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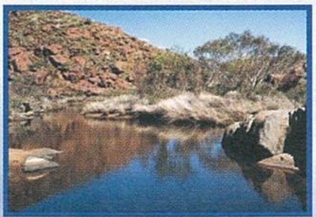
RED HILL HARD ROCK QUARRY
TOODYAY ROAD
SURFACE WATER MANAGEMENT



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RED HILL HARD ROCK QUARRY, TOODYAY ROAD

SURFACE WATER MANAGEMENT

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1.1 GENERAL

Hanson Construction Materials Pty Ltd (Hanson) currently operates the Red Hill hard rock quarry (granite and diorite) and processing facilities located on Lot 11, Toodyay Road (see Figure 1). The area for assessment is identified to be Lot 11, and the surrounding areas, that have the potential to be impacted upon by the proposed operations.

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 enable long-term continuation of quarry operations. Hanson also proposes to extend the area of the existing stockpile and dispatch area (see Figure 2).

The proposed extension of the quarry operations has a footprint of approximately 78ha (about 73ha for the pit, and about 5ha for the stockpile extension) and 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 surface water study to determine if the proposed Red Hill Quarry operation will impact on groundwater and surface water resources in the vicinity of the project, in terms of flow volumes and stream water quality. Aquaterra has been commissioned by Hanson to address the following issues:

- Flow trends for Susannah Brook
- Potential impacts to Susannah Brook
- Potential impacts of the proposed operation on surface water runoff and downstream riparian water users
- Potential impacts of the proposed quarry operation on groundwater and surface water quality
- Surface water quality of Susannah and Strelley Brooks

1.3 SITE DESCRIPTION

The proposed quarry site straddles two catchments feeding the Swan-Avon river system. Most of the existing quarry footprint and the proposed future footprint lie on the southern boundary of the Susannah Brook catchment.

The dominant land use in the local catchments (both Susannah and Strelley Brooks) is agriculture. The upper catchments of Susannah Brook, upstream of Lot 11, have been utilised as pastoral lands. There are several small dams in the upper reaches. The middle catchment, which includes the Red Hill Quarry area, has some tracts of remnant vegetation, State Forest as well as industrial sites.

The lower Susannah Brook, and Strelley Brook, catchments downstream of Lot 11, open onto the Swan Coastal Plain, and support horticulture, namely orchards, vineyards and hobby farms and some suburban developments.

Susannah Brook was also identified in Perth Water Future study as a medium-term water source option (pipe head reservoir).

Over 70% of the native vegetation, within the Susannah Brook catchment, has been cleared with little remnant vegetation on the upper and lower reaches, and remnant vegetation of varying condition present along the middle reaches.

Table 1 identifies the level of degradation present in various sub catchments of the Strelley and Susannah Brook system. Remnant vegetation varies between 15% in the vineyard/orchard growing areas, up to 69% in the vicinity of Bush Creek (middle catchment area).

Table 1
Strelley & Susannah Brook: Summary of Sub Catchment Health (Western, 2000)

Sub Catchment	Area		Composition (%) of Remnant Vegetation				
	(ha)	(km^2)	V.Degraded	Degraded	Good	V.Good	Total
Strelley	2,833	28.33	0.12	2.84		23.59	26.55
Lower Susannah Brook	1,697	16.97	0.43	1.75		15.28	14.76
13 Mile Flat	1,356	13.56		2.33	18.36	2.11	22.79
Upper Susannah Brook	955	9.55		1.06	20.08	14.18	35.32
Burgess Road	1,313	13.13		0.3	26.2	22.45	48.95
Bush Creek	611	6.11		0.55	0.95	67.47	68.97
Susannah Brook Sub-total	5,932	59.32					

2.1 GEOLOGY AND SOILS

2.1.1 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 granite-gneiss rock, with bands of diorite rock, in various stages of erosion on the Scarp face. The reserves of granite and diorite/dolerite are quarried and processed.

Ages of the granites vary from 3.1-2.2 billion years old. The dolerites are considerably younger, between 750 and 450 million years old. The laterites are late Tertiary to Pleistocene.

2.1.2 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. A number of vertical shears intersect across the area. 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 some are older than others.

Dolerite dykes post date these structures and have intruded along the fractured rock zones.

2.1.3 Soils

Soil formation in the project area is influenced by the laterite mantle on ridges and the plateau, and valleys, which show considerable variation, depending 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.

The soils in Swan Coastal Plain are the gravelly and sandy Forrestfield and Guildford soils on the western plains. There is a small area of more fertile alluvial soils close to the Swan River.

2.2 SUSANNAH BROOK SURFACE HYDROLOGY

Susannah Brook is a relatively unregulated ephemeral stream (June to November) that originates at Stoneville and drains the Darling Scarp. It has several small dams in the upper reaches, but is otherwise unmodified. The creek flows east-west across Lot 11, and most of the existing and proposed Red Hill quarry operation lies within the Susannah Brook catchment. The creek flows into the Swan River just west of the Swan Valley Sports Ground in Herne Hill. The decommissioned Herne Hill quarry operation lies on the western side of the ridge and drains to the west.

At the Swan River, Susannah Brook has a catchment area of approximately 59km^2 and a length of about 20km. At the quarry site, the creek has a catchment area of about 28km^2 and a length of about 12.5km.

The creek is fed by smaller ephemeral creeks, and surface flow dominates with groundwater tending to have a relatively minor contribution. The Northern Dam lies at the upper reach of one of these small tributaries. Two additional tributaries will be encroached upon by the proposed development footprint. The remaining footprint, including most of the overburden dump, stockpile and processing areas, lies on the northern perimeter of the Strelley Brook catchment.

The Susannah Brook catchment is considered moderately sloped, with typical topographic slopes of 20-40% in the vicinity of the project area (Figure 9). The quarry site lies on a natural crest, elevated some 115-120 m above the creek bed, which runs east-west between Herne Hill and the Midland Brick Clay pits.

Sub-catchment areas downstream of the project area are outlined in Figure 4.

2.3 STRELLEY BROOK SURFACE HYDROLOGY

A small portion of the existing Red Hill quarry operation is within the catchment of Strelley Brook. Strelley Brook flows from its origin on Lot 11, in a south westerly direction, to its confluence with Jane Brook near Great Northern Highway. Its catchment area is approximately 28km². The creek is flanked mainly by horticulture, hobby farms and some suburban development.

3.1 CLIMATE

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 5).

3.2 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 5). 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 and is likely to be the hardest and earliest hit part of the Australian mainland in terms of reduced rainfall.

3.3 FLOOD ESTIMATION

The “Australian Rainfall and Runoff” (ARR) document (1987 and revised 1998) is produced by the National Committee on Hydrology and Water Resources, to provide the best available information on design flood estimation. ARR recommends the use of the Rational Method and Index Flood Method, as most appropriate for the Perth area. The Rational Method calculates the 10 year Average Recurrent Interval (ARI) flood which can then be factored for larger or smaller floods by “frequency factors”. The Index Flood Method calculates the 5 year ARI flood which can then similarly be factored. The accuracy of any flood estimate is low, and the SEE (standard estimate of error) for the methods generally lie in the 70-150% of the actual calculated estimate.

The calculated 100 year ARI flood flow for Susannah Brook at the quarry is 500m^3/s for the Rational Method and 200m3/s for the Index Flood Method. Based on previous experience, the lower estimate of 200m^3/s (between 150m^3/s and 300m^3/s) is adopted.

3.4 WATER BALANCE

The requirements for water use for the proposed operations are anticipated to be similar to those for the existing operations i.e. approximately 380kL/d (kilolitres/day, KL/d) in summer and 80kL/d in winter, or in the order of 100,000kL per annum. Water is used for dust suppression on stockpiles and roads via trucks and tower sprays, truck wash down, and aggregate washing in the screening plant.

The current quarry operation has a footprint of approximately 81ha (20% pit and 80% other operational areas). Assuming an annual rainfall of approximately 760mm per annum, the volume of runoff into the pit and dams is expected to be approximately 90,000 -125,000m³ (based on a volumetric coefficient of runoff of 15%-20%. Water that collects in the pit is stored as required during the winter in the bottom of the pit, and pumped to the Northern Dam, ready for reuse in the summer. It is understood that there is a reasonable water balance on site at present and the site is generally self-sufficient in water. There is no public water supply (Water Corporation) to site (potable water is bottled). It is understood that the Northern Dam has overflowed before, but this is not common.

The proposed development of the quarry operations (including the existing footprint) has an overall footprint of approximately 160ha (63% pit and 37% other operational areas). The volume of runoff into the pit and dams is then expected to be approximately 190,000 -250,000m³.

Assuming that the operational use for captured water remains similar to that at present, it is anticipated that the need to release excess water from the quarry operations into Susannah and Strelley Brooks, after sediment management measures have been in enacted, will increase over time.

3.5 LICENCE TO DISCHARGE WATER

Certain industries with a significant potential to pollute the environment must hold a Works Approval (for construction) and a Licence or Registration (for operation) under the Environmental Protection Act 1986. Licences and Works Approvals are issued with legally binding conditions that apply to specific premises, and are intended to prevent or minimise this potential for pollution. Registrations are issued to premises that are managed through industry-generic Regulations and Codes of Practice.

The existing Red Hill Quarry 1991 approvals and current operating license, contains conditions relating to stormwater management, vehicle washdown areas, water quality monitoring and reporting. For water discharge purposes, under 2004 Department of Environment and Conservation (DEC) guidelines, the quarry operation is classed as a “Category 12 premise”, which is a premise on which material extracted from the ground is screened, washed, crushed, ground, milled, sized or separated (provided it produces more than 50,000 tonnes of product per annum). The current licence may continue to be renewed as required by DEC, or a new licence issued to encompass the proposed operations. Licensing requirements will be determined in consultation with the DEC.

4.1 MONITORING SITES

Two gauging stations, operated by Department of Water (DoW), in the Susannah Brook catchment are relevant to the project area; Gilmours Farm (1981-2000) and River Road (1997- present).

Gilmours Farm (catchment area 23km²) is located 3.4 km to the north east of the project area (Figure 3). Surrounding land is predominantly cleared for pasture, except directly to the west, where a small section of woodland (~0.85 km²) runs east-west toward the Midland Brick Clay Pits. The site provides a long term description of general upstream water conditions.

River Road (catchment area 55km²) is located 6km west / northwest of the project area, on a downstream reach of Susannah Brook (Figure 3). Surrounding land use is predominantly orchard/viticulture. The site is about 750m from the junction of Susannah Brook and the Swan River. It can therefore be taken to represent the entire Susannah Brook Catchment.

No flow volumes were available for Strelley Brook.

4.2 SUSANNAH BROOK

Summary statistics from the DoW gauging stations are given in Table 2 and flow rates are compared with local rainfall in Figure 6.

Table 2
Upstream & Downstream Flow Statistics

Monitoring Period	Gilmours Farm		River Road	
	Mean Flow (m^3/s)	Standard Deviation	Mean Flow (m^3/s)	Standard Deviation
1981-2000	0.306	0.738		
1997-2000	0.191	0.249	0.436	0.445
1997 - 2006			0.422	0.524

There is a strong correlation between stream flow and rainfall, with flow peaking during periods of heavy rainfall (winter) and dropping to zero during summer months. This seasonal trend is consistent over the entire monitoring period, though the fluctuation in flow across seasons has decreased since 1991.

This seasonal fluctuation in flow, is supported by the water level time-series plot for Gilmours Farm (Figure 7). At this station the water level at the brook has an historical range of 1.4 m, with a peak level of 217.57m (AHD) reached on 28/01/1990.

The period 1997-2000 was monitored at both the upstream and downstream gauging stations. Comparison of the mean flow rates indicates that flows downstream are approximately 30% greater than the upstream flows, indicating that run-off which enters the brook in the reaches between the stations (which includes the project area) is a significant contribution to flow in the Susannah Brook system.

Based on rainfall and runoff comparisons (1997-2006) in Susannah Brook, the average runoff coefficient for the catchment was calculated as C= 0.27 (i.e. approximately 27% of the rain that fell on the catchment, was measured as runoff at the gauging station).

Rating curves were generated for both gauging stations, graphically presenting the functional relationship between stream discharge and stage (Figure 8). The ratings curves show some consistency in their shape between the two sites, with a stronger correlation between stage and discharge observed at Gilmours Farm. The break point in a rating curve is taken as the stage at which the river or stream spreads out over its banks changing the cross-sectional profile of the flow. Graphically, this corresponds to a significant decrease in the slope of the rating curve. The break points for Gilmours Farm and River Road respectively are 10.4-10.5 m (0.4-0.5m above stream bed) and 10.5m-10.7m (1.1-1.3m above stream bed). The upstream break point is typically exceeded every winter since 1981, except in 1995 and 1997. Changes to the pattern of break point exceedances can alter the composition of the riparian zone.

4.3 REDUCTION IN FLOWS

The footprint of the quarry operations will progressively increase over the life of the proposed development (i.e. 100 years); to approximately double what it is now (i.e. 160ha versus 81ha). This is an increase of 78ha. About 2/3 of this area (52ha) falls within the Susannah Brook catchment, and the remaining 1/3 (26ha) falls within other catchments on the west side of the development (Herne Hill Quarry), south (Strelley Brook) and north (tributary to Susannah Brook).

If all water falling on the increased quarry operational areas is captured and used within quarry operations, then the effective subcatchment of Susannah Brook in the vicinity of the quarry would be reduced from about 28km² to 27.4km² (2% reduction). The effective catchment at the junction of Susannah Brook and the Swan River would be reduced by about 1%.

The Strelley Brook catchment (at Jane Brook) would be reduced by about 10ha (0.4% reduction).

The rating curve suggests that this reduction in flow is expected to correlate to a drop in the order of 10-20mm of the Susannah Brook stream stage. Such a drop will not have a significant effect on typical stages down stream. There is no information on the rating curve for Strelley Brook, which is considerably smaller than the Susannah Brook system, but is also far less impacted by the proposed quarry development.

However, any reduction in run-off would be mitigated by the fact that excessive water captured by the proposed development may be released back into the creeks from the two dams, after sedimentation management measures have been enacted.

Therefore, for both catchments, downstream flow signatures are not expected to be significantly altered by the loss of catchment area to the proposed quarry extensions.

SECTION 5 - FLOODING IN SUSANNAH BROOK

5.1 POTENTIAL IMPACT OF FLOODING ON THE QUARRY

No physical interference with Susannah Brook will be permitted at any stage during development or operation of the quarry, and a minimum 50m (mostly 100m) vegetated buffer zone will be maintained each side between the Brook and any quarrying activity.

The bed of Susannah Brook adjacent to the quarry is at RL125-RL90m. The proposed quarry floor will ultimately reach RL32.5m, so the creek bed will lie 60m-90m above the proposed quarry floor. For comparison purposes, the top surface water level in the Northern Dam is approximately 60m above the creek bed, while the toe of the dam structure is 30m above Susannah Brook.

Based on the estimated 100 year ARI flood flow of 200m^3/s, it is estimated that the flood depth in Susannah Brook would reach a maximum of about 5m depth. The slope of the ridge down from the proposed quarry is in the order of 1:2.5 to 1:3 (Figure 9). For a minimum 50m buffer zone, the top of the quarry at any point will therefore remain at least 15m above the creek bed, and 10m above any flood levels in the creek.

It is therefore concluded that the quarry will always retain a large margin of safety from flooding in Susannah Brook.

5.2 POTENTIAL IMPACT OF THE QUARRY ON SUSANNAH BROOK

The regional groundwater level is in the order of 60m below the surface (as is the case in the adjacent Red Hill Waste Site, Aquaterra Report 004b, 2007). 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. It is noted that average Transmissivity values at the site are low, and the infiltration rate is expected to be low (Transmissivity is the rate at which water is transmitted through a unit width of aquifer under a unit head of hydraulic gradient). Some seepage does occur, typically being restricted to fractures within the granite basement.

Susannah Brook is ephemeral, only running during the winter rainfall period. The stream system is dominated by surface water run-off influences, rather than groundwater interaction, which is supported by the elevation above the weathered/fractured rock aquifer, and the receptivity of water quality to variations in rainfall. Therefore on a regional scale, the stream is not groundwater dependant.

The stream is therefore a losing stream, above the water table, that discharges into the underlying groundwater system (a losing stream is a stream or river that loses water as it flows downstream).

