Twelve groundwater sites are recorded to fall within 5km of the quarry site that are situated in the Achaean Basement (Table 1). Only seven of these sites are bores, the others being soaks. Two of the bores are abandoned. Information on the bores is limited.

- Bore 20039328 is drilled into the weathered kaolinised granite and is recorded as having a seepage water supply.
- Bore 20039331 is recorded as being drilled into the alluvium on the bank of a creek and less than 7m deep.
- Bore 20039949 is recorded as being drilled 3.4m deep and is recorded as having a poor supply in summer.
- Bore 20039954 is drilled 4.2m deep.
- Bore 20039822 is a well.

It appears that the DOW identified groundwater sites are reliant on the shallow perched water table aquifer (assuming the regional groundwater level is 60m below surface) and would have a sporadic yield that relates to rainfall and infiltration during winter months. The perched water tables appear to be relatively isolated and at most have a local influence and therefore would probably not be affected by any quarrying activity. The bores are also situated in catchments up hydraulic gradient to the quarrying activity.

Groundwater dependant ecosystem (GDE's) are unlikely to tap the deeper aquifer system with water levels at 60m depth, so any GDEs that might exist would generally tap the perched aquifers and would be reliant on the ephemeral water supply of the perched aquifers. As discussed these aquifers are isolated, elevated and temporary and are unlikely to be effected by the quarry development and any potential changes to the deeper regional groundwater flow.

The Susannah Brook lies to the North of the proposed quarry area, while Strelley Brook is located to the south west of the quarry operations. Both streams are ephemeral, only running during the winter rainfall period. Both streams are likely to be influent streams due to their elevation above the weathered/fractured rock aquifer. These are losing streams above the water table that discharge into the underlying groundwater system. Therefore on a regional scale the streams are not groundwater dependant.

Table 1
Bore Sites located in Archean Geology

WIN Site Id	AWRC Name	Easting	Northing	Owning Authority / Site Purpose	Comments
20039328	Bore	416190.00	6478955.00	Domestic/household	Quality originally: less than 2000ppm. Bore is in fine silty kaolin pallid rock (i.e. weathered fine grained granite). The fine material seeps through casing slots and gravel pack & periodically fills bore. Bore not sunk to hard rock. Water is corrosive.
20039331	Bore	417232.00	6479066.00		Shallow well is sunk into alluvium on bank of creek. Depth originally: less than 20ft.
20039833	No. 423	409108.00	6480844.00	Andraich	
20039882	Well no. 22	417015.00	6480450.00	Hill	
20039894	Soak 35	417027.00	6478162.00	Power	Sample taken 1971
20039895	Soak 35	417027.00	6478162.00	Power	Sample taken 1970
20039896	Soak 35	417027.00	6478162.00	Power	Sample taken 1970.
20039897	Soak 35	417027.00	6478162.00	Power	Sample taken 1969
20039949	1	417245.00	6476864.00	BARRETT - Livestock	Petrol pump. Not very good supply in summer. High iron content. 3.4m deep
20039954	8	416035.00	6479043.00	FOULGER Domestic Livestock	
20039955	9	415560.00	6480082.00	Midland Brick	Abandoned
20039956	10	415569.00	6480180.00	Midland Brick	Abandoned.

Groundwater receptors including groundwater supplies (bores/wells/stock bores), streams and/or groundwater dependent ecosystems (GDEs) or users should not be vulnerable to any quarry impacts, as they tap the elevated perched aquifers which are isolated from any deeper aquifers the quarry will be mined into.

The deeper hydrogeology of the Red Hill Quarry Site would be similar to the adjacent Red Hill Landfill Site. On average the groundwater levels at the Red Hill Landfill Site are 60m below ground level and tend to follow the surface topography. Figures 3 and 6 show schematic cross sections of the anticipated elevation of the groundwater level relative to the proposed pit. If this is extrapolated to the Red Hill Quarry Site, quarrying at the final phase (32.5mAHD) will be approximately 100m below the regional water table.

