CLIENTS | PEOPLE | PERFORMANCE

Shire of Serpentine-Jarrahdale

Mundijong Whitby District Structure Plan

District Water Management Strategy

March 2010

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

{Blank Page for Double Sided Printing}

Contents

Table Index

Figure Index

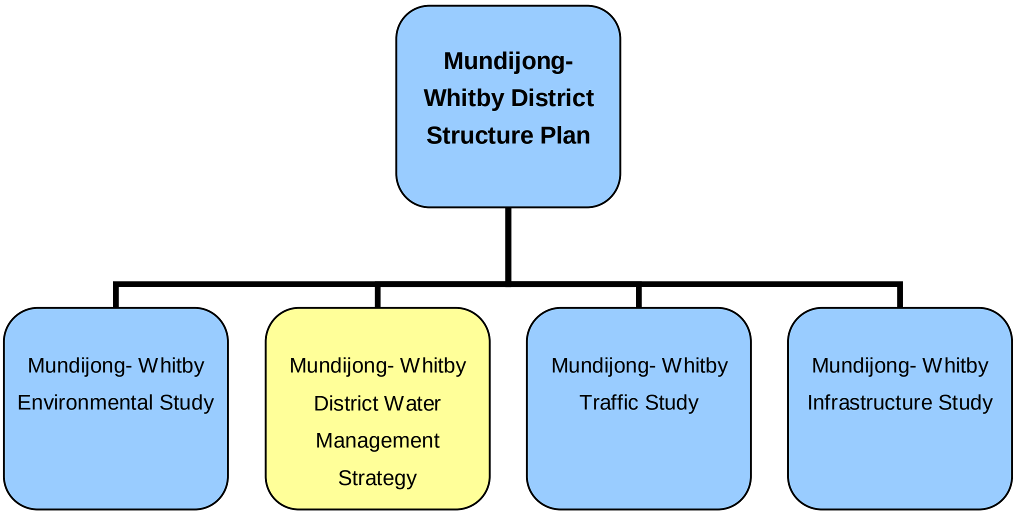
Appendices

1. Introduction

The Shire of Serpentine Jarrahdale is currently developing a District Structure Plan for the Mundijong- Whitby region. This plan aims to guide development/ redevelopment in the region where it is expected the population will increase significantly in the next thirty years[1].

This Mundijong-Whitby District Water Management Strategy (DWMS) is a component of the Mundijong-Whitby District Structure Plan. Referring to Figure 1, concurrent Traffic, Infrastructure, and Environmental Studies are being undertaken.

Figure 1 Mundijong-Whitby District Structure Plan Arrangement



The aim of this DWMS is to[1]:

1. Define land area requirements for conveyance of flood flows and protection of future urban development from peak flood events;
2. Propose a drainage design strategy appropriate for local conditions in the strategy area that incorporates best practice water sensitive urban design measures. This strategy should identify Water Sensitive Urban Design (WSUD) practices to be implemented within both private allotments and the public domain, and the legal mechanisms by which all identified practices will be implemented;
3. Prescribe the design criteria for water quantity and water quality for each sub-catchment;
4. Outline the hydrologic and hydraulic framework parameters and subsequently develop the overall drainage network concept;
5. Define an implementation plan for the drainage design strategy, that will outline timing, cost estimates, mechanisms and responsibilities; and