It may therefore be concluded that a portion of the creek flows already infiltrates into the ground, down towards the regional groundwater level below; and that the proposed quarry floor (ultimately 60m-90m below the creek bed) would have no further impact on the creek flows lost to the ground.

6.1 MONITORING

There are three monitoring sites (W1-3) on Susannah Brook maintained on-site by Hanson since 2002 (Figure 3). They periodically record; pH (a measure of the acidity or alkalinity of the water), Total Dissolved Solids (TDS, a measure of the water salinity), Total Suspended Solids (TSS, a measure of sediments and other particles in the water), Chlorides (Cl), and oil/grease levels. W1 is located 400m down hill from the product stockpile area. W2 is located at the spillway of the Northern Dam, while W3 lies downstream of the project area's hydrological influence.

An upstream monitoring station, managed by Department of Water (DoW) is located at Gilmours Farm, approximately 2.5km to the north east of W1 (Figure 3). At Gilmours Farm, there is data between 1981-2001, for various water quality parameters, including pH (1981-2001); TDS (1981-1992), and Chloride (1981-2000), although recording was not always consistent across the entire life of the station,

Monitoring data at Strelley Brook has been provided by Hanson (W5, W6) and by the Eastern Metropolitan Region Council (EMRC) from their Red Hill Waste Management Facility upstream of Red Hill Quarry area (Figure 3).

W5 and W6 are located 1-2km to the south west of the quarry on separate reaches of Strelley Brook (Figure 3). Data is available from 2002 – 2006. The EMRC monitoring site has data from 1995-2006 collected at one sampling location upstream from the quarry site.

6.2 WATER QUALITY PARAMETERS

Water quality data downstream of the quarry is available from 2002 onwards in both Susannah Brook and Strelley Brook. Quarry operations began in the 1960s well before water quality monitoring, consequently, collected data is used to assess whether current and proposed quarry operations are likely to exceed set desired levels.

The long term water quality data collected upstream at Gilmours Farm has been used to characterise the water upstream from the Quarry site in Susannah Brook and the ERMC Red Hill Waste Facility monitoring site has been used for Strelley Brook.

The *ANZECC Guidelines for Recreational Water Quality and Aesthetics* have been used as the bench mark for all parameters listed in Table 3, except for Total Suspended Solids (TSS) which is taken from the *ANZECC Livestock Guidelines*.

Table 3
ANZECC Guidelines for Recreational Water Quality & Aesthetics (ANZECC, 2000)

Parameter	Guideline Value
pH	6.5-8.5
TDS	1000 mg/L
Cl	400 mg/L
Hardness	500 mg/L
TSS	80 mg/L

Most of the available data set spans a short period of time (5 years). Fluctuations in water quality may be expected to occur between years, depending on whether it is a wet or dry year. Long-term monitoring is required to identify typical ranges. Continued monitoring will bolster the data set, and provide for better understanding of water quality dynamics.

Also, surface water flows vary greatly in ephemeral streams, and therefore the time between the last rainfall event and the time of monitoring can influence recorded values within a particular day. This is particularly important for parameters which are dependent on run-off volumes, such as TDS, TSS, pH, and chlorides. Furthermore disturbance events, such as road works or land clearing can induce short term changes to run-off quality.

The data may be measured using statistical methods. Regression analysis sets a linear relationship to the data set, giving some indication of the trends present over time. The correlation coefficient indicates the strength and direction of a linear relationship between two random variables, in this case time versus the water quality parameters under consideration. Values range between -1 and 1. A value closer to +/- 1 indicates a strong relationship between the two variables. A correlation greater than 0.8 or less than -0.8 is generally described as strong, whereas a correlation less between -0.5 and 0.5 is generally described as weak.

In addition, the data may trend upwards or downwards over time. The negative/positive sign in the correlation coefficient indicates whether the dependent variable decreases/increases over time. A high correlation coefficient tends to confirm the trend. Additionally, the range in monitored values can be used to verify whether a trend in the data is present. If the parameter achieves similar maxima and minima over the years, then annual fluctuations remain within the same general range and there is no increasing or decreasing trend in the data. If the annual maxima and minima both increase over the years, then this is further confirmation of an upward trend. If the annual maxima and minima both decrease over the years, then this is further confirmation of a downward trend.

6.3 UPSTREAM WATER QUALITY SUSANNAH BROOK

The long term water quality data (20 years) collected at Gilmours Farm has been used to characterise the water upstream from the quarry site. Piper and Durov diagrams (Figures 10, 11) plotting concentrations of TDS, EC, pH, Cl, SO_4, HCO_3, CO_3, Fe, Mn, Ca, K, and Na determined that the water is Na^+ /Cl^- dominant. In this type of water, alkali metals exceed alkaline earths, and strong acidic anions exceed weak acidic anions, and typically this composition is indicative of water with the potential for salinity problems. The results of the hydrochemical analysis are consistent with the land use history of the region, which shows an increase in salt loading into the creek since the inception of European settlement and agriculture. However, over a more recent time frame, salinity levels at Gilmours Farm have remained statistically stable between 1981 and 2001 (Figure 15).

The hardness of the water based on the $CaCO_3$ concentration is, on average, classified as Very Soft (<50 mg/L), though it has peaked at more than 300mg/L (Very Hard).

Summary statistics for salinity (EC, TDS), alkalinity (pH) and hardness are given in Table 4 and Figure 15.

Table 4
Upstream Water Quality Long-Term Summary Statistics

	pH	EC (micro S/cm)	TDS (mg/L)	Hardness
No. of Samples	65	63	63	63
Mean	7.0	123,993	634	42
Minimum	6.1	32,600	186	0.0
Maximum	8.3	328,000	1514	320
Median	6.9	89,250	448	0.0
Std Deviation	0.5	77,308	415	79
5% Percentile	6.3	45,465	234	0.0
95% Percentile	7.8	289,000	1,414	244

These values are taken as characteristic of the stream flow upstream of the quarry site. The large variation in TDS and hardness is a function of the flow characteristics of Susannah Brook. Since stream flow is ephemeral, water quality is influenced by the nutrients and analytes flushed downgradient by run-off and surface flows. During low and no flow periods, the concentrations of dissolved solids tend toward maximum values, while during periods of rainfall, levels of TDS and hardness are achieved which can be 1-2 orders of magnitude less than the low flow scenario. Measurement of a first flush (first rains) may also produce higher values.

The Piper and Durov analysis suggests that it is soluble contaminants (salts, nitrogen and phosphorous compounds) that are most readily flushed in the first surface water flows of the season and contribute to the high readings. Then, as the winter rainfall continues, water quality improves as dilution effects temper analyte concentrations. The large variation also suggests that Susannah Brook is well flushed, and high TDS/Hardness events are quickly washed downstream into confluence with larger water bodies.

The pH levels at Gilmours Farm consistently fell below the lower pH limit (6.5), as stipulated in the ANZECC guidelines. pH levels below 6.5 were observed every year in the monitoring period (1981-2001), except in 2001 when only one pH reading was recorded. There is a slight decreasing trend in pH, with a weak correlation coefficient (0.32). The maximum observed pH levels appear to drop over the monitoring period (Figure 15).

Salinity data at Gilmours Farm is more limited, but there is no increasing or decreasing trend over the monitoring period. TDS levels have remained inside the guideline limits, while Chloride concentrations have exceeded the guideline levels in 1981, 1982, 1988, 1991 and 1995.

The receptivity of water quality to variations in rainfall support the assumption that the stream system is dominated by surface water run-off influences rather than groundwater interaction.

6.4 UPSTREAM WATER QUALITY STRELLEY BROOK

The EMRC Red Hill Waste Facility monitoring site provides upstream trends for; salinity (TDS), heavy metal concentrations and nitrogen compounds (Figure 12). The EMRC monitoring site lies approximately 400m from the commencement of Strelley Brook - the upstream users are limited to the Midland Brick pits and the EMRC Waste Facility.

Average annual TDS for 1997-2006 is 258mg/L, an order of magnitude below the ANZECC guideline. There is no statistical evidence in the data demonstrating any increasing trend. TDS levels were highest in 2003, which was a significantly below average rainfall year.

There is an observable increase in nitrogen compounds over time, in particular nitrate. Regression analysis shows a linear increase in Total Nitrogen (TN) since 1997 (correlation coefficient 0.69). Metal concentrations remained constant between 1997 and 2002, after which time they dropped. The reduction in concentration, which occurred in 2003, is dramatic and is likely to be the result of a change in upstream management.

Nitrates and nitrites remained below the ANZECC guidelines, while ammonia exceeded the guidelines on several occasions between 2003-2005.

6.5 DOWNSTREAM WATER QUALITY: SUSANNAH BROOK

6.5.1 pH Trends (Acidity and Alkalinity)

The pH level of surface water depends on a number of factors (underlying geology, organic loading, and catchment land use). The potential impacts of elevated pH levels include an increase in the river's buffering capacity, but also a greater risk of eutrophication.

At all Hanson monitoring sites, the pH was within the range of 6.0-8.0 (Figure 13). This range is comparable to the range observed at the upstream monitoring location (pH 5.8-8.3). Fluctuations in pH were driven by seasonal climate variations, with drier summer conditions tending towards acidic conditions.

The Susannah Brook sites, W1, W2 and W3 displayed an average pH of 6.9, 6.8 and 7.0 respectively. There is little variation in both the range and averages of all three sites in the Susannah Brook catchment. Acidity dropped below the ANZECC guidelines in the early monitoring years, with levels dropping to 6.0 in 2003. Across the monitoring period, there is a weak linear trend of increasing pH at all monitoring stations (W1-W6) including in Susannah Brook (W1, W2 and W3) with low correlation coefficients. The effect of this weak trend is to centre pH levels toward the guideline mean of 7.5, which has remained within guidelines since 2004. It is unclear what may have caused the lower pH previously, and what is causing the pH to increase. Continued monitoring will allow the validity of this trend to be explored with greater accuracy.

The Strelley Brook sites, W5 and W6, displayed comparable trends to Susannah Brook, with an average pH of 6.8 and 7.0 respectively. The pH also ranged between 6.1 – 7.8, with all minima recorded pre-2005. The pH has remained within ANZECC guidelines since 2004.

6.5.2 Salinity Trends

The range and average values for all six sites are presented in Table 5 and Figures 13 and 14. All downstream sites (W1-W6) displayed TDS levels below the ANZECC guidelines. Variations in salinity levels followed rainfall patterns, reaching maximum concentrations in the drier months.

Regression analysis determined only weak trends for TDS values at W1 and W3, suggesting that there is no evidence of an increase or decrease in average TDS values since 2002, in the Susannah Brook systems.

In the Strelley Brook catchment, regression analysis revealed no trend for TDS values at W5, but an increasing trend was observed at W6 (over a very short period of time, but correlation coefficient = 0.88).

Based on the current data there is no statistical evidence to suggest that TDS levels will approach or exceed guideline levels except at W6.

Table 5
Downstream TDS Statistics

Monitoring Site	Average (mg/L)	Minimum (mg/L)	Maximum (mg/L)
W1	355	180	700
W2	297	160	460
W3	369	160	670
W4	429	190	840
W5	349	130	570
W6	272	110	460

Chloride levels remained below the ANZECC guideline level for all sites since 2002, with site averages ranging between 140mg/L (W2) and 199mg/L (W3). Only W6 shows a weak linear increasing trend with a correlation coefficient of 0.77. Given the high correlation coefficient, this confirms the TDS trend at W6. At W6, the salinity readings in 2006, remain well below the ANZECC guidelines, but show an increasing trend over the short length of monitoring record monitored. The W6 monitoring station is located on the Swan Coastal Plain, where it is more likely that there is interaction between ground and surface water, noting that the salinity of the groundwater lies in the range of 1500-3000mg/L for this area. Continued monitoring will allow the validity of this trend to be explored with greater accuracy.

The other sites do not show any historic trend for chloride levels to increase or decrease. The range and average values for all six sites are presented in Table 6 and Figures 13 and 14.

There is also little variation between chloride levels in each downstream sub-catchment.

Table 6
Downstream Chloride Statistics

Monitoring Site	Average (mg/L)	Minimum (mg/L)	Maximum (mg/L)
W1	191	130	360
W2	140	110	180
W3	199	120	350
W4	160	54	250
W5	175	87	270
W6	163	98	260

6.5.3 Suspended Solids Trends (sediment load)

Levels of suspended solids (TSS) are low at the Susannah Brook monitoring sites with all three stations averaging less than 5.4 mg/L. The Strelley Brook sites display greater variation, with averages at W5 and W6 of 98mg/L and 109mg/L respectively. This is due to two high readings observed during the winter months of 2006, when TSS levels reached 250mg/L (W5) and 290mg/L (W6). It is assumed that they both reflect the same event, and noting W5 reflects a reach of Strelley Brook which is not directly downstream of the quarry site (Figure 3). As such it would appear that the elevated sediment on one occasion was generated in a catchment not under the clemency of the quarry site.

Table 7
Downstream TSS Statistics

Monitoring Site	Average (mg/L)	Minimum (mg/L)	Maximum (mg/L)
W1	< 5	< 5	5
W2	< 5	< 5	5
W3	5.4	<5	6
W4	44.67	<5	120
W5	98.14	<5	290
W6	109.4	<5	260

These two events on Strelley Brook are the only instances in which the ANZECC guidelines were exceeded. There is no statistical evidence of any increasing or decreasing TSS trends in either of the reaches downstream from the project area.

6.5.4 Oil & Grease Trends

Concentrations of oil and grease remained below 5mg/L at all sites between 2002-2006, except at the seven events listed in Table 8. Furthermore, there is no evidence of any trends in oil/grease concentrations.

Interrogation of the records for the laboratory sampling regime, revealed that in 2004 plastic bottles were used to hold water samples, rather than the standard glass bottles. Plastic bottles contain traces of hydrocarbons left over from the manufacturing process, which can compromise oil/grease readings obtained from these samples. It is therefore assumed, that the spikes in oil/grease concentration are not the result of ongoing contamination issues; rather they are likely to be the result of one-off anomalies in the laboratory analysis methodology. When the correct sample bottles were used, the samples collected returned to levels below the detectable limits, as shown in October and November 2004. A note regarding this was made in the Hanson's *Environmental Summary Report* (2004), together with supporting evidence from the laboratory.

Apart from the sampling errors referred to above, all samples were below detectable limits of 5mg/L for oil and grease.

Table 8
Oil/Grease Concentrations Maxima

Monitoring Site	Date	Oil/Grease Concentration (mg/L)
W1	2004	10
W2	2004	10
W3	2004	10
W3	2004	10
W4	2003	11
W4	2004	10
W6	2004	10

6.5.5 Water Quality Summary

Comparison of the upstream and downstream water quality data can be summarised as follows:

- There was little variation in pH levels, with an average historic pH of 7.0 (upstream) and 6.8-7.0 (downstream). Furthermore, there is a weak increasing trend in downstream pH, which has so far served to improve the water quality in relation to the ANZECC guidelines.
- There is a marked decrease in salinity levels between the upstream (average TDS 634mg/L) and downstream (average TDS 340mg/L) Susannah Brook monitoring sites. This suggests that rainfall run from the non-agricultural middle section of the Susannah Brook catchment plays an important role in improving the water quality of the entire creek system. Land use changes to this middle section (remnant vegetation) could carry upstream salinity issues further downstream, if the beneficial freshwater flushing effect of this middle catchment is impacted.
- ANZECC guidelines are not expected to be exceeded.
- There is no significant difference between the upstream and downstream salinity levels on Strelley Brook (average TDS 258mg/L and 310mg/L respectively). Both remain well below the ANZECC guidelines.
- In general, TSS and oil/grease monitoring confirm that on-site water management, which collects and stores runoff generated on site, has been successful in isolating site water from the surrounding catchment hydrological process.