If groundwater is encountered it is likely that any inflows will be minor (as has been seen at Herne Hill Quarry and the current Red Hill excavation) due to the typically low yielding (low transmissivity) character of the Achaean basement aquifers in this area; and the inflows may be relatively easily controlled. Thus the risk of minor dewatering causing a detrimental impact on the local hydrogeological regime is considered to be low. Further, there could be compartmentalising of the groundwater which means the effects of any dewatering could be limited by groundwater boundaries created by the network of dolerite dykes in the area.

Potentially contaminating activities, including the use, storage and disposal of potentially hazardous substances (e.g. fuels, lubricants and degreasers), may pose a potential risk to groundwater quality in this area if not correctly controlled. However, it is noted that the unsaturated profile in this area which includes approximately 10m of laterite sediments would provide a means of natural attenuation in the event of a spillage or incident.

5.2 MANAGEMENT AND MONITORING

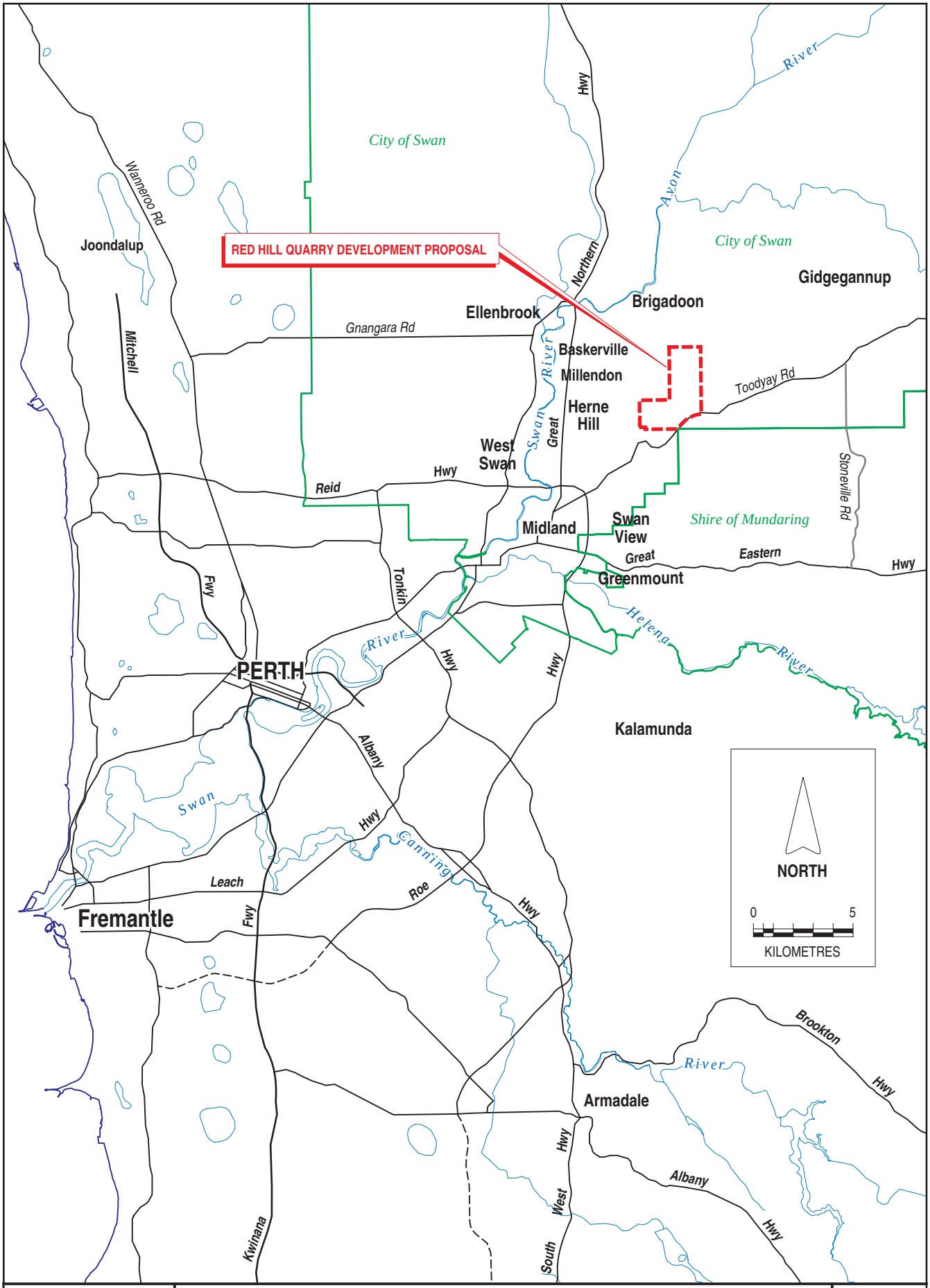
No specific management or monitoring requirements are proposed at this stage, as it appears unlikely that the open quarry will directly impact on the regional groundwater. However, the DOW will be notified if significant groundwater flows are encountered during quarrying, and appropriate groundwater investigations and monitoring will be undertaken in consultation with the DOW.