[1] Mundijong-Whitby Urban Water Management Strategy Tender Brief 013/2007-08

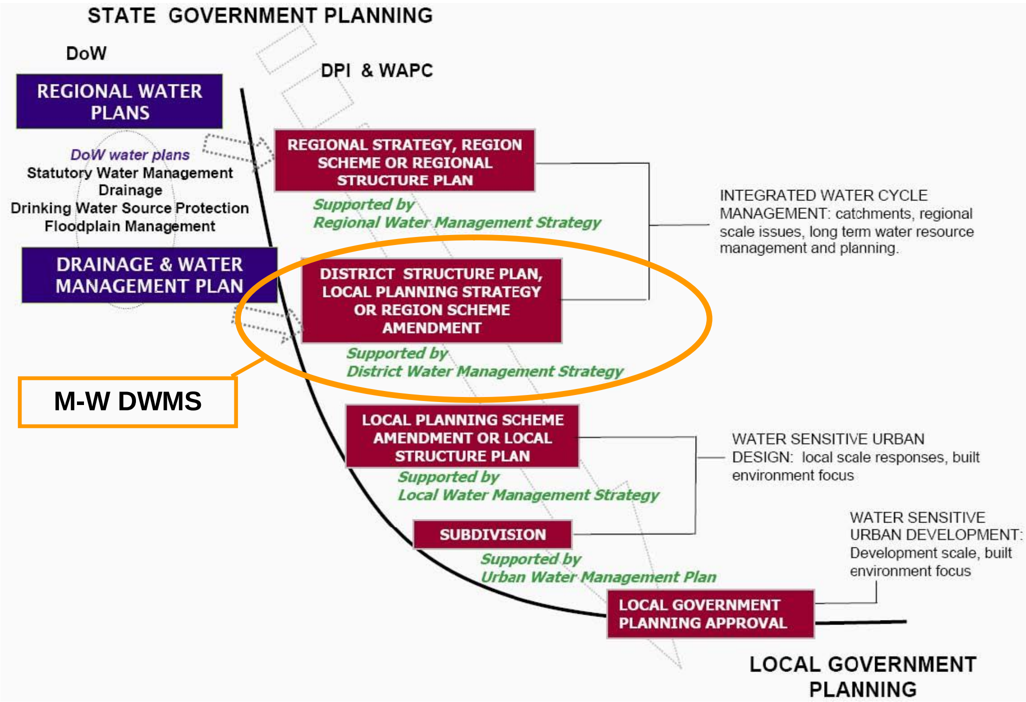
6. Recommend monitoring programs for water quantity and water quality pre, during and post development as well as for ensuring hydraulic performance over the lifetime of the drainage structure.

A number of investigations are being undertaken in order to assist in the preparation of the District Structure Plan and subsequent planning stages. These investigations include Environmental, Flood Management, Groundwater Modelling, and Whole of Water Cycle studies. In developing this Urban Water Management Strategy, GHD has referred to results of studies undertaken and provided by the Shire.

1.1 Planning background

This Mundijong-Whitby DWMS has been prepared in accordance with the responsibilities for Drainage Planning assigned to the Department of Water (DoW) and the Shire of Serpentine-Jarrahdale by the State Government. The document aims to combine DoW's Drainage and Water Management Plan with Council's District Water Management Strategy as illustrated in Figure 2.

Figure 2 Planning framework integrating drainage planning with land planning processes



In addition to Better Urban Water Management (WAPC 2008) this DWMS uses the following documents to define its key principles and objectives:

- Planning Strategy for the South-East Corridor: Stage B Report (1979);
- Shire of Serpentine Jarrahdale Green Towns Study (1995);
- South-East Corridor District Structure Plan (1996);
- Shire of Serpentine Jarrahdale Rural Strategy (2000);
- State Planning Strategy (1997);

- Network City (2004);
- Peel-Harvey Water Quality Improvement Plan (EPA 2004), including:
  - Peel-Harvey Coastal Catchment Water Sensitive Urban Design Technical Guidelines (Peel Development Commission 2006);
- Mundijong Townsite Drainage Study (JDA 1998);
- Stormwater Management Strategy and Plans for Byford and Mundijong (Evangelisti & Associates et al 1994); and
- Liveable Neighbourhoods Edition 4 (WAPC 2008);

1.2 Previous studies

A number of key investigations have been undertaken and are currently being prepared for the Mundijong-Whitby district. It is the aim of this District Water Management Strategy (DWMS) to incorporate information from all of these studies and present design criteria and management strategies.

Local scale groundwater modelling has recently been completed for the Byford area (including Mundijong and Whitby) by CyMod Systems (2007) for the Department of Water to assess any impacts from variations in climate or planned development in the study area.

A Floodplain Management Study including 2-Dimensional flood modelling (MIKE Flood) has been completed by SKM (2007) for the Department of Water. A high resolution Digital Elevation Model (DEM), created to assist flood modelling has been made available as part of the surface water modelling outputs to supplement Landgate contour information.

A Draft Environmental Study was completed by SMEC (2008) and identified a series of potential environmental impacts associated with the proposed development, as well as recommendations for the management of identified impacts.

The study area has been assessed for acid sulphate soil risk, the results of which are presented in the Western Australian Planning Commission Planning Bulletin No. 64 'Acid Sulphate Soils' (2003).