SECTION 7 - POTENTIAL IMPACTS OF OPERATION ON SURFACE WATER QUALITY

7.1 GENERAL SURFACE WATER MANAGEMENT OBJECTIVES

General surface water management objectives for the Red Hill quarry operation include:

- Maintain the integrity, functions and environmental values of the downstream watercourses; to prevent or minimise impacts on the quality of surface water resulting from quarry operations and contain any contaminated water on site.
- Maintain or improve the quality of surface water returned to local and regional surface water resources to ensure that existing and potential uses, including ecosystem maintenance are protected

7.2 POTENTIAL IMPACTS FROM QUARRY ACTIVITIES

Potential surface water impacts in the zone of influence downstream from the quarry and its operational activities include:

- Interruption to existing surface water flow patterns.
- Erosion and sedimentation risk, particularly on disturbed or degraded lands. There is potential for the water quality of water courses downstream of the proposed infrastructure to deteriorate if safeguard measures are not put in place. These sediments can reduce capacity of water courses and impact water course ecology.
- Reduction of surface water runoff volume and quality in the downstream environment.
- Impact on downstream vegetation communities that may be dependent on this drainage.
- Discharge of various chemicals, including hydrocarbons from workshops, stockpiles, etc.
- Haul roads and other infrastructure which, because of their comparatively high run-off coefficients, have the potential to accelerate the transport of sediments and contaminants into creek systems, if management is inadequate.

7.3 SITE CONTROLS

Drainage associated with the proposed development will be managed consistent with existing drainage management measures. A drainage management program for the proposed quarry operations will be provided prior to the commencement of work on-site to ensure no unacceptable detrimental effects from drainage of the quarry site on the water quality of Susannah Brook and other surrounding creeks.

The quarry activities will potentially mobilise additional sediments to the natural drainage systems with the main potential sediment sources being the waste dumps, stockpiles and plant area. The most effective method of sediment management is to control sediment at their sources.

All onsite rainfall runoff from the disturbed areas will be prevented from leaving site, and directed via diversion drains to onsite sumps that will temporarily store the water before use in dust suppression or processing. No untreated runoff from disturbed areas of the quarry area will be permitted to enter any water course. It is important therefore to segregate flows that originate from disturbed areas, from flows that originate from undisturbed areas (e.g. vegetated areas), which would typically have lower sediment levels.

Diversion drains and onsite channels will be constructed to ensure that they are stable and do not themselves cause downstream erosion, and onsite pollution control practices will ensure that spills of pollutants will not be transported to clean runoff water storage areas.

All such runoff will first be treated by means of sedimentation basins or silt traps, to remove excess suspended sediments. Sediment basins are a means to control surface water erosion and sediment, constructed downslope of all stockpiles and pits (as appropriate) and should be used in conjunction with erosion minimisation strategies, such as rehabilitation and vegetating batters, and constructing internally draining dishes in stockpiles.

Any runoff likely to contain oil contamination will be treated to remove such contaminants. The quality of water leaving the project area would continue to be monitored by regular sampling.

The disruption to natural drainage patterns will be minimised, outside those directly affected by quarrying activities. No physical interference with Susannah Brook will be permitted at any stage during development or operation of the quarry. To this end, a minimum of 50 m buffer zone will be maintained each side between the Brook and any quarrying activity. In most instances, this buffer will be around 100 m

The project will incorporate site-specific surface water controls during and after construction activities including clearing; drainage works; removal and storage of topsoil and earthworks. Ground disturbance will be kept to the minimum and areas of major erosion hazard will be identified and avoided where practicable, or specific management measures implemented to reduce the erosion risk. Mitigation strategies should be capable of accommodating at least the design rainfall event, selected according to risk, but a minimum of the 10 year ARI flood event.

Closure objectives for surface water management strategies aim to maintain baseline surface water quality and flow regimes in a post-quarry environment.

7.4 SEDIMENT BASINS

Bunds and drainage diversion works constructed around the perimeter of infrastructure areas separate natural runoff from potentially sediment contaminated internal site runoff, and direct it through sedimentation basins. Sediment basins collect this runoff and treat it to remove sediments to acceptable levels prior to use in quarry operations or, in the case of large rainfall events, release to the surrounding catchment.

Sediment basins are located at a low point and constructed by forming earth bunds. Storage volume consists of the permanent pool settling zone and sediment storage zone. The trap size is calculated to match the settling velocity of the target sediment size with the design flow. For design of the sediment traps, a target of medium sized silt particles > 0.02mm (20µm) is common, using a 10 year ARI 6hr design rainfall event. The sediment trap is then expected to be effective in removing sand and medium to coarse silt. The removal of fine silt and clay is generally not as effective. The two existing dams on site act as sedimentation traps.

The outlet structure in each consists of a spillway only (no ‘control’ outlet such as an overflow pit/pipe system is generally provided). Thus smaller flow events are fully contained (and no sediment released downstream).

Larger events are still treated within the dams, prior to discharging downstream over the spillway. The larger volume of water, however, partially offsets this lowered efficiency. Water in the dams slowly infiltrates, and evaporates, and is used for on-site processing and dust suppression.

7.5 DISCHARGE FROM SITE

There will be no uncontrolled discharge of untreated water from disturbed areas of the site, and discharges from site will only occur when excess stormwater flows into the existing dams. At these times, flow volumes in Susannah Brook will be high, and any water released will be small in the context of existing flows.

Any discharge of water from the quarry will result in a reduction of salinity of the stream flow. Monitoring of the proposed site, the current quarrying operations and their surrounds also suggest that any issues of surface salinity in the vicinity of the existing operations are likely to be the result of previous upstream agricultural clearing, as opposed to current quarry activities.

SECTION 8 - SUMMARY

Hanson Construction Materials Pty Ltd (Hanson) currently operates the Red Hill hard rock quarry and processing facilities at Lot 11, Toodyay Road. Hanson is proposing to continue to develop the quarry pit, and stockpile and dispatch area to enable long-term continuation of quarry operations. The proposed extension of the quarry operations will progressively increase over the life of the proposed development to approximately double what it is now (i.e. 164ha versus 81ha), and will allow quarrying to continue for around 100 years.

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 that passes the quarry site to the Swan River. Strelley Brook is located to the south west of the quarry operations. The dominant land use in the local catchments is agriculture, with some tracts of remnant vegetation, State Forest as well as industrial sites.

The requirements for water use for the proposed operations are anticipated to be similar to those for the existing operations i.e. approximately 100,000kL per annum. It is anticipated that the need to release excess water from the quarry operations into Susannah and Strelley Brooks will increase over time.

Downstream flow signatures are not expected to be significantly altered by the loss of catchment area to the proposed quarry extensions

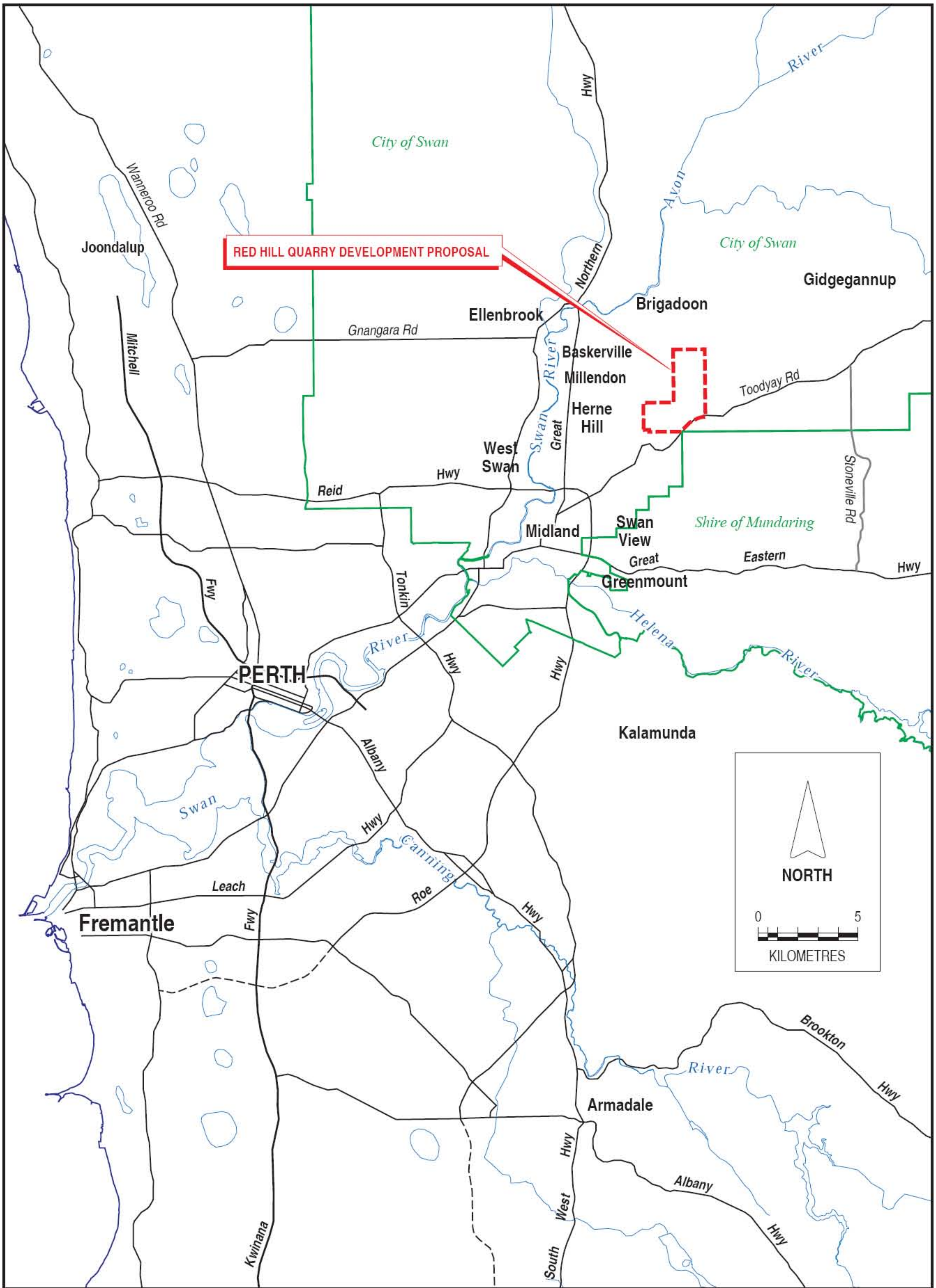
The bed of Susannah Brook adjacent to the quarry is at RL125-RL90m, while the proposed quarry floor will ultimately reach RL32.5m. Buffer zones between the quarry and the creek will ensure that any point on the quarry will always retain a large margin of safety from flooding in Susannah Brook.

Water quality data downstream of the quarry is available from 2002 onwards in Susannah Brook, and 1996 onwards for Strelley Brook. The ANZECC *Guidelines for Recreational Water Quality and Aesthetics* have been used as the bench marks. Comparison of the upstream and downstream water quality data shows there has been little variation in pH levels, which remain within ANZECC guidelines. There is a marked decrease in salinity levels between the upstream and downstream Susannah Brook monitoring sites, which suggests that rainfall runoff from the non-agricultural middle section of the Susannah Brook catchment plays an important role in improving the water quality of the entire creek system. There is no significant difference between the upstream and downstream salinity levels on Strelley Brook, which remain well below the ANZECC guidelines.

TSS and oil/grease levels remain within ANZECC guidelines.

The general objectives with regards to surface water, erosion and runoff include the maintenance of environmental values of watercourses and sheet flow, and the quality of surface water to ensure that existing and potential uses including ecosystem maintenance are protected. In general, water quality monitoring confirms that on-site water management, which collects and stores runoff generated on site, has been successful in isolating site water from the surrounding catchment hydrological process.

FIGURES



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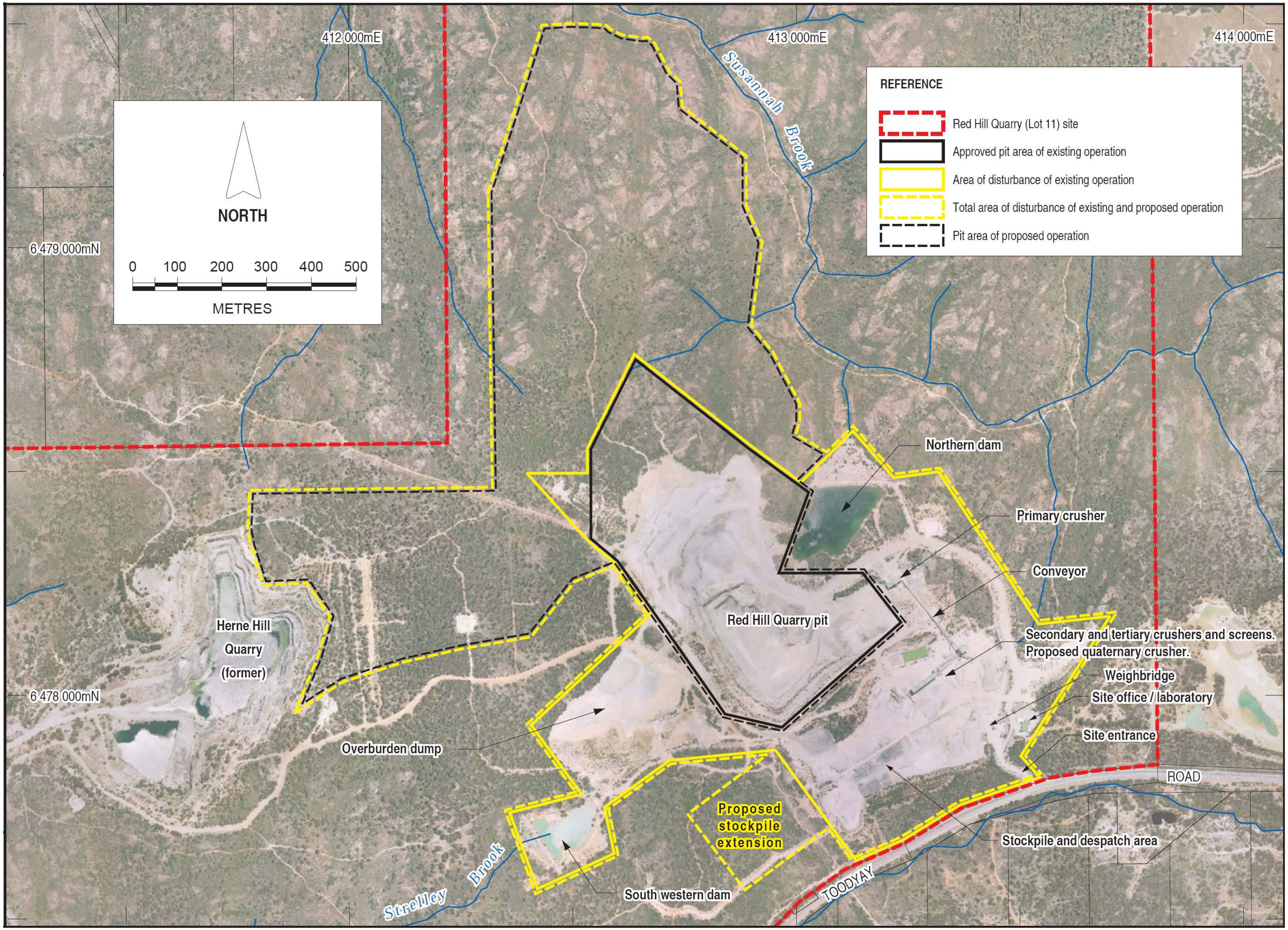
Hanson Construction Materials Pty Ltd
RED HILL QUARRY DEVELOPMENT PROPOSAL