In addition, best practice measures will be adopted to control the use, storage and disposal of all potentially hazardous or polluting substances.

SECTION 6 - REFERENCES

ATA Environmental, 2007. *Hydrogeology of the Red Hill landfill site, and conceptual model of groundwater flow and contamination by leachate: A review for EMRC*. Version 2. March 2007. Report No. 2007/007.

FIGURES



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Hanson Construction Materials Pty Ltd
RED HILL QUARRY DEVELOPMENT PROPOSAL

REGIONAL LOCATION OF THE RED HILL QUARRY DEVELOPMENT PROPOSAL

Figure 1

Environmental GIS (08) 9486 9222
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412 000mE

413 000mE

414 000mE

6 479 000mN

6 478 000mN

NORTH

0 100 200 300 400 500

METRES

REFERENCE

Red Hill Quarry (Lot 11) site

Approved pit area of existing operation

Area of disturbance of existing operation

Total area of disturbance of existing and proposed operation

Pit area of proposed operation

Susannah Brook

Northern dam

Primary crusher

Conveyor

Red Hill Quarry pit

Secondary and tertiary crushers and screens.
Proposed quaternary crusher.

Weighbridge

Site office / laboratory

Site entrance

ROAD

Herne Hill
Quarry
(former)

Overburden dump

Proposed
stockpile
extension

Stockpile and despatch area

South western dam

Strelley Brook

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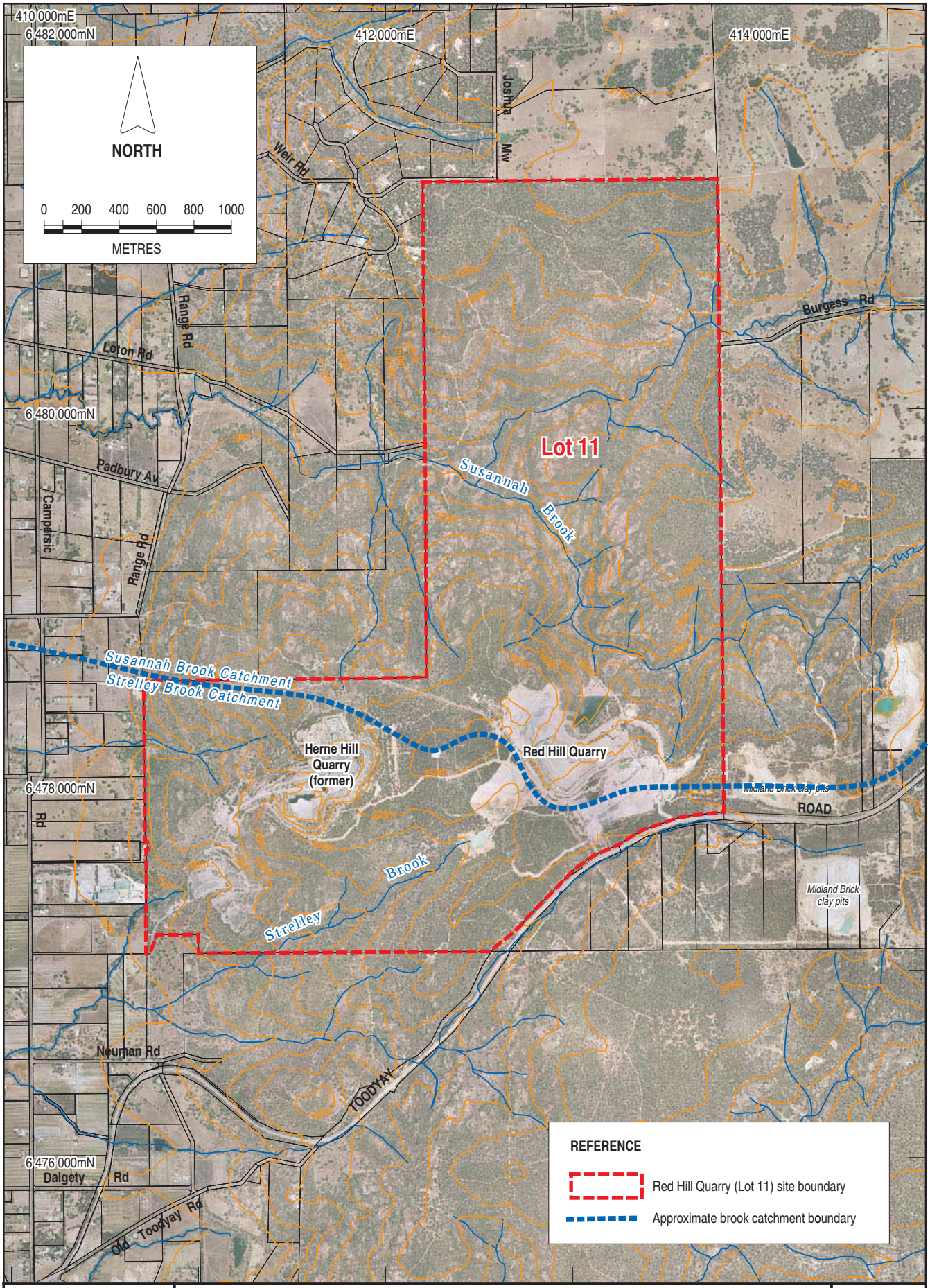
Current & Proposed Site Layout
Figure 2



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Hanson Construction Materials Pty Ltd
RED HILL QUARRY DEVELOPMENT PROPOSAL