Environmental Water Requirements (EWRs) of groundwater dependent ecosystems have not yet been published for this area.

2. Pre-Development Environment

2.1 Study Area

The 1800 ha study area is located approximately 38 km southeast of the Perth CBD, within the Shire of Serpentine-Jarrahdale. The area defined by the M-W DSP is bounded by the Tonkin Highway Reserve to the south (south of Watkins Road), the Tonkin Highway Reserve to the west, Bishop Road and Norman Road to the north and the South Western Highway to the east.

The existing land use in Mundijong town area is predominantly urban and is the only existing administrative centre of the Shire. The remainder of the study area including the outlying Whitby area comprises a mix of rural residential/low density residential and rural/agricultural developments, as well as some areas of remnant vegetation and those set aside as Regional Parks and Recreation under the Metropolitan Region Scheme (MRS).

The site location plan is presented in Figure A.1.

2.2 Topography and Geomorphology

The catchment of the Mundijong-Whitby area encompasses three landforms – the Darling Plateau, the Darling Scarp and the Swan Coastal Plain. The Darling Plateau extends eastwards from the Darling Scarp near the eastern boundary of the Study Area. The part of the catchment that lies within the Darling Scarp is hilly with steep grades and well-defined watercourses. The lower (western) section of the catchment is the Swan Coastal Plain, which is predominantly low-lying with a gently undulating to flat surface.

Erosive processes principally related to runoff from the escarpment have defined step valleys in the upper reaches of the catchments. Reduced velocities as runoff reaches the floodplain have resulted in wide flat floodplains along the lower reaches of the catchment.

Ground elevations at the site slope from the western boundary to the north west point of the site from approximately 25 mAHD to 75 mAHD, reaching a high point of 96 mAHD along the Eastern Boundary (SMEC 2008).

Figure A.2 presents the topography of the study area.

2.3 Soils and Geology

The SMEC Environmental Report indicates that the MW Cell consists of three soil types classified as Forrestfield, Pinjarra and Bassendean.

The Forrestfield soils are situated along the foothills of the Darling Scarp. The soils are predominantly duplex sandy gravels, pale deep sands and deep sandy duplexes, susceptible to water erosion and phosphorus export, particularly in drainage channels and on the steeper slopes (Wade, 2006).

The formation of the Pinjarra soils is attributed to alluvial materials deposited across the plain extending from north to south adjacent to the Forrestfield group including through the centre of the Shire to its western boundary (Wade, 2006).

In isolated pockets, the alluvial soils are overlain by wind blown sand typical of the Bassendean System. These areas are prone to wind erosion, but only minor areas of the remainder of the flats are susceptible to either wind or water erosion (Wade, 2006). Most of the low lying heavy soils are susceptible to water logging and substantial areas have some risk of developing secondary salinity (Wade, 2006).

Referring to the Environmental Report prepared by SMEC, approximately half of the soils in the study area have a 0% phosphorus export risk. The phosphorus export risk of the remaining soils ranges is highest on the western side of the railway, where alluvial deposits are highest.

The soils of the study area are all highly permeable, which will allow for rapid exchange between groundwater and surface water resources. This has the potential to cause flooding if groundwater levels are high, and also allows the transport of pollutants into the groundwater aquifer.

Figure A.3 presents the geology of the study area.

2.4 Acid Sulphate Soil

The Environmental Report prepared by SMEC indicated that the majority of the Mundijong / Whitby cell is classified as having a moderate to low risk of acid sulphate soils. In addition there are areas of existing wetlands west of Paterson Street / Soldiers Road as well as adjacent to Manjedal Brook east of Robertson Road have a high to moderate risk of acid sulphate soils. In comparison maps show there is no risk of ASS along the eastern boundary of the cell.

Cardno conducted a preliminary ASS investigation for the identified areas with high risk of ASS. The assessment concluded that overall within the shallow soil profile (3.0 mBGS) the high risk regions for the development of ASS are restricted to three relatively small areas within the Cell. These areas are wetlands west of Soldiers Road and a wetland east of Robertson Road and north of Evelyn Street adjacent to Manjedal Brook.