REGIONAL LOCATION OF THE
RED HILL QUARRY DEVELOPMENT PROPOSAL

Figure
1



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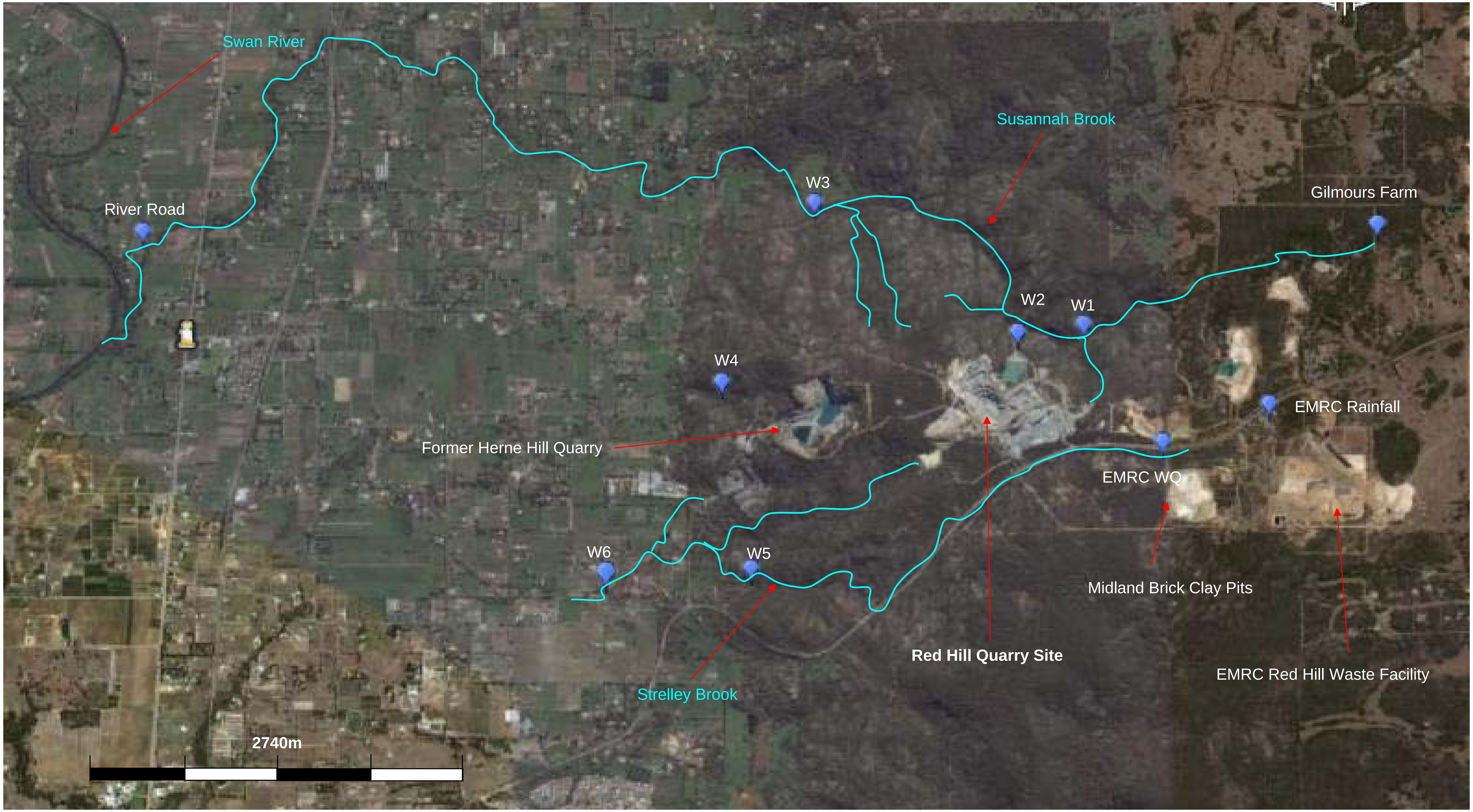
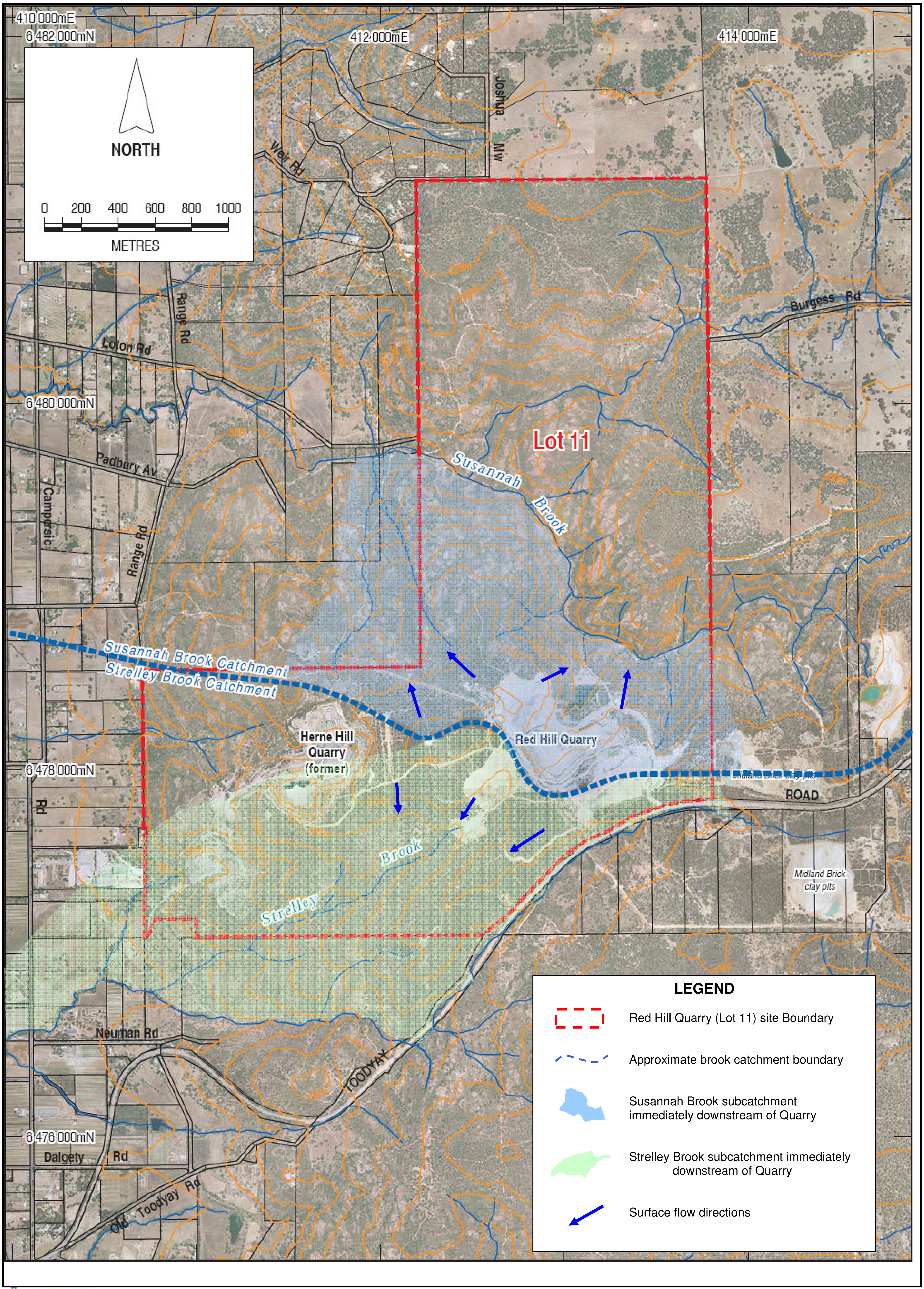
Current & Proposed Site Layout