TOPOGRAPHY / CROSS SECTION A-B

Figure 3

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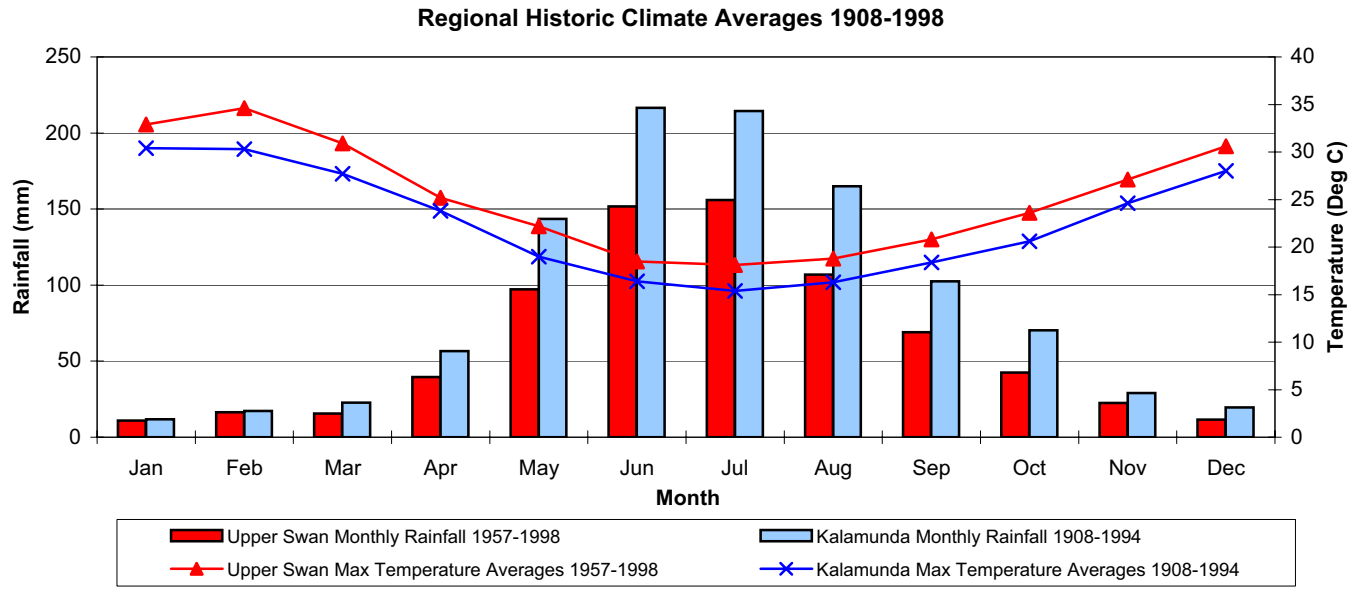