A site investigation confirmed that at the wetlands west of Soldiers Road suitable conditions persist for ASS development. There was also evidence of ASS oxidation with the presence of an oily bacterial scum and rust-staining. This was thought to result from acidic water mixing with water of a higher pH, precipitating a rust-red scum containing iron and it is possible ASS are located within 3.0m of the natural soil surface in this area.

The Cardno (2007) ASS investigation identified the depth of the water table for much of the north east corner of the Cell is more than 3.0m below existing ground surface. Consequently ASS may persist deeper in the soil profile (>3.0m) which is unlikely to be disturbed by shallow surface works. Should deeper excavation works be proposed further investigations should be undertaken to assess the risk of disturbing ASS material.

Overall the distribution and extent of ASS within the Mundijong-Whitby Cell is limited to wetlands generally situated in the central part of the Cell. Should deep excavations or dewatering be proposed within the Cell, further more detailed investigations are recommended.

Figure A.4 presents the acid sulphate soil risks of the study area.

2.5 Environmental Assets and Water Dependent Ecosystems

Environmental Assets and Water Dependent Ecosystems are presented in Figure A.5.

An EPBC Act Protected Matters Report and a Declared Rare and Priority Flora search (SMEC, 2008) identified a total of 13 species of threatened flora with the potential to occur within the study area. Three DRF and one Priority 3 Flora species were identified within the study area.

There are 5 State listed Threatened Ecological Communities (TEC's) within the MW Cell, 2 of which are also protected under the EPBC Act (SMEC 2008). All TEC's in the MW Cell are located in Bush Forever sites. The five Bush Forever sites present within the MW Cell form the basis of the regional ecological linkages and are protected at the State level.

Three types of geomorphic wetland have been identified within the MW Cell (SMEC 2008). These include palusplain, sumplands and creeks. A large portion of the MW cell is situated on Multiple-Use wetlands while there are also a several Conservation category wetlands present as well as one area of Resource Enhancement wetland. Of these wetland areas, currently a significant portion remains undeveloped.

A number of minor watercourses and drains discharge through the site and the MW cell. SMEC (2008) have classified and assessed four significant watercourses in the MW cell for ecological significance and vulnerability to development. Manjedal Brook is the only watercourse in the MW cell to drain through the site. SMEC (2008) noted that this perennial groundwater dependant ecosystem had no evidence of erosion and excellent visual water quality, despite some weed incursion. Manjedal Brook is discussed further in section 2.6.

The DEWR identifies one groundwater ecosystem (Swan Coastal Plain damplands and sumplands with paperbark and Banksia woodlands) within the MW Cell. This ecosystem is highly dependant on groundwater.

Table 22 in SMEC 2008 study details the prioritisation of natural areas in the MW Cell.

A total of four native mammal and 2 introduced mammal species, six amphibians, 12 reptiles and 24 birds have been recorded at sites within the study area (SMEC 2008). Key fauna includes the four native mammals and one spider species.

2.6 Surface Water

There are a number of watercourses and drains discharging through the study area, with the Manjedal Brook being the most significant. Natural watercourses in the study area typically drain in an east-west direction from the escarpment to Folly River further downstream. Referring to Figure A.2, Manjedal Brook enters the study area after traversing the South Western Highway and then draining in a west-nor-westerly direction, skirting Mundijong town site, and flowing parallel to Keirnan Street. Manjedal Brook is crossed by Robertson Road, the Southern Railway, Soldiers Road and finally Taylor Road before draining out of the study area at the Tonkin Highway Reserve.

Other minor watercourses draining through the site include:

- The unnamed perennial creek between Watkins Road and Evelyn St/ Galvin Road. This creek drains through two farm dams before crossing Roman Road, Watkins Road, Hicks Street, Wright Road, and the Southern Railway; and
- A highly modified unnamed creek/drain entering the study area at the South Western Highway south of Perrett Rd. This creek/drain discharges in a westerly direction through an incised channel before crossing Robertson Road, the Southern Railway, Soldiers Road and finally Taylor Road before draining out of the study area at the Tonkin Highway Reserve.

The surface water drainage system comprises numerous small catchments draining from east to west. The upper catchments of the Darling Range foothills are well defined with steep catchment slopes whereas the lower catchments are less defined. Due to the flat topography of the study area, structures such as roads have a significant influence on the size and shape of catchments.