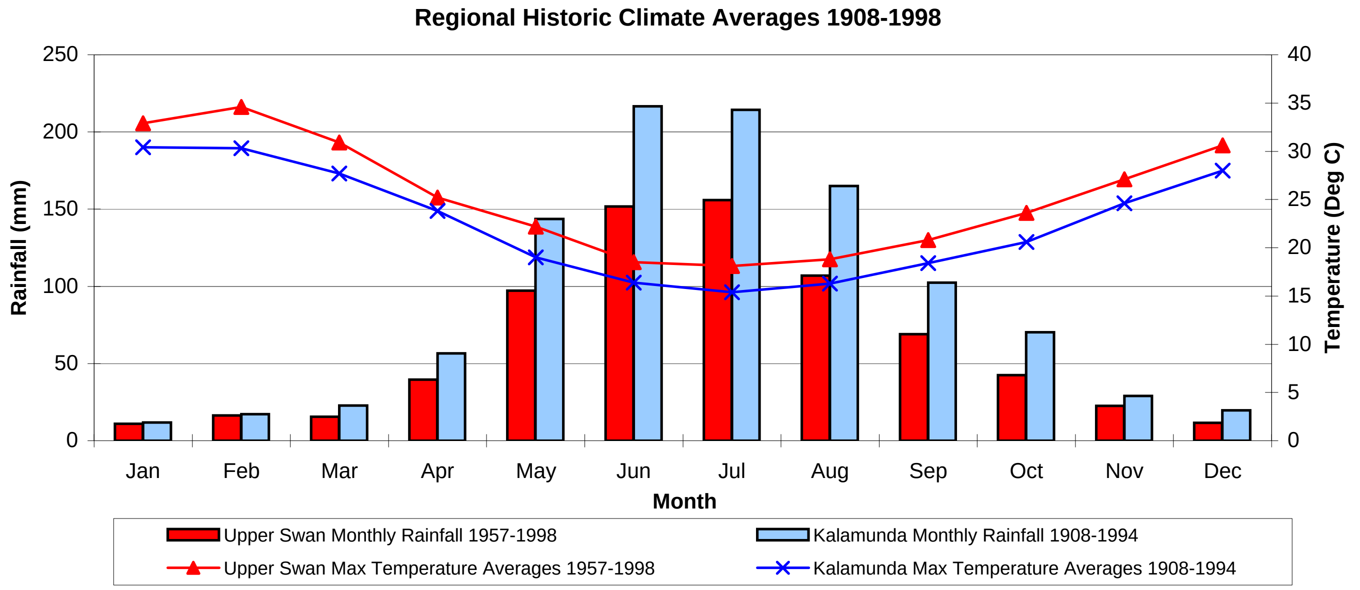
Figure 2

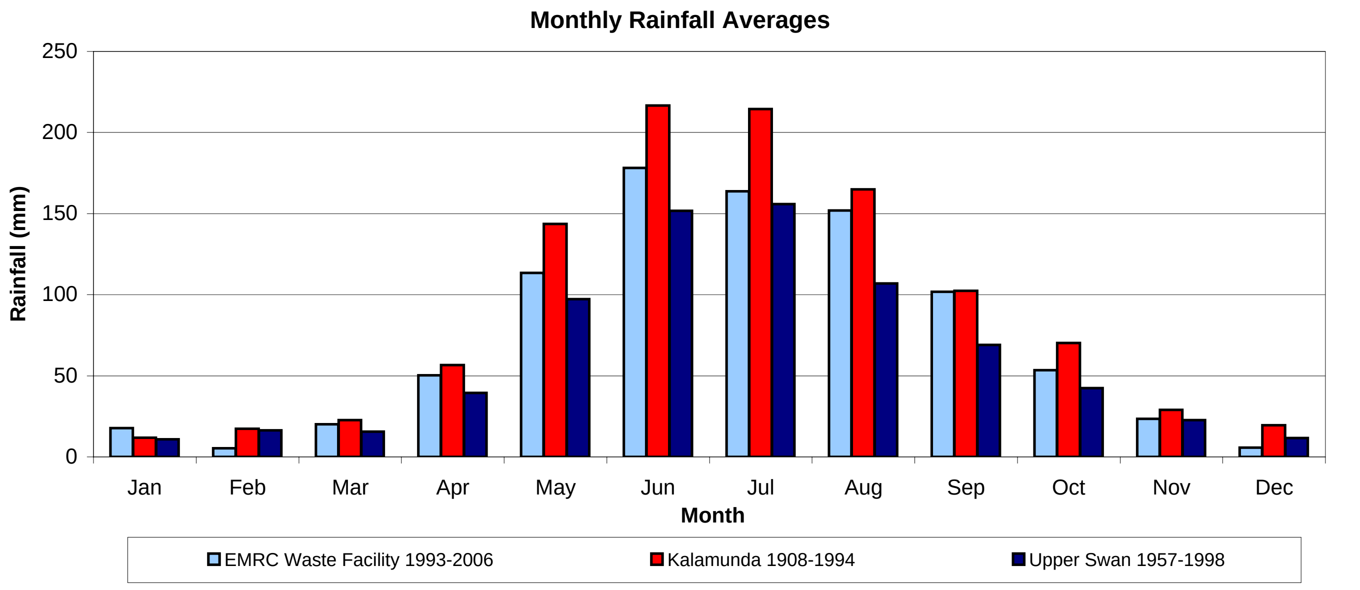


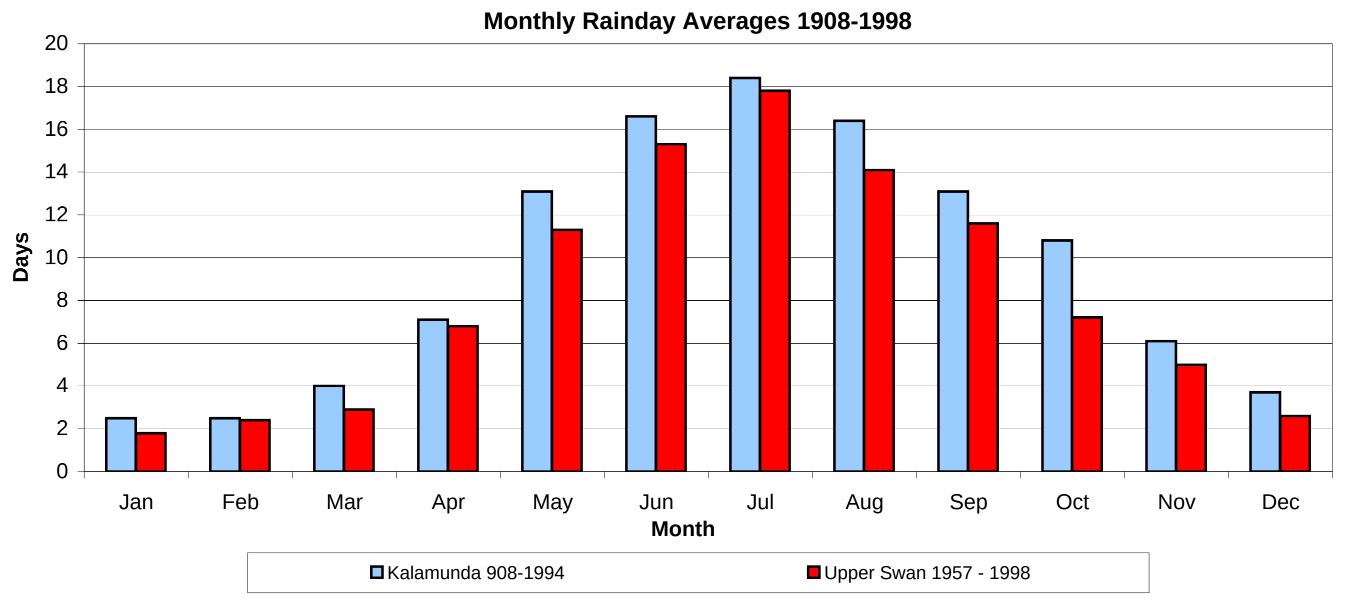
Locations of Monitoring Sites
Figure 3



Susannah & Strelley Brook: Subcatchments & Drainage
Figure 4







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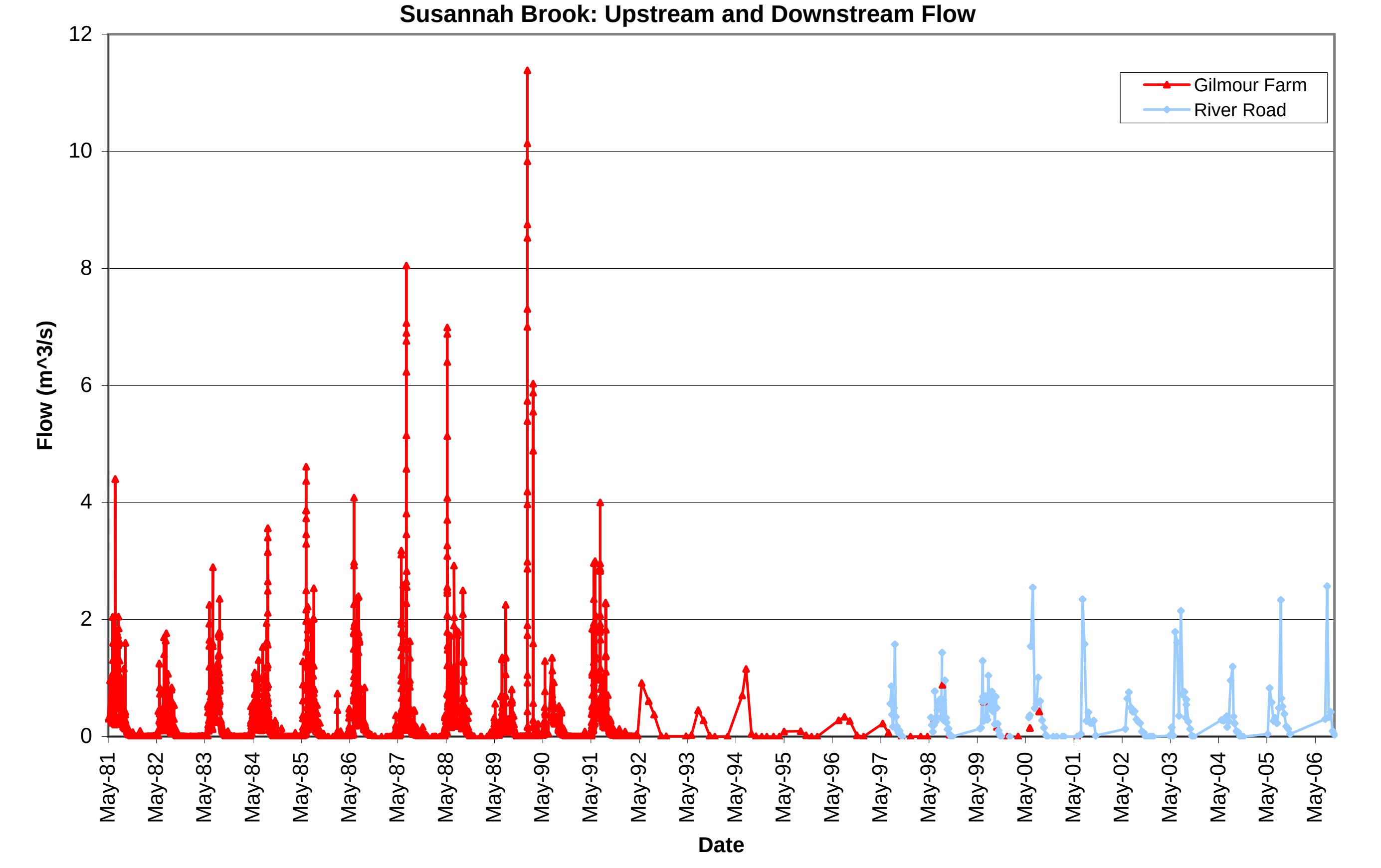
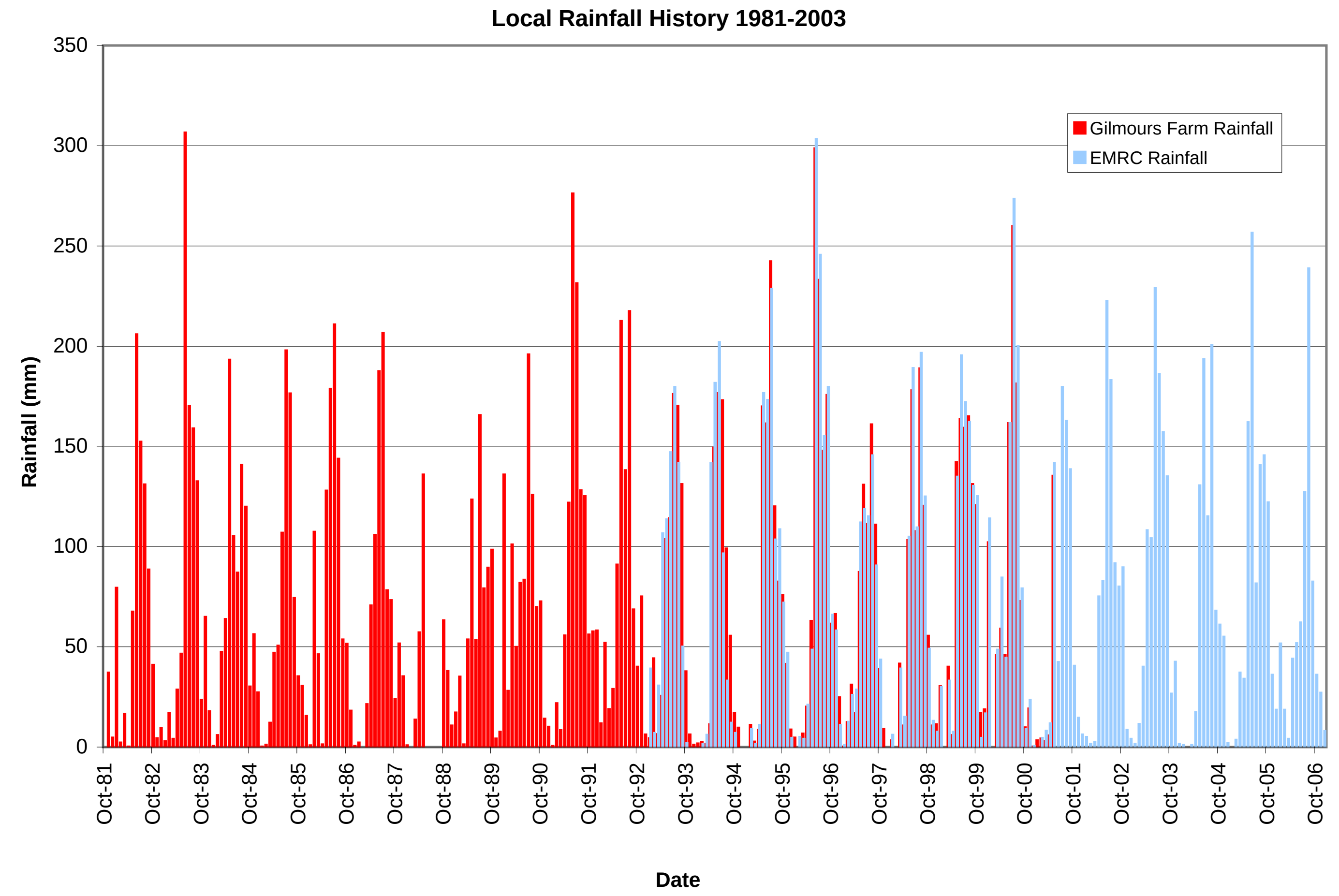
Regional Historic Climate Trends
Figure 5





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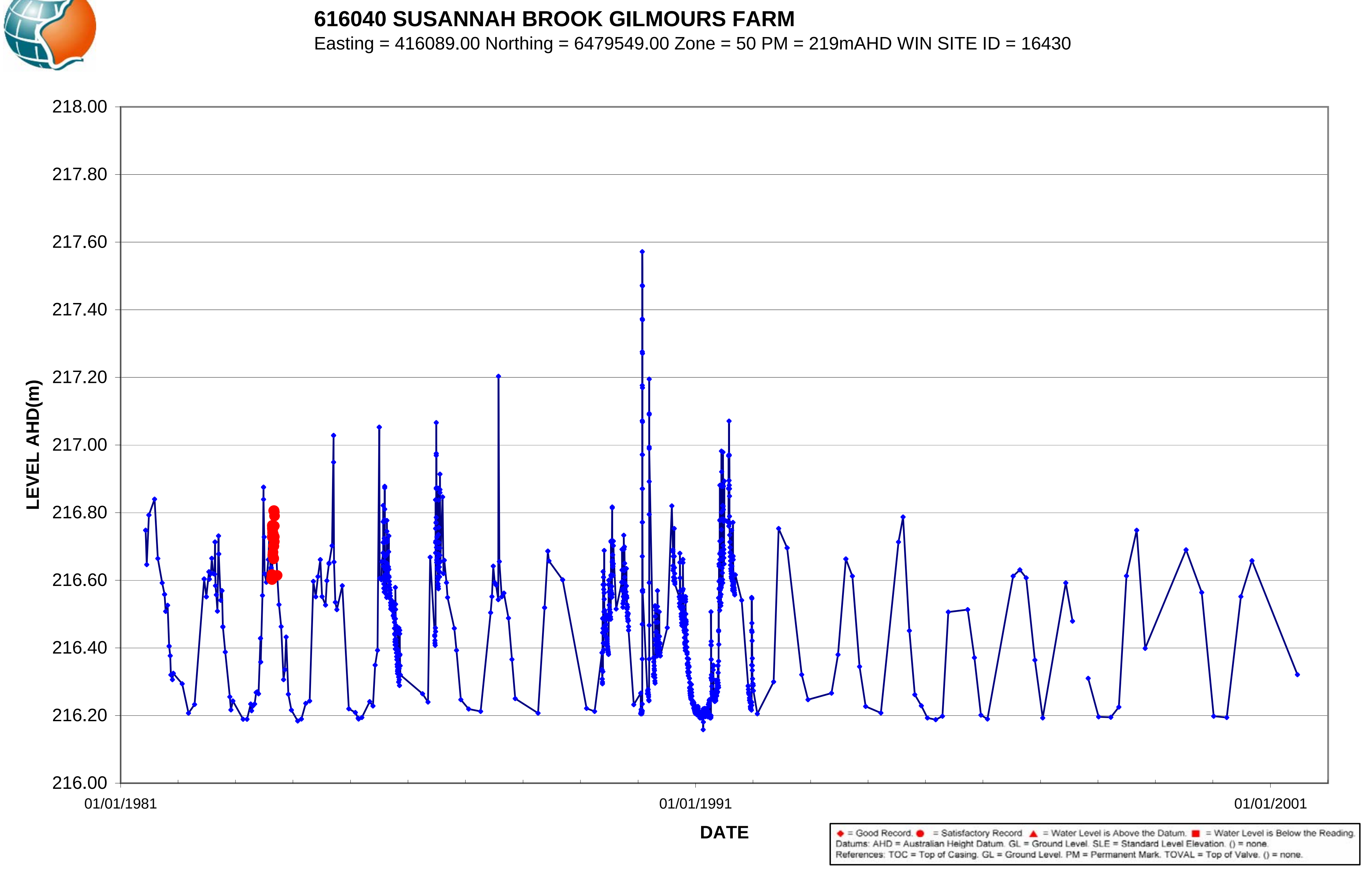
Susannah Brook Historic Flow Data

Figure 6



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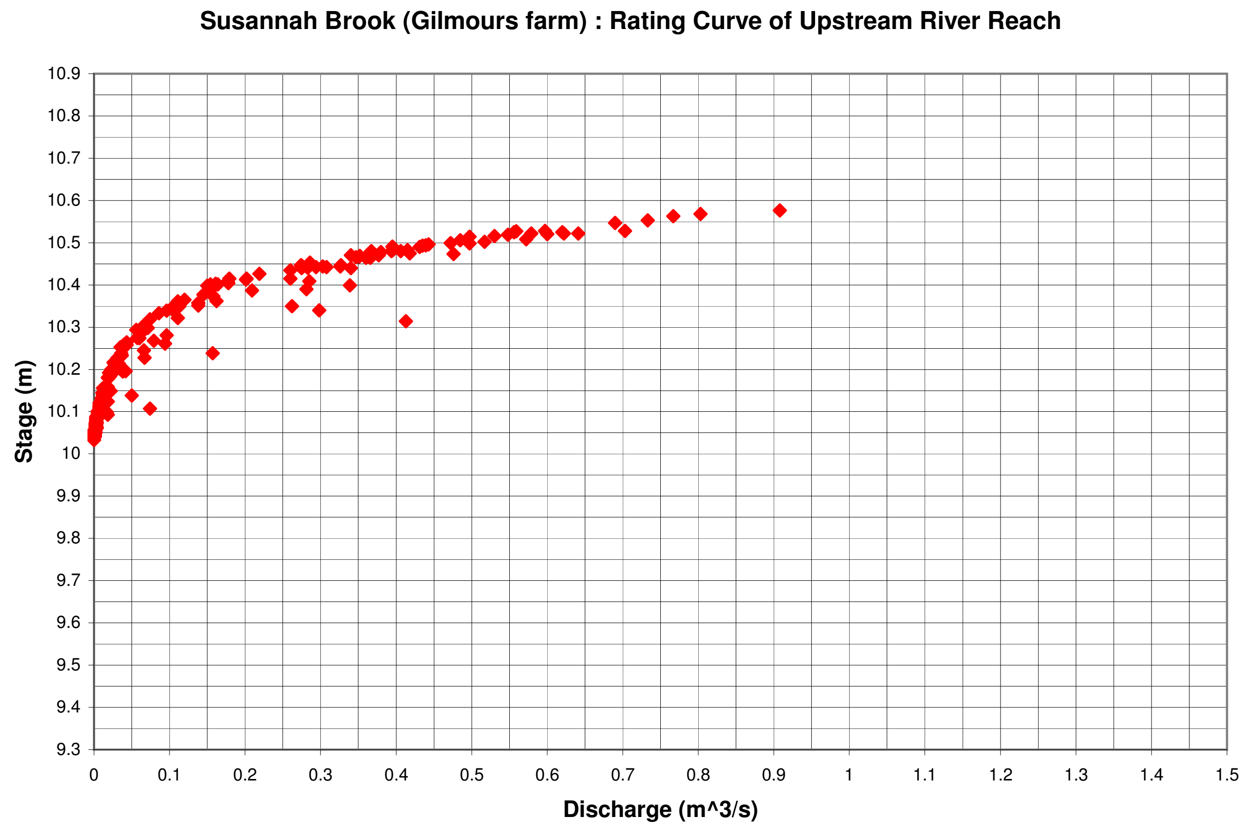
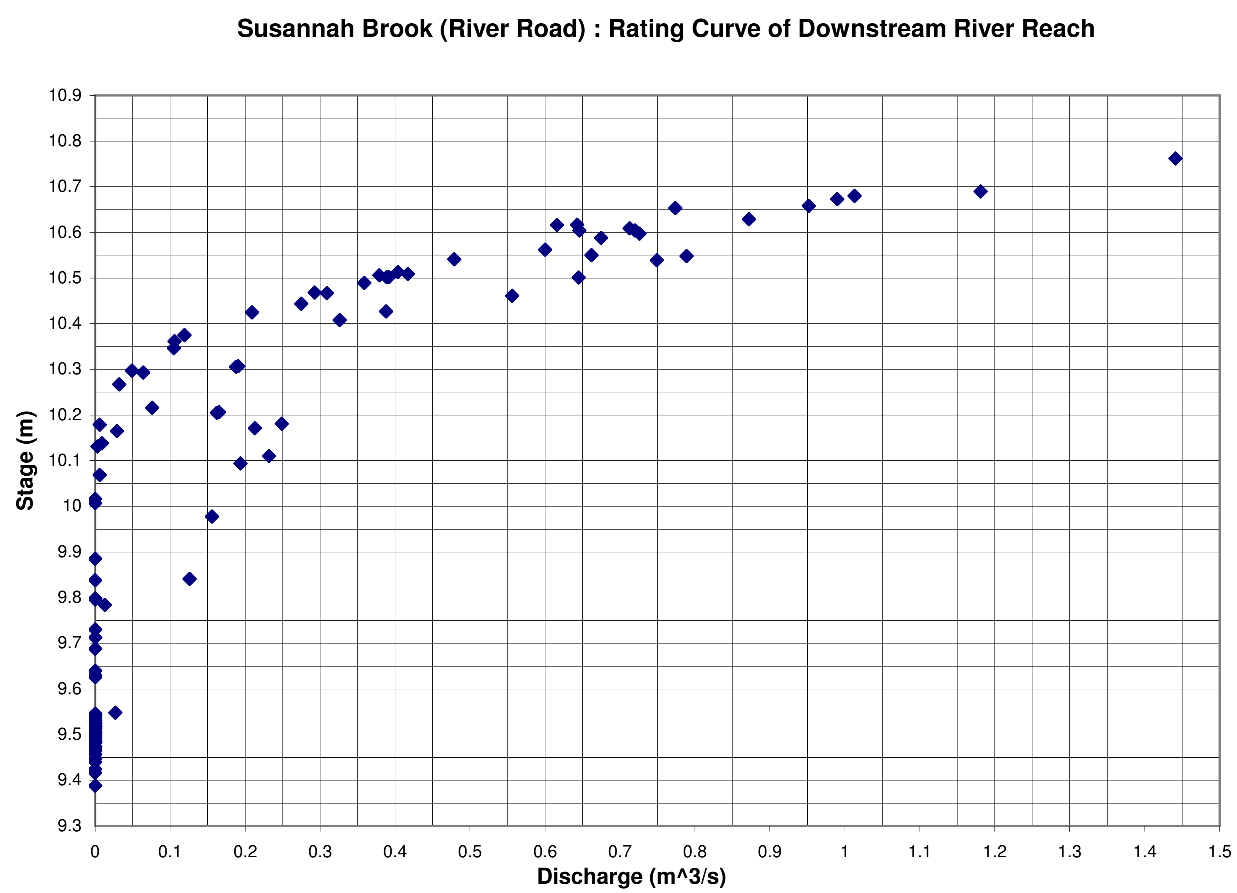
Susannah Brook Water Level Times-Series Plot
Figure 7