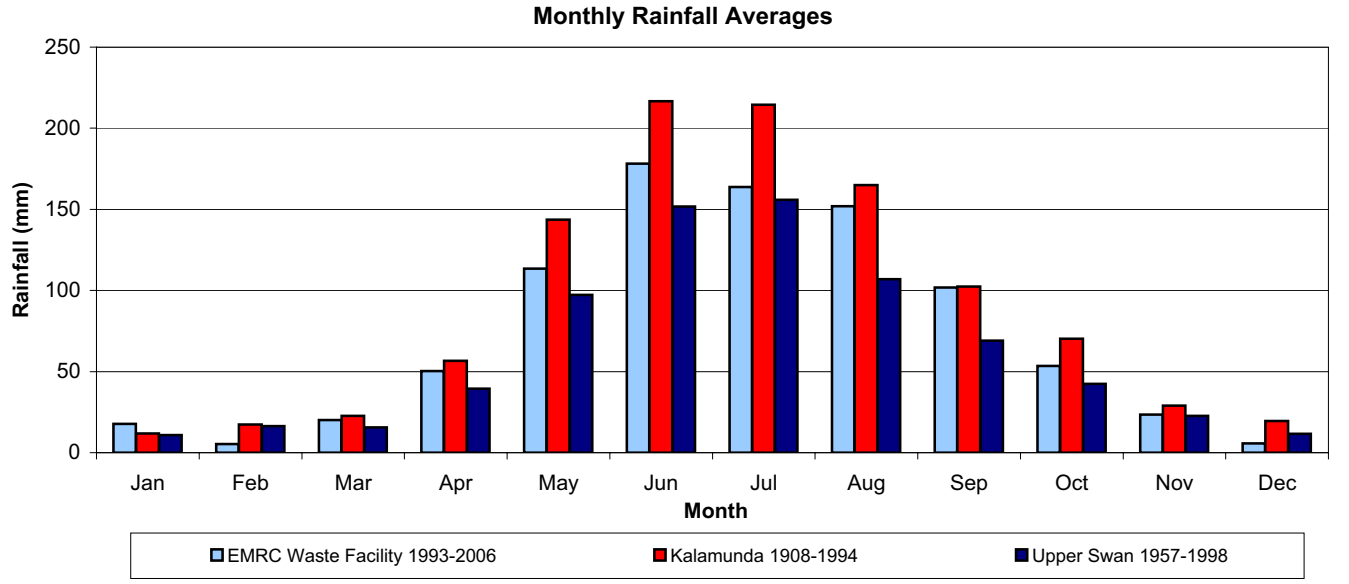

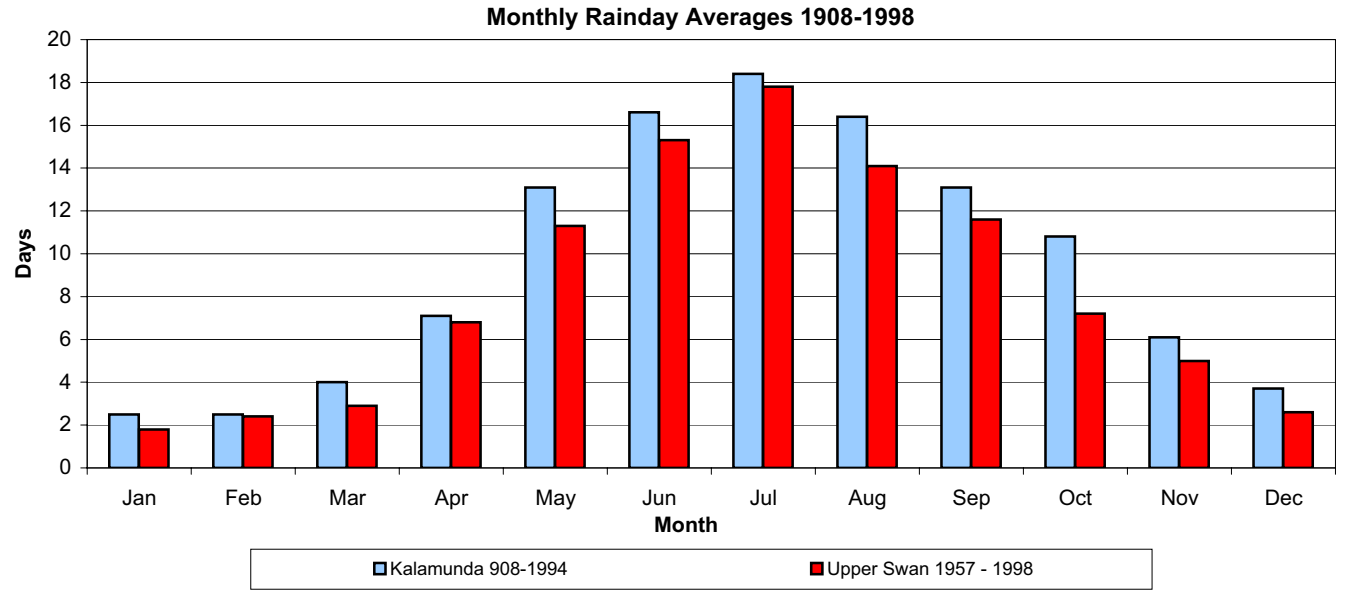