The Mundijong-Whitby area is known to experience regular water logging in the low-lying areas of the study area. This inundation is due to a combination of persistent winter rainfall elevating the shallow water table, which rises to the surface and inundates vast areas of the flat terrain, as well as sparse drainage, with insufficient capacity that does not allow runoff to leave the area. There is also potential for wetlands within the study area to receive additional flood water from outside their natural catchment by overtopping of drains and watercourses.

There are several local depressions east and west of the South Western Highway, which result in local perching of surface water after a large rainfall event.

2.6.1 Wetlands

Approximately half of the study area is designated as Multiple Use Wetlands (MUW), with one site designated Resource Enhancement (REW) east of Roman Road, and eleven sites designated Environmental Protection Policy Wetlands (EPPW). The most significant of these wetlands lie between the duplicate Soldiers Roads and west along the course of the Manjedal Brook (Figure A.2). The preservation of the predevelopment Hydraulic Grade Line (HGL) along the Manjedal Brook, together with predevelopment peak flow rates will ensure that the potential for development impacts to this area will be minimised.

The south-west corner of the study area also supports significant wetlands in the vicinity of Mundijong Road and Wright Road. Likewise, it is anticipated that the maintenance of predevelopment peak flow rates at the south-west corner of the study area, will ensure that there is no impact on this wetland.

Development will result in the loss of significant areas of MUW. The addition of imported fill and subsurface drainage will control groundwater levels and soil wetness and therefore reduce the extent of inundated areas. In addition, improvements to surface water drainage will result in less extensive surface inundation which will be confined to predetermined locations within Public Open Space areas.

2.6.2 Flood Mapping

SKM has undertaken a Mundijong Floodplain Management Study (2007) to describe and map existing flood behaviour in the Mundijong-Whitby study area. This study utilised a hydrologic model and a 2-D hydrodynamic hydraulic model to simulate a number of design storms of varying intensity, frequency, and duration. The study found that the 6-hour duration storm was the critical storm for most of the study area. Flood mapping was undertaken for the 10-, 25- and 100-year Average Recurrence Interval (ARI) storms, and is provided in Appendix G.

The flood mapping presented a number of floodways through the study area, typically following the watercourses described in section 2.6. In addition, two smaller floodways were identified through the town as illustrated in Appendix G.

2.6.3 Water Quality

There is limited surface water quality data available within the study area. The SMEC Mundijong- Whitby DSP Environmental Study (Draft 2008) collected samples on the 30th October 2007 from four sites along Manjedal Brook and one from a wetland on the western side of Soldiers Road. Table 1 summarises the results.

Table 1 Water Quality Results[2]

Variable	Range	Comments
pH	6.89-8.25	Meets ANZECC water quality objectives
Electrical Conductivity	343 – 1150 μs/cm	Lower conductivity values are often associated with seasonal rainfall
Salinity	0.14 – 0.58 ppt	fresh to slightly brackish
Turbidity	5.30 – 25.8 NTU	
ORP	170-286 mV	
Dissolved Oxygen	82.7 – 138.6%	should avoid falling below 5mg/L to avoid stress to aquatic species
Heavy Metals		Within ANZECC Drinking Water Guideline Values 2004
Total Phosphorus	0.01 to 0.03 mg/L	Meets ANZECC water quality objectives
Reactive Phosphorus	<0.01 mg/L	Meets ANZECC water quality objectives
Total Nitrogen	0.35 mg/L (average) 2.1 mg/L (max)	All but site 3 meets ANZECC water quality objectives
Total Kjeldahl Nitrogen	0.2 – 0.7 mg/L	
Ammonia	>0.105 – 0.118 mg/L	Above ANZECC trigger values
Nitrite and Nitrate (NO_x)	<0.010 - 1.380 mg/L	Mostly less than ANZECC trigger values

The draft Water Quality Improvement Plan (WQIP) for the Rivers and Estuary of the Peel-Harvey System (2007) has considered further the water quality of the Serpentine, Harvey and Murray catchments specifically developing objectives for Total Phosphorous and indicating the % reduction required in each subcatchment to achieve the objectives. Recommendations from the WQIP have been incorporated into the Water Quality Management Strategies presented in section 6.3.