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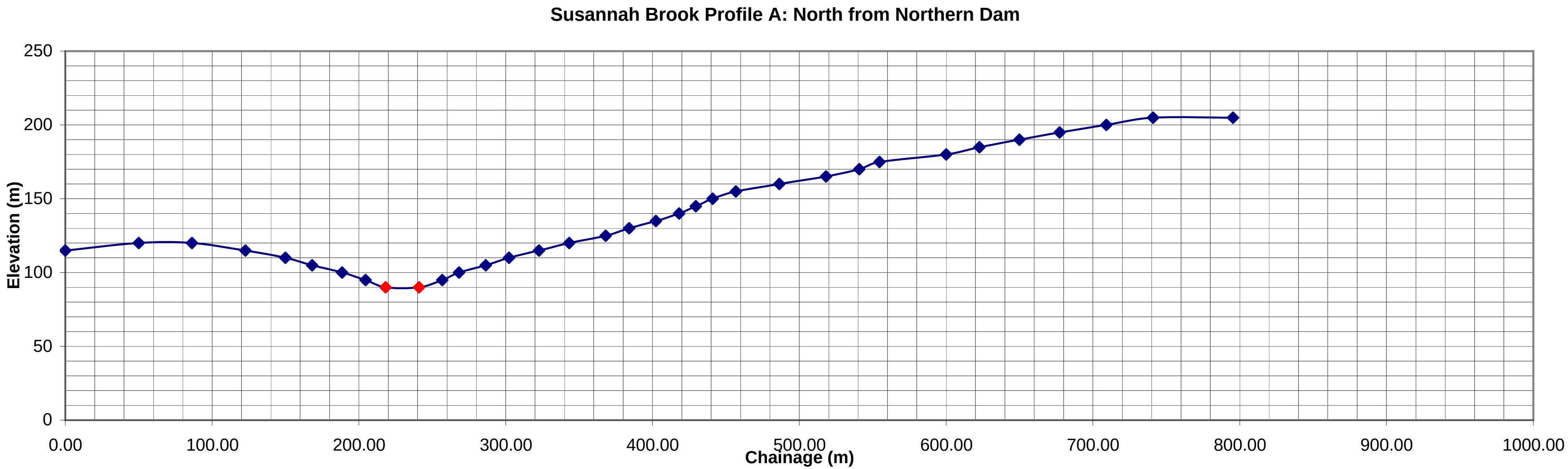
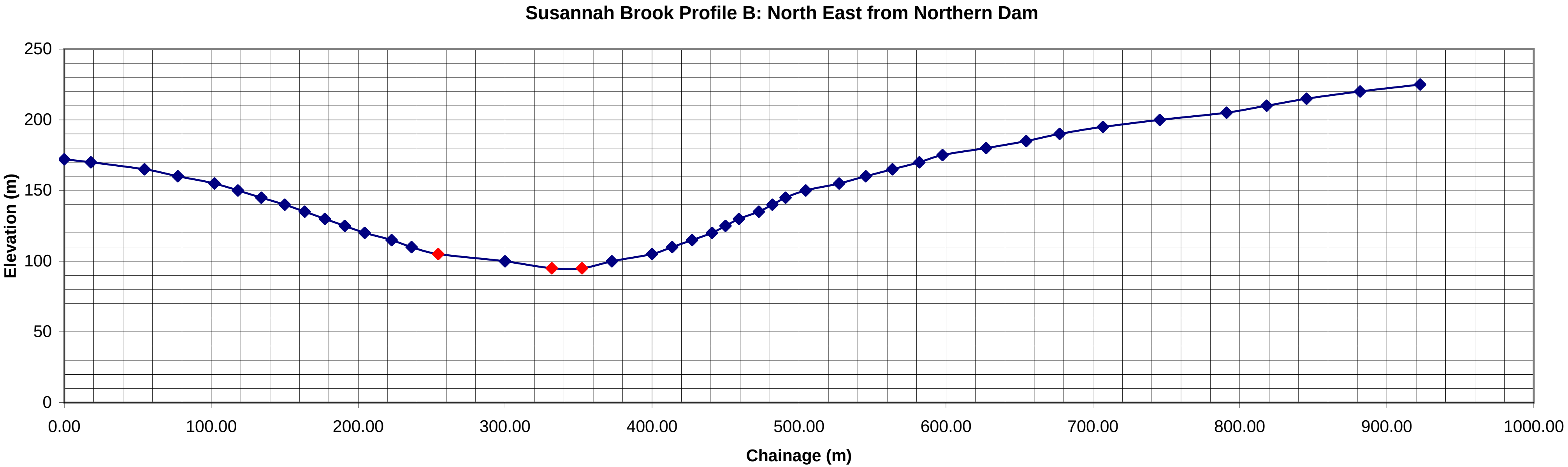
Susannah Brook Rating Curves

Figure 8





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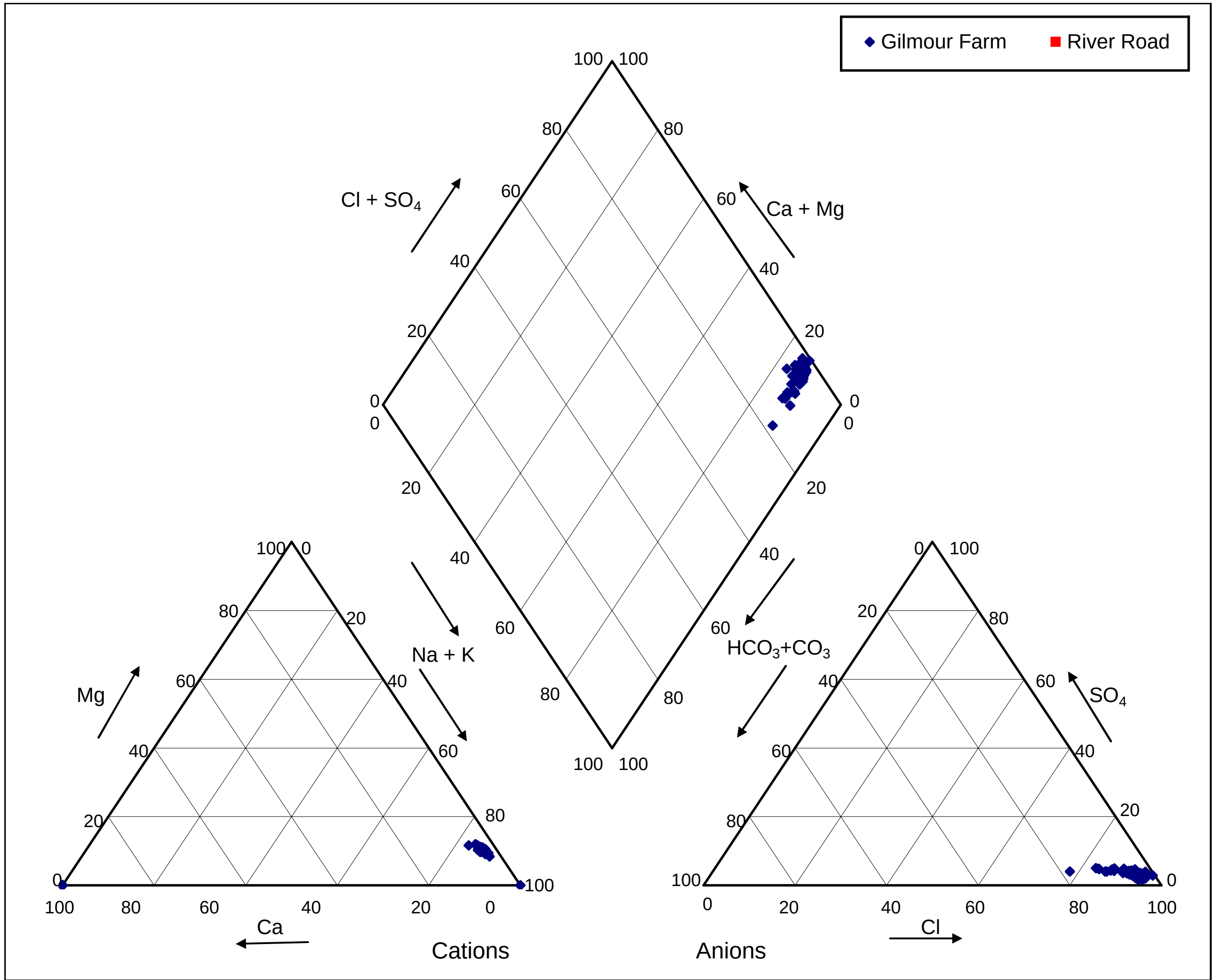
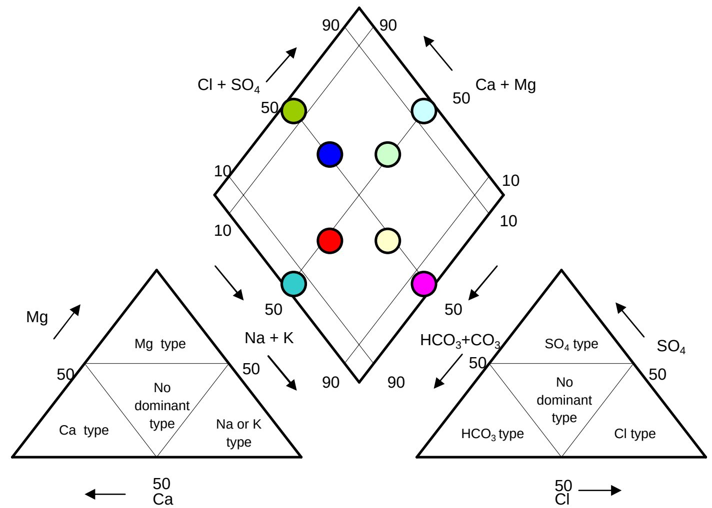
Susannah Brook : Downgradient Cross-Sectional Profiles

Figure 9



WATER TYPE CATEGORISATION



WATER TYPE SUB-FIELDS

- Ca + Mg, Na + K type
- Ca + Mg type
- HCO_3, Cl + SO_4 type
- HCO_3 + CO_3 type
- Na + K, Ca + Mg type
- Na + K type
- Cl + SO_4, HCO_3 type
- Cl + SO_4 type

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Piper Diagram

Figure 10

Date: 23/05/07

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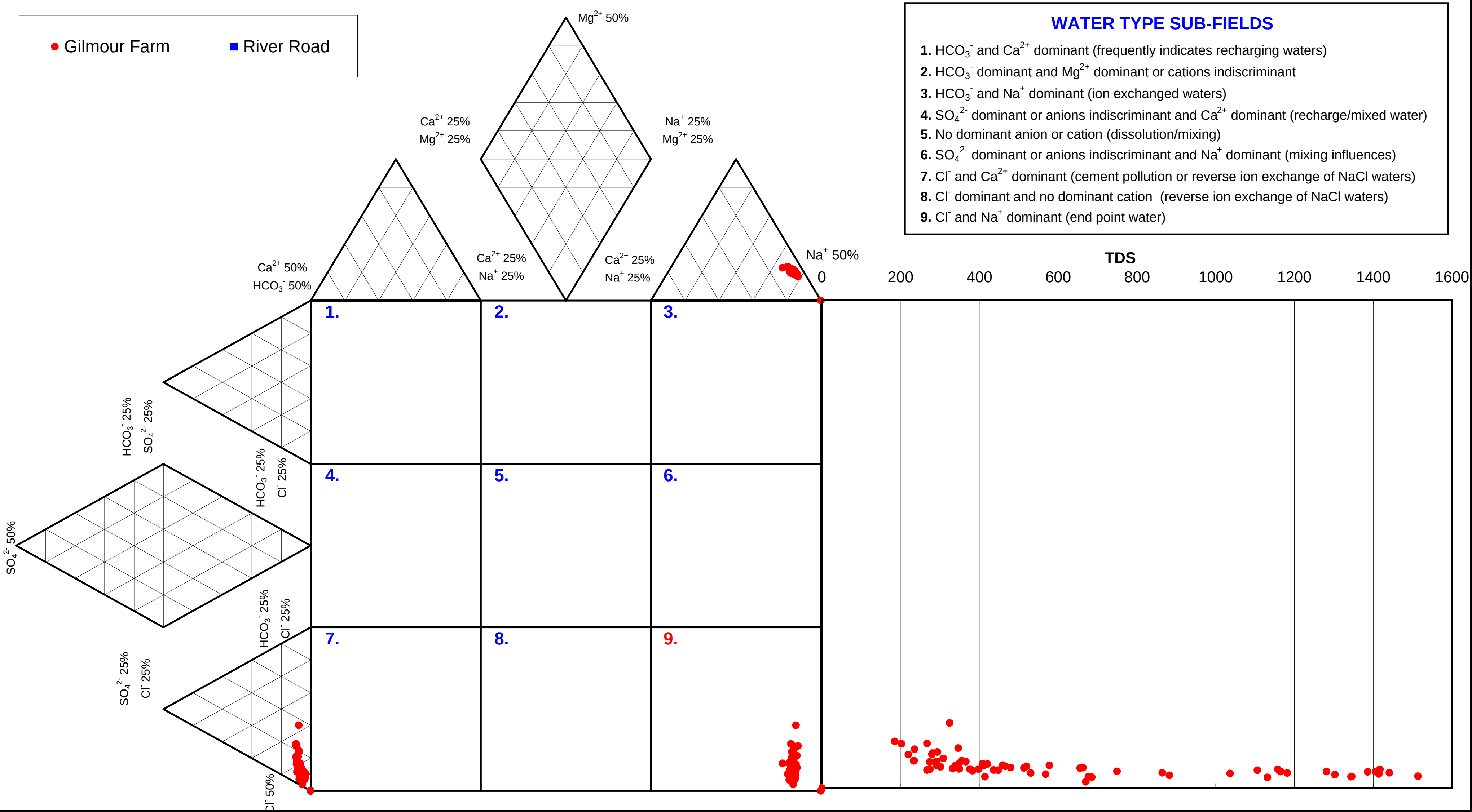
Project: Red Hill Quarry Expansion

Project No: 782

Description: Hydrological Assessment

Client: Hanson Construction Materials Pty Ltd

HydroCHEM 2.0



WATER TYPE SUB-FIELDS

1. HCO_3^- and Ca^{2+} dominant (frequently indicates recharging waters)
2. HCO_3^- dominant and Mg^{2+} dominant or cations indiscriminant
3. HCO_3^- and Na^+ dominant (ion exchanged waters)
4. SO_4^{2-} dominant or anions indiscriminant and Ca^{2+} dominant (recharge/mixed water)
5. No dominant anion or cation (dissolution/mixing)
6. SO_4^{2-} dominant or anions indiscriminant and Na^+ dominant (mixing influences)
7. Cl^- and Ca^{2+} dominant (cement pollution or reverse ion exchange of NaCl waters)
8. Cl^- dominant and no dominant cation (reverse ion exchange of NaCl waters)
9. Cl^- and Na^+ dominant (end point water)