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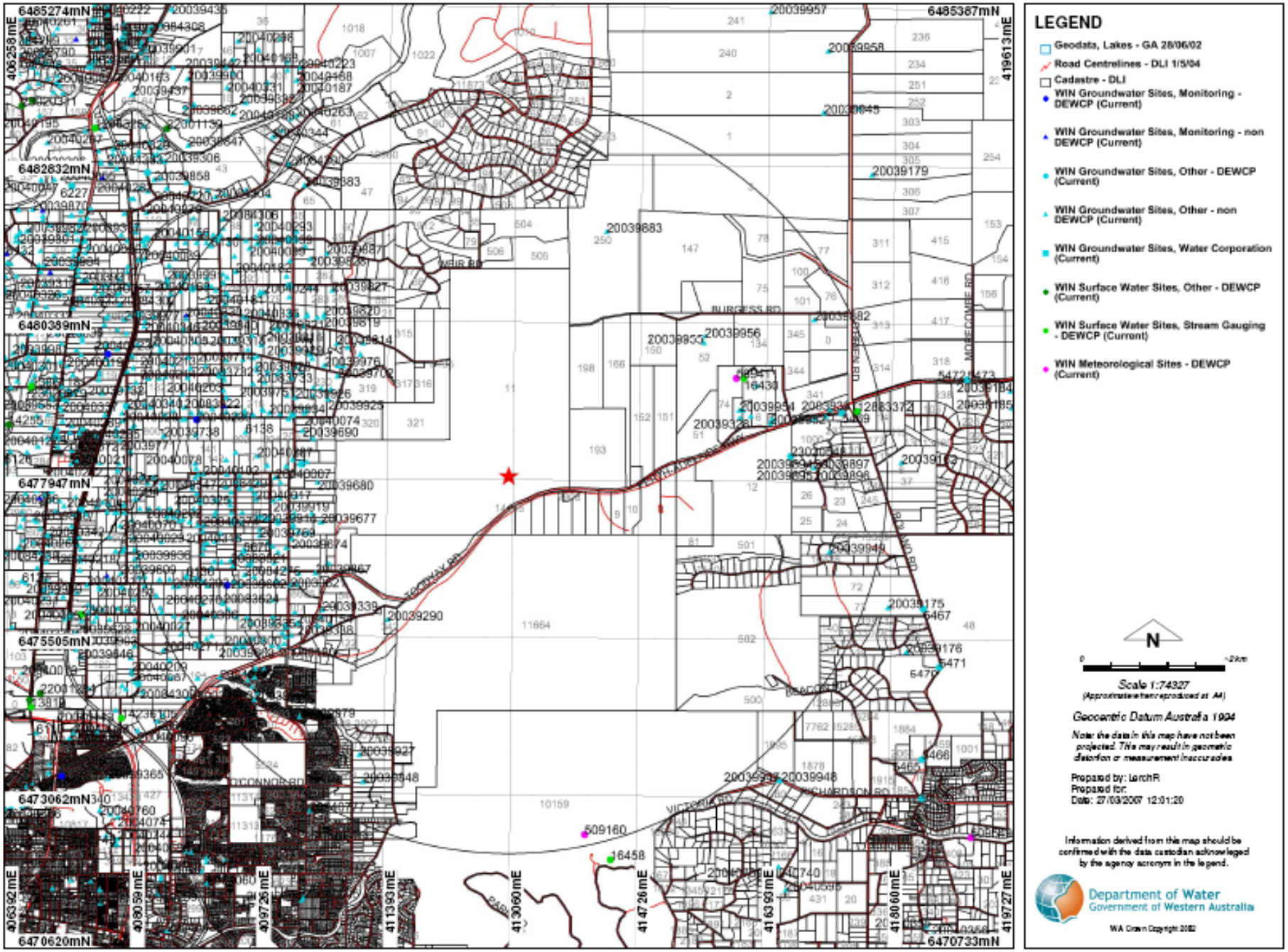
Regional Historic Climate Trends