[2] Extracted from SMEC (2007) Mundijong- Whitby Environmental Study

2.7 Groundwater

2.7.1 Levels

Local groundwater modelling for Mundijong- Whitby has been carried out by CyMod Systems. The groundwater model was run for three scenarios:

1. No development under average rainfall conditions (current climate);
2. Proposed development under average conditions; and
3. Proposed development under wet rainfall conditions.

Dry conditions were not selected as a post-development groundwater model. The results of the modelling indicate that there is currently a downward trend in groundwater levels and that this is likely to continue and reduce even further as development occurs.

CyMod Systems also advised that absolute groundwater levels may decrease over the next 20 years due to increased abstraction in the artesian aquifers. If the water table continues to decline, wetland dependent ecosystems may come under increasing stress. As general urban development either increases recharge in sandy areas, and hence increases groundwater levels, or increases run off in clayey areas, which may be diverted to wetland systems, such development could mitigate against these general declines and thus decrease the stress on adjacent wetlands, if well designed.

CyMod Systems notes that abstraction within the study area is either from licensed abstraction by private users or unlicensed abstraction by private users.

Within the study area, there are 159 recorded DoW Water Information System sites. 10 of these sites are for monitoring or observation of groundwater.

2.7.2 Quality

There is very limited groundwater quality data available for the study area. In terms of salinity of groundwater within the study area, CyMod Systems (2007) found that the surface superficial groundwater is generally fresh or slightly brackish, whilst the groundwater of the Leederville aquifer is generally fresh (<1000 mg/L TDS).

2.8 Infrastructure

2.8.1 Existing

The existing infrastructure of the Mundijong- Whitby study area is illustrated on Figure A.6 and includes:

- Roads:
    - Approximately 45 km of local roads ranging from sealed and unsealed access roads, to collector roads and main roads
    - A bridge at Manjedal Brook and an overpass at the southern railway siding; and
    - 4.5 km of South-Western Highway, with numerous culverts and a bridge over Manjedal Brook.
- Rail:

- 4.7 km of Main Southern Railway, with bridges at Manjedal Brook and the unnamed creek near Watkins Road; and
- 3.3 km of sidings;

- Water:
  - Approximately 16.1 km of potable water supply pipes ranging from 20 mm to 200 mm in diameter.
- Sewer:
  - No reticulated sewerage is known to exist for Mundijong-Whitby.
- Drainage:
  - 1 km of open drains (south-west corner of study area only).
- Communications:
  - Telstra telephone connections available at all lots; and
- Electricity:
  - Low and high voltage services typically distributed via pole mounting to residential users.
- Gas:
  - No Alinta gas cables currently exist in the area.

2.8.2 Proposed

The Infrastructure Study for Mundijong- Whitby is yet to be completed. However, it is understood that the Tonkin Highway is to be extended to Mundijong Road as a 4 lane dual carriageway. Funding for this project does not exist to date and is dependant on urban development in the Mundijong area.

Urban development in the area will be accompanied by new and upgraded roads, water, sewer, electricity, gas and communication services.

2.9 Social Considerations

2.9.1 Aboriginal Heritage

12 Aboriginal heritage sites have been identified within the Study Area. The sites are concentrated along the western flank of the study area and have been the subject of numerous cultural heritage surveys and reports. Of the 12 known sites within the Study Area, detailed site information, a description of the condition of the site and an analysis of its significance is available for eight of the sites.

Detailed heritage surveys of the north east sector of the Study Area between South West Highway and Reilly Road, carried out on behalf of Cardno BSD (Robert Day, 2005), found no Aboriginal heritage sites in the area. Therefore, it is not expected that Aboriginal heritage issues are likely to constrain any proposed development in that area.

The significance of each Aboriginal heritage site has been described by the Blockley and Greenfield (1995), O'Connor & Quatermaine (1989) and Blockley (1996). Site SO2329, on

Soldiers Rd is a stratified archaeological site that conforms to the general pattern and nature of other sites located on the Swan Coastal plain, suggesting that Aboriginal habitation of the Swan Coastal Plain was mainly concentrated along the eastern interface with the Darling Scarp.

SMEC recommends that Shire of Serpentine-Jarrahdale consult with the South West Land & Sea Council (SWLASC) in relation to all matters pertaining to Aboriginal heritage sites identified in this report should they be subject to disturbance as a result of Mundijong-Whitby District Structure Plan.