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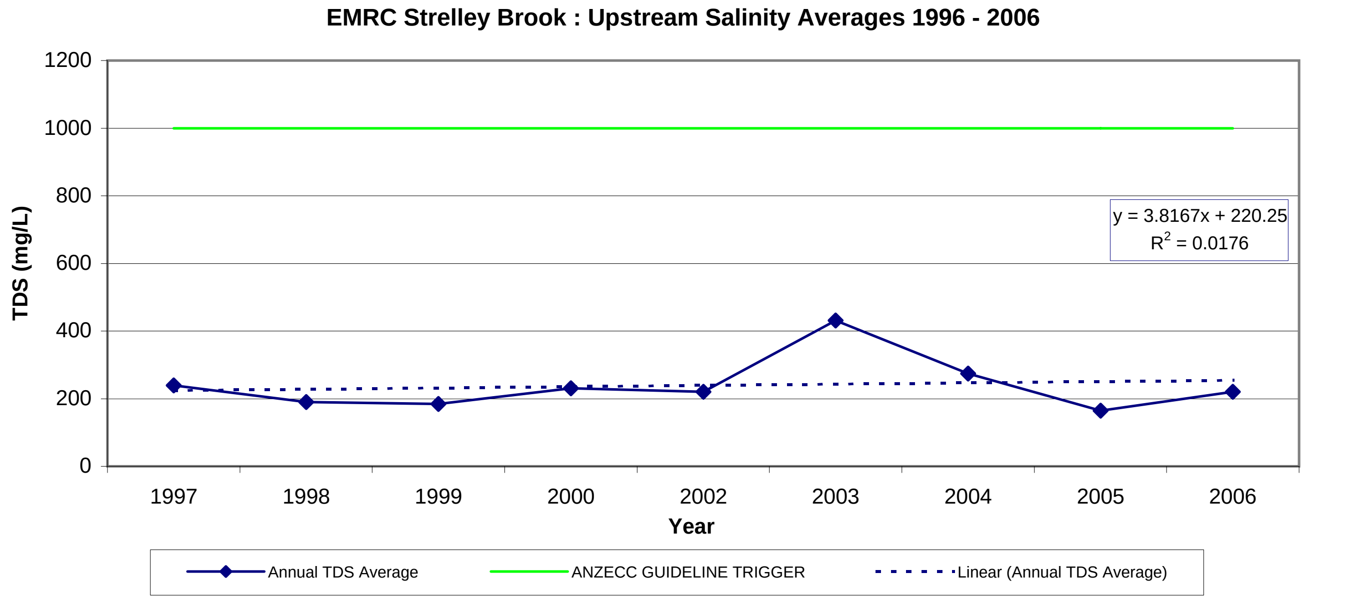
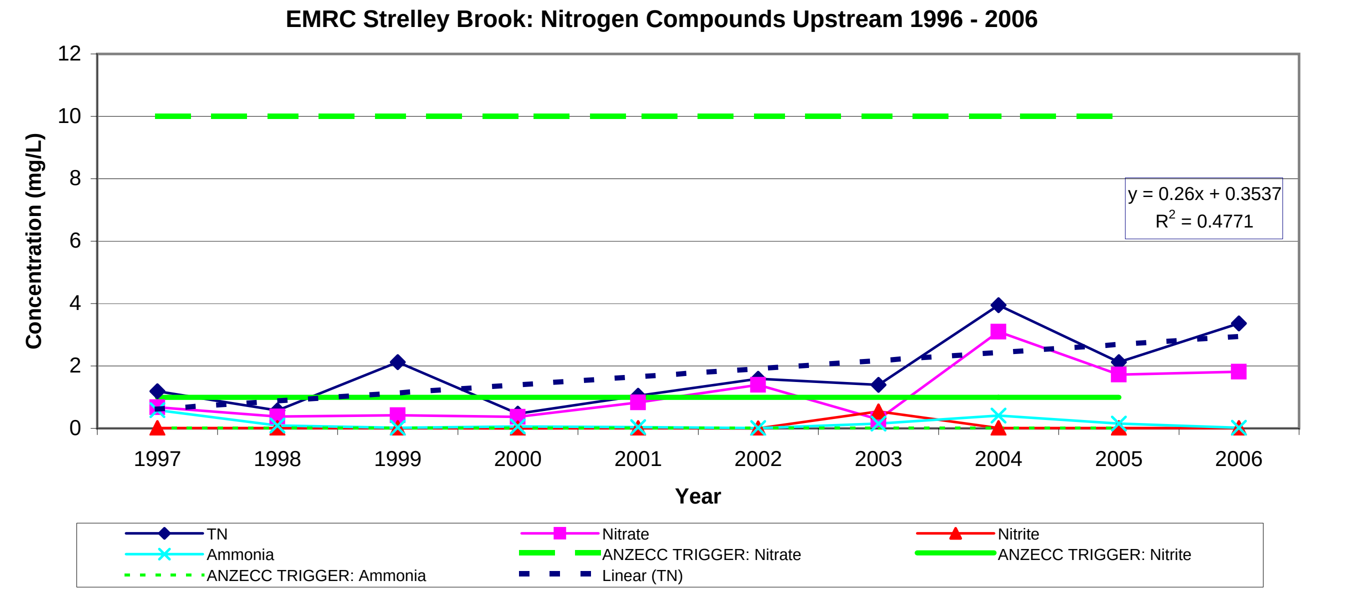
Expanded Durov Diagram

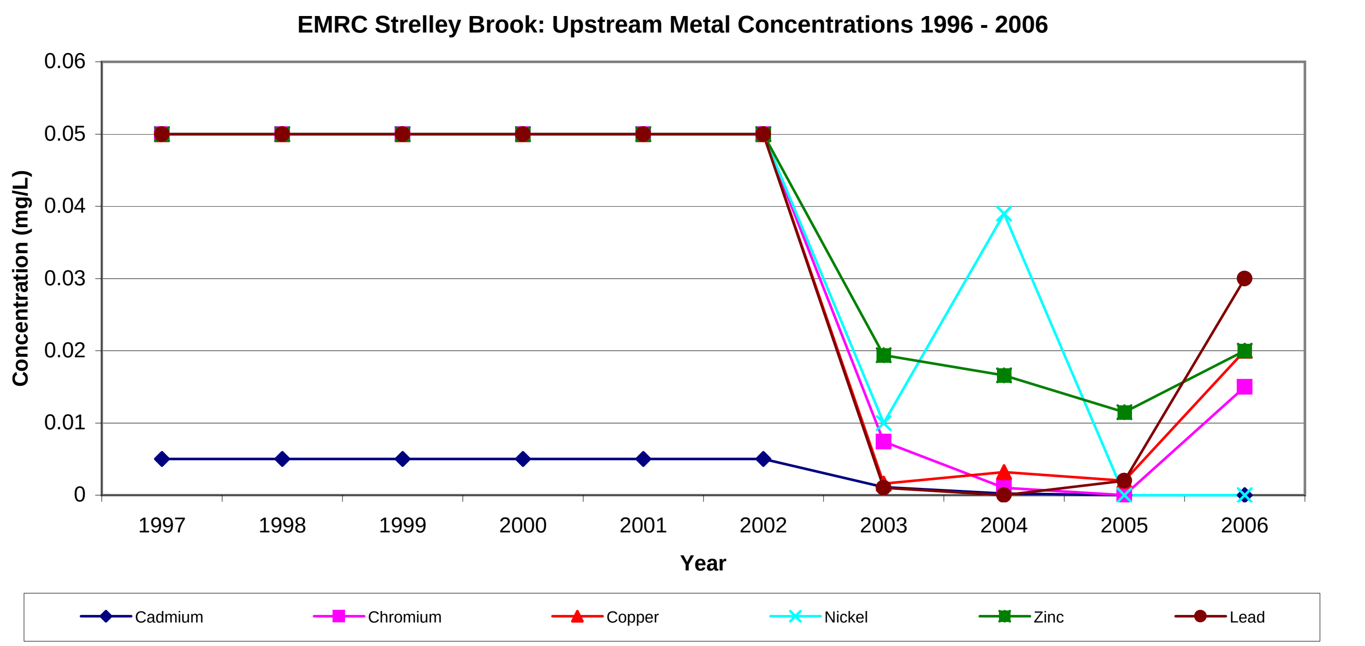
Figure 11

Date:	23/05/07	Project:	Red Hill Quarry Expansion	Description:	Hydrological Assessment
F:\Jobs\782\Background Info\[Hydro Chem RED HILL.xls]EXPANDED DUROV (1)		Project No:	782	Client:	Hanson Construction Materials Pty Ltd

HydroCHEM 2.0







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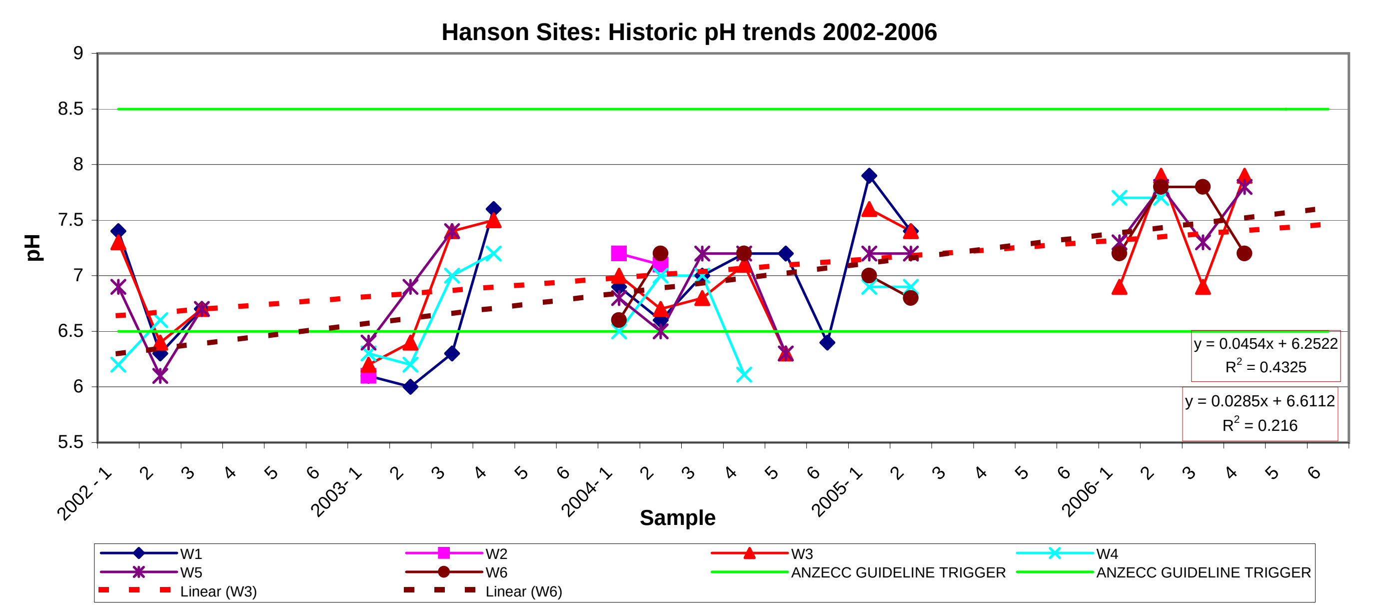
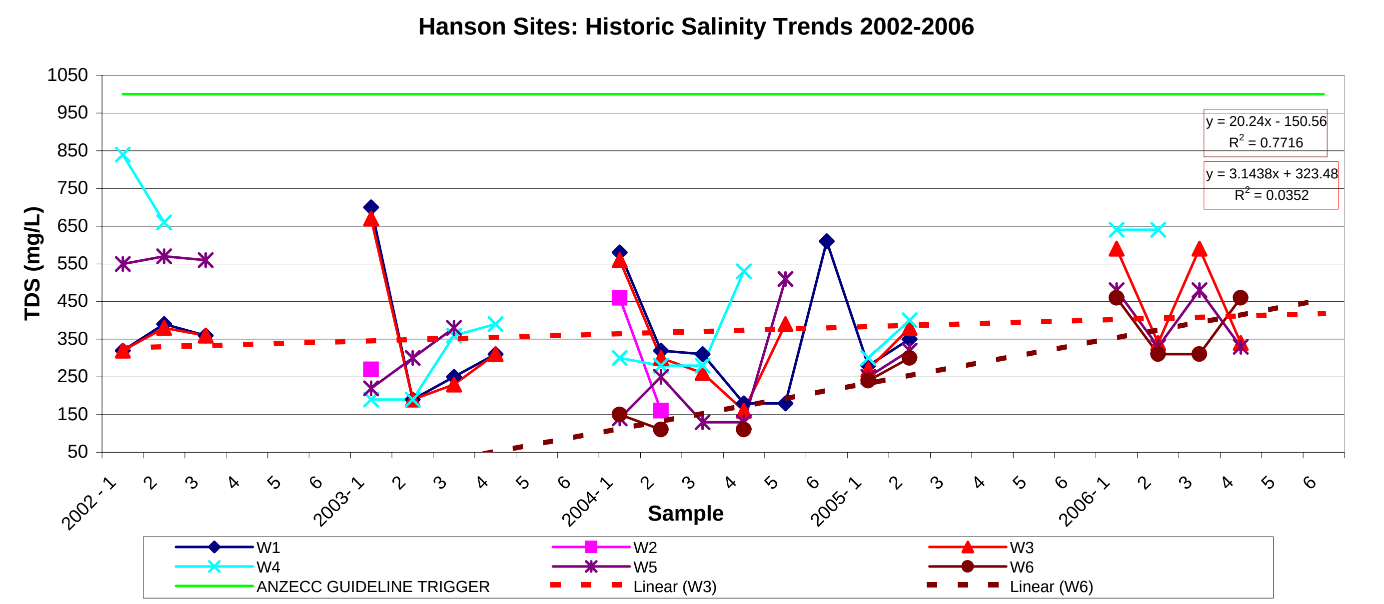
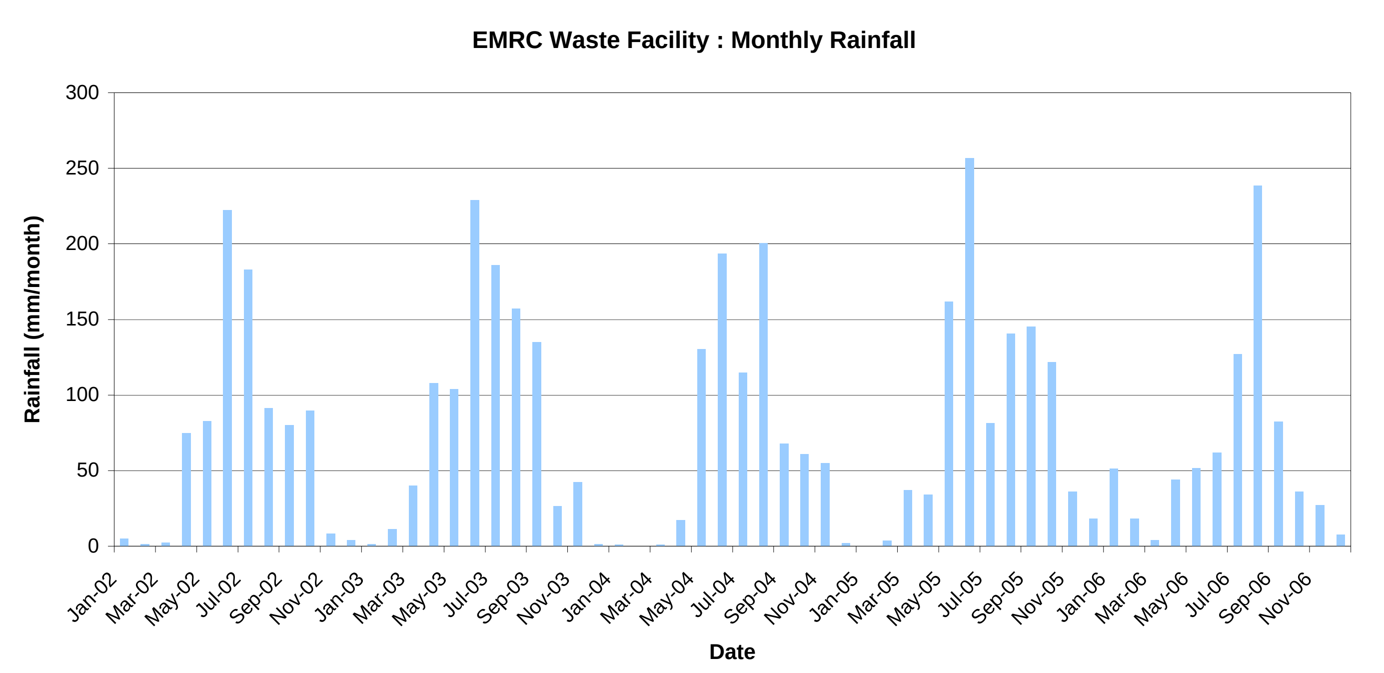
Strelley Brook Upstream Water Quality : EMRC Trends