Figure 4



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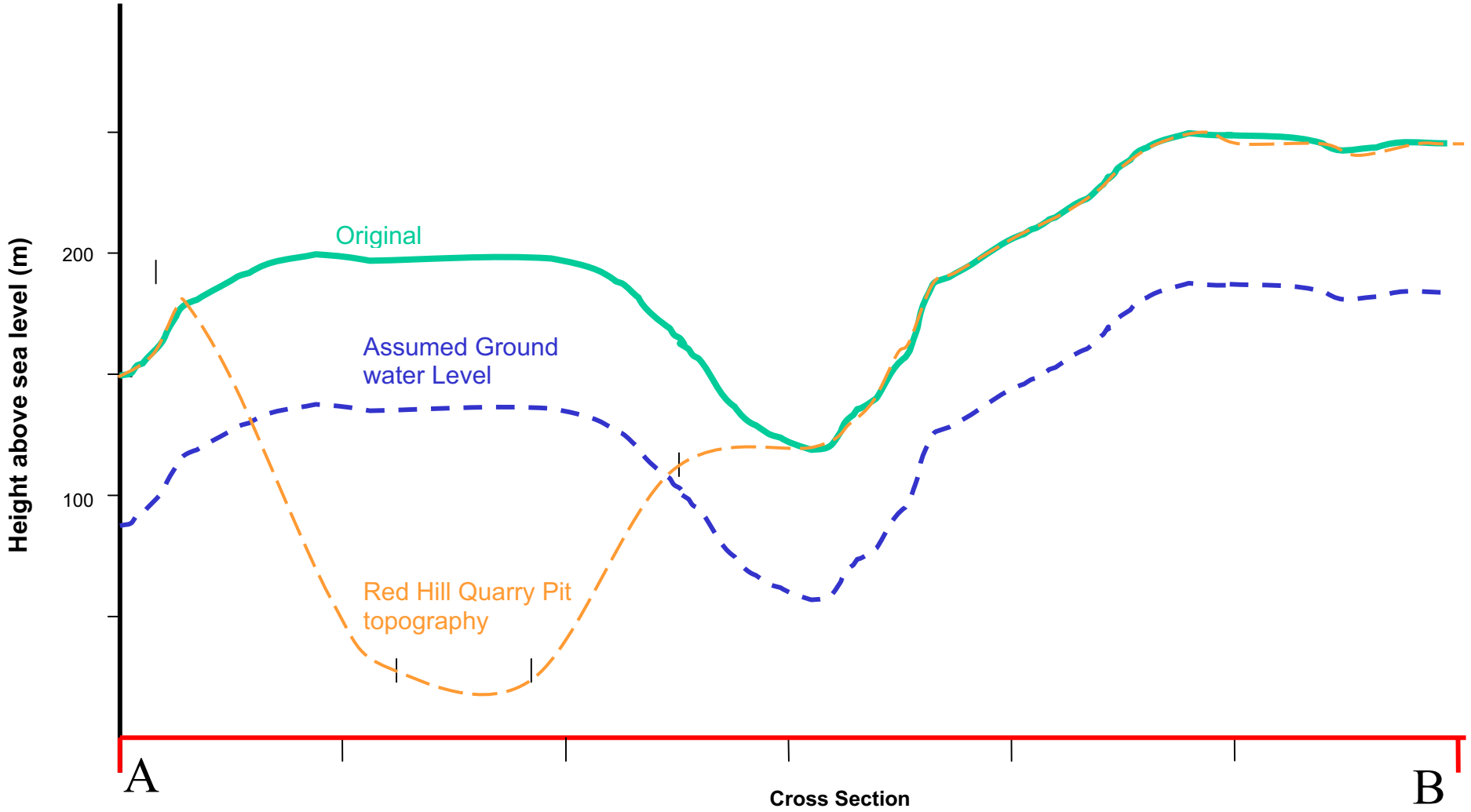
F:\Jobs\782\B1\Figures and Tables\Figure 5

Department of Water bores for Red Hill Quarry 5km surrounding radius
Figure 5



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Proposed Quarry Section and Elevation of Groundwater Relative to Pt
Figure 6

PLATES

Plate 1: Fractures in granites in present quarry.

Plate 2: Diorite dykes intruding the granite.

Plate 3: Herne Hill Quarry South West of present excavation showing two pits with different water levels separated by an impermeable dyke.

Plate 4: Dykes trending North West cutting through Herne Hill Quarry walls.

Plate 5: Present Red Hill Quarry showing workings approximately 100m deep, probably below regional groundwater table.