SMEC also recommends that further ethnographical and archaeological surveys are undertaken in the southeast of the study area, should this area be subject to development under that Structure Plan, as previous surveys were unable to locate this site and assess its significance.

3. Proposed Development

3.1 Structure Plan

A draft Mundijong-Whitby Structure Plan for the Shire of Serpentine-Jarrahdale has been released and outlines the shires proposed plan for future subdivision and development/redevelopment of the townsites and the surrounding rural residential area.

The plan proposes substantial development of low-lying, rural floodplains areas. Much of the proposed development is residential with a number of schools and pockets of mixed commercial, industrial and town centre. Drainage corridors and proposed drainage basin locations have been included in the plan in accordance with the identified existing natural drainage corridors.

Outside and adjoining the study area is largely categorised rural, with the exception of public purpose land to the east of the study area reserved for a hospital or other special uses.

The MWSP will have an impact on the surface water management strategy for the study area, as it will define on a district-scale the areas available for surface drainage infrastructure and corridors. There is flexibility within the MWSP on the types of Best Management Practices that may be used for surface and groundwater quantity and quality management.

A particular concern is that the main proposed town centre site is situated in an area at substantial risk of flooding. The Draft Mundijong-Whitby Structure Plan currently indicates that drainage through this area will be along road reserves (there are no indicated drainage corridors). The viabilty of such an option will need to be addressed in future structure plans and local water management statergies.

The Draft Mundijong-Whitby District Strucutre Plan has been refined to suit the objectives of the DWMS. In consultation with Council, five categories of development have been defined and located as illustrated in Figure A.8. Features of these land use categories are described in Table 2 below.

Table 2 Preliminary Land Use Categories

	Commercial/ Industrial	Residential R20-R40	Residential R40-R60	POS (Drainage, Parks, Wetlands)	Other (School, Road, Rail)
Area (ha)	100	750	170	520	190

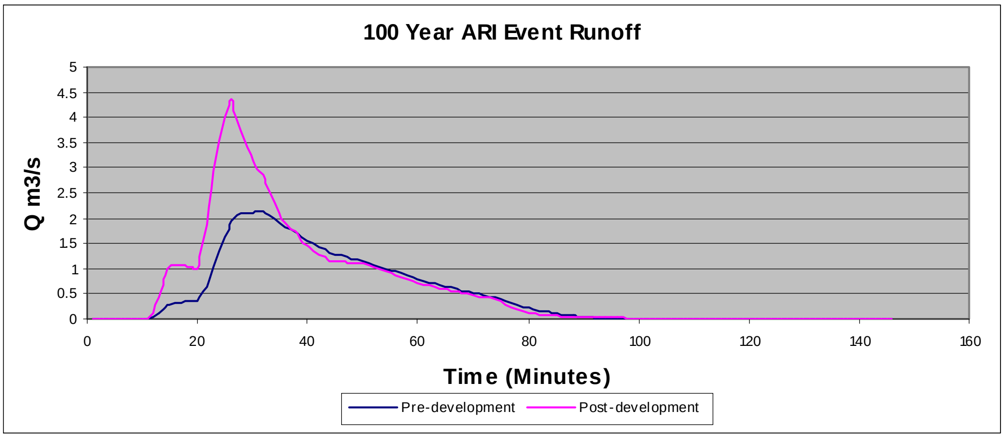
4. Protection of Environmental Assets

The following strategies have been developed to protect and enhance the value of environmental assets in the study area.

Minimise changes to hydrology to prevent impacts on watercourses and wetlands.

Changes in land use from rural to urban may lead to local increases in peak flows and volumes of runoff due to increases in impervious area (Figure 3 below). Large increases in peak flows and volumes have the potential to adversely impact on receiving environments by causing erosion and increasing the extent of inundation of vegetation.

Figure 3 Typical pre- and post-development runoff hydrograph comparisons



Surface water management must ensure that urban development does not increase the peak flows discharging to receiving environments although there may be increases in total runoff volumes (Figure 4 below). Development must also ensure that watercourses and wetlands do not dry out due to over abstraction of water resources or lowering of groundwater levels.