Figure 12







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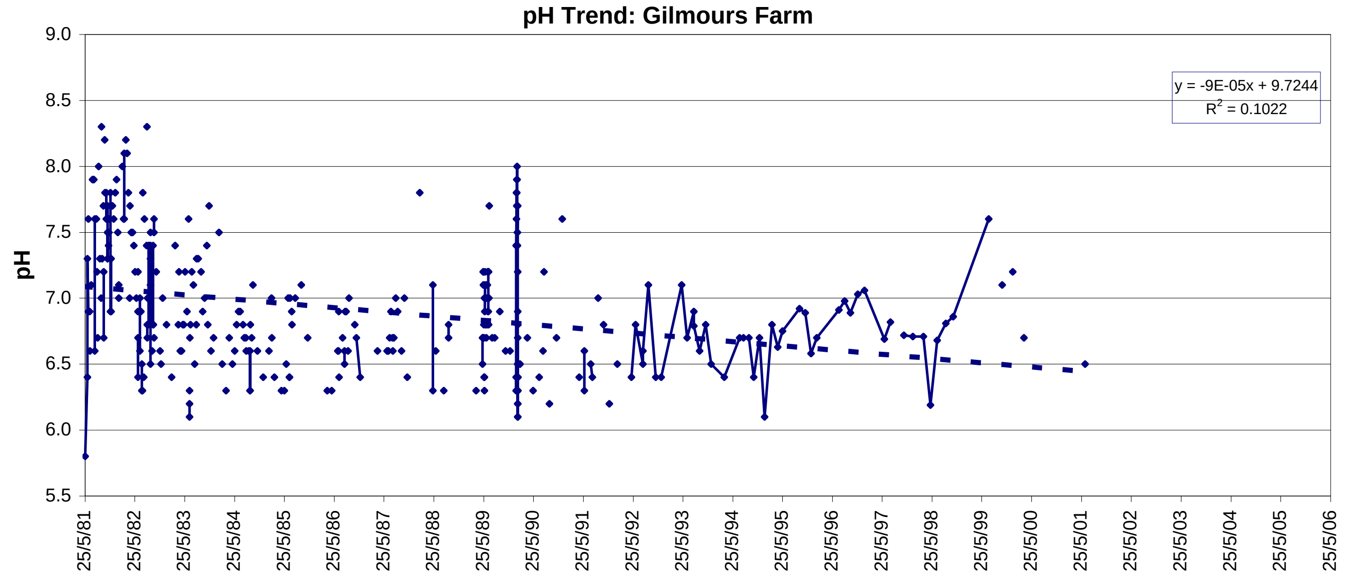
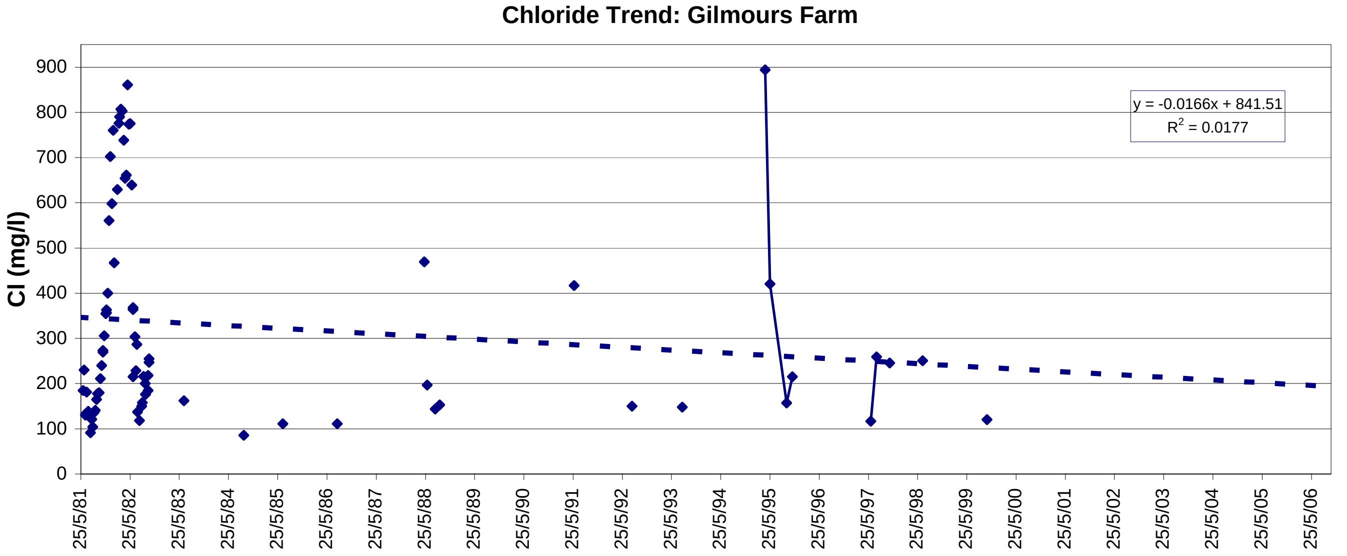
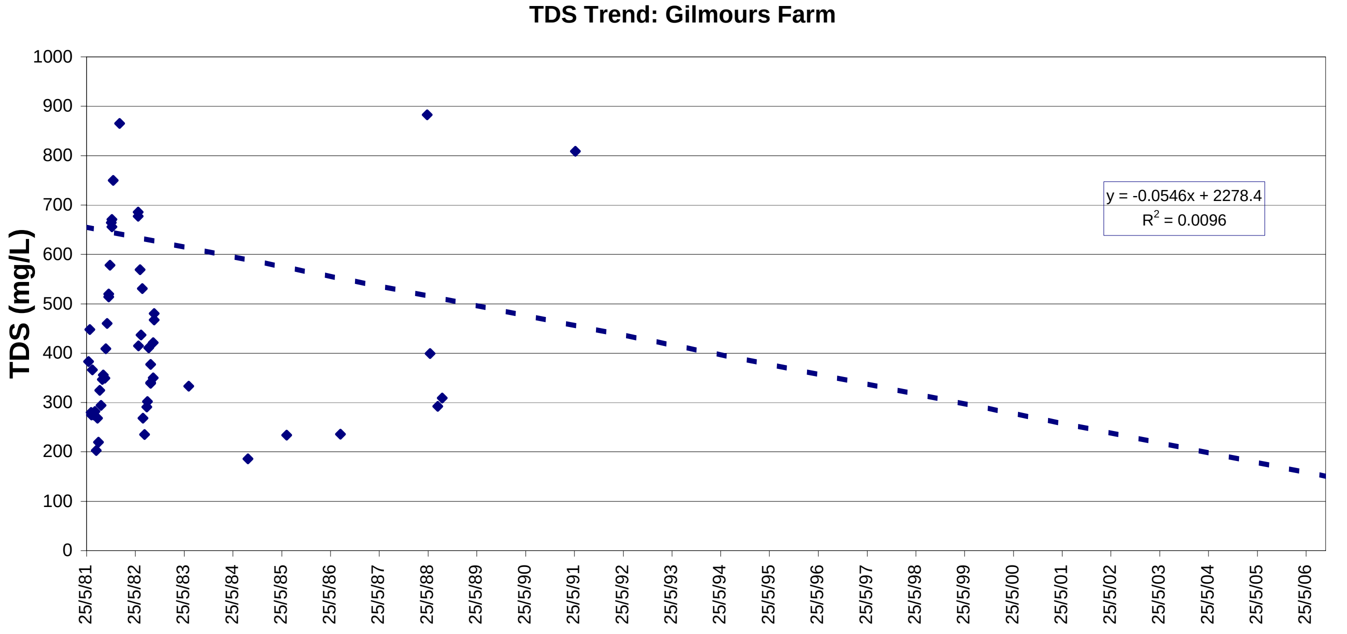
Hanson Monitoring Sites: pH & Salinity Trends

Figure 13







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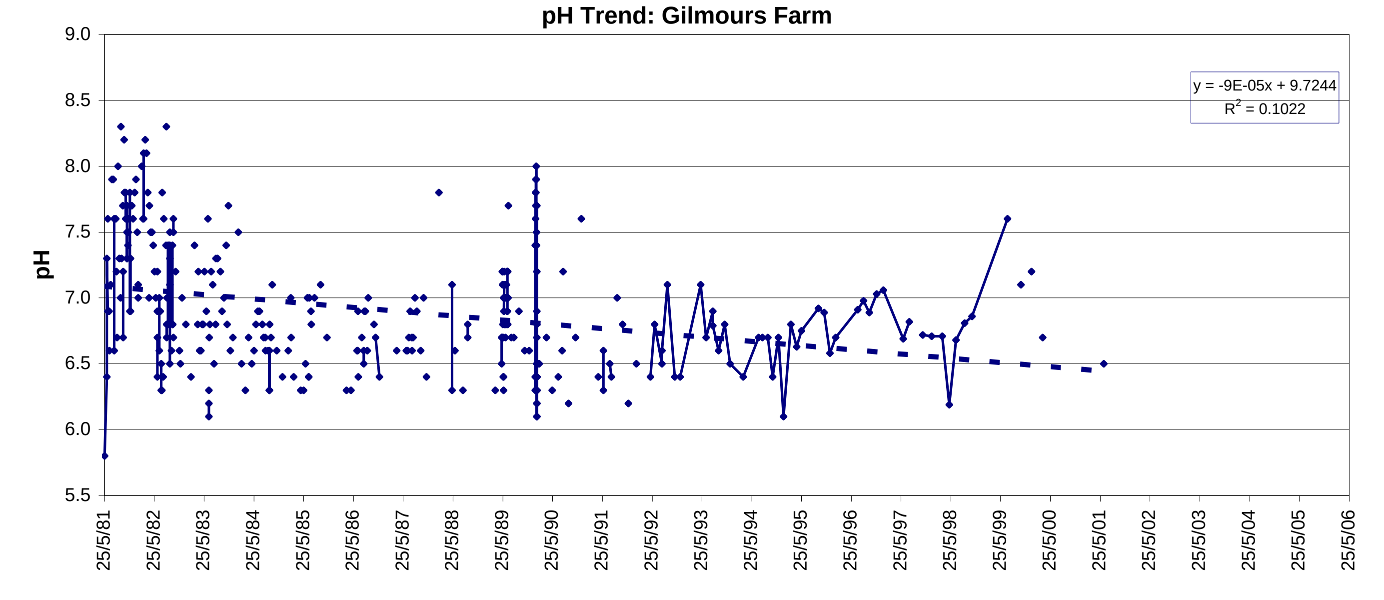
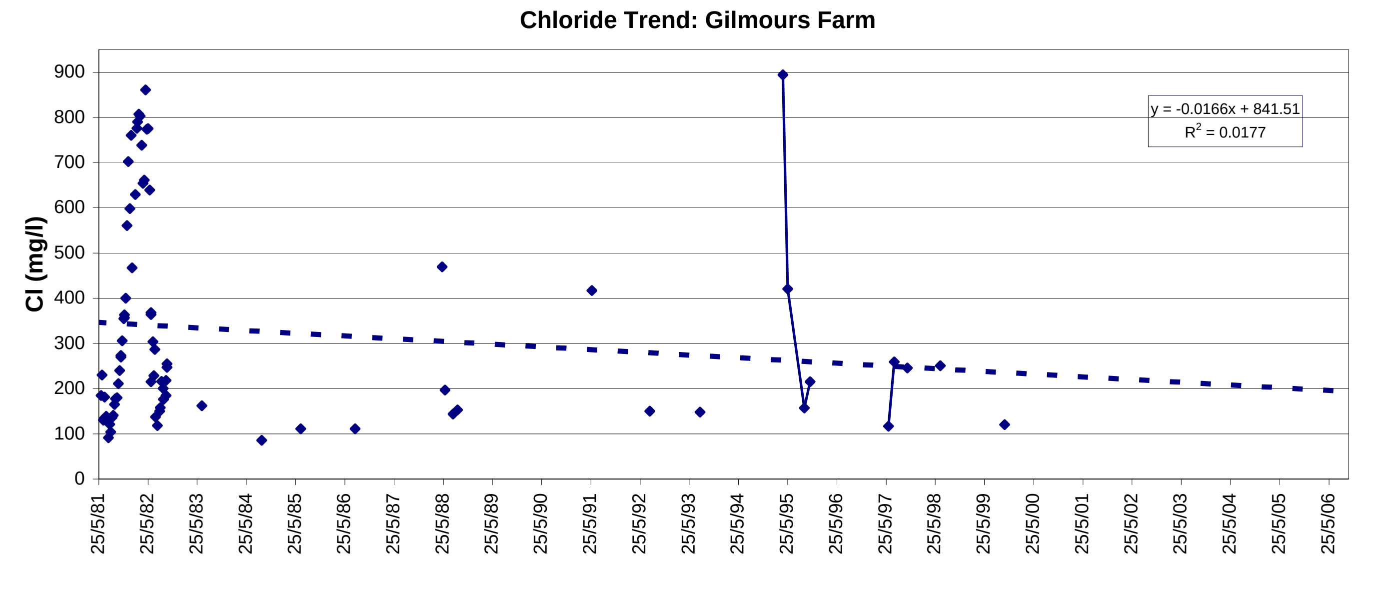
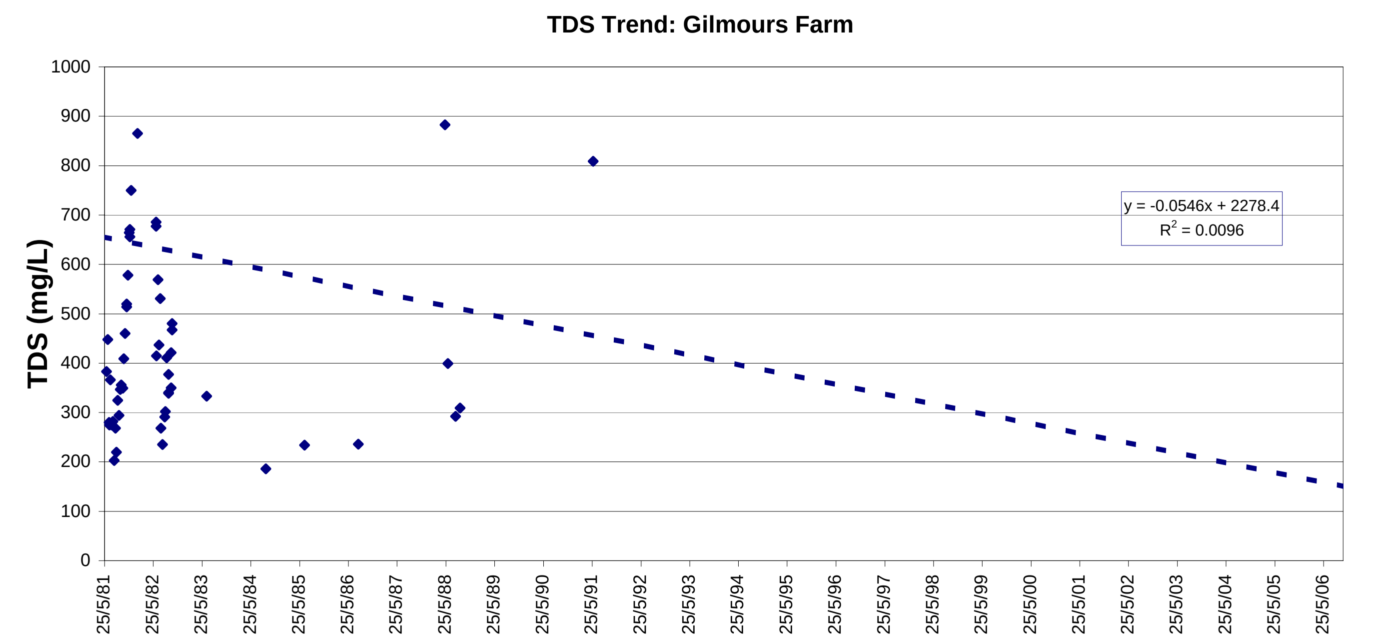
Gilmours Farm Upstream Water Quality

Figure 15







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Gilmours Farm Upstream Water Quality

Figure 15