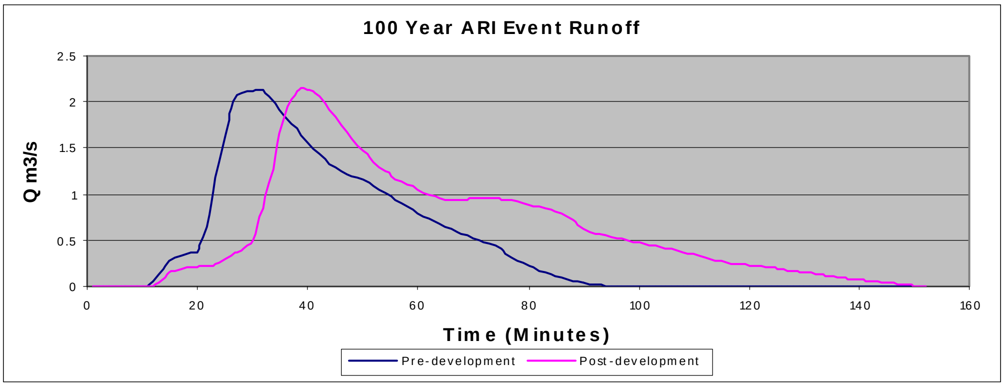
46% of the study area is designated as multiple use wetlands, with a further 3% designated as resource enhancement wetlands or conservation category wetlands. The most significant wetlands lie along the course of Manjedal Brook (Figure A-4). The preservation of the pre-development hydraulic grade line along the Manjedal Brook will ensure that the potential for development impacts to this area will be minimised.

Further conservation category wetlands are located downstream of Galvin Road, Watkins Road, and along Mundijong Road. The preservation of the pre-development hydraulic grade line along this drainage route will ensure that the potential for development impacts to these wetlands will be minimised.

All proposed compensating basins have been located outside Conservation Category wetlands.

Development will result in the loss of significant areas of multiple use wetlands. The addition of imported fill and subsurface drainage will control groundwater levels and soil wetness and therefore reduce the extent of inundated areas. In addition, improvements to surface water drainage will result in less extensive surface inundation, which will be confined to predetermined locations within public open space areas.

Figure 4 Typical pre- and post-development runoff hydrograph comparison, with compensated post-development flows.



Manage and restore watercourses and wetlands

There are wetlands classified as Environmental Protection Policy (EPPW), Resource Enhancement (REW), and Multiple Use (MUW) within the study area. The EPA requires all EPPWs to be protected and managed for conservation purposes. The EPA also recommends the consideration of existing watercourses and inclusion of requirements for restoration, revegetation and reservation of an appropriate corridor width. For REWs, the EPA recommends the maintenance and enhancement the existing ecological functions.

Various guidelines are available for all aspects of wetland and watercourse protection and restoration and are published by the DoW and DEC.

Assess and manage impacts on native flora and fauna

As presented in Figure A.5 there are a number of declared rare and priority flora species within the study area, with one species shown (CALM 2003). Detailed flora and fauna assessments are required to be undertaken as part of more detailed levels of planning to ensure that development and subdivision is cognisant and sensitive to the protection of native flora and fauna.

Assess and manage impacts on sites of indigenous significance

As discussed in section 2.9.1 of this report, the Department of Indigenous Affairs has identified several sites of indigenous significance in the study area (Figure A-4). Prior to construction of individual developments, assessment should be undertaken by a qualified consultant to determine whether a more thorough Aboriginal heritage investigation of the area needs to be undertaken for any specific location to identify unregistered sites.

5. Urban Water Use

The key objectives for urban water use are to:

- Ensure the efficient use of all water resources in the newly-developing urban form and aim to achieve highest value use of fit-for-purpose water; and
- Maintain opportunities for future generations by using water more efficiently. This is best achieved by combining several approaches such as raising community awareness, regulation, market mechanisms to facilitate recognition of the true value of water and financial incentives/assistance to facilitate change.

These objectives will be met by the adoption of the following strategies:

5.1 Potable Water

The use of potable water should be minimised where water of drinking water quality is not essential, particularly outside the house.

Adopt Drinking Water Consumption Targets

The State Government has identified demand reduction and efficient use of potable water as a priority. The *State water plan* (Government of Western Australia 2007) sets household consumption targets of less than 100 kilolitres per person per year (kL/person/year for consumers within Perth and not more than 40 to 60 kL/person/yr of scheme water).

Gardens (private and public) and public open space areas need to be waterwise in design to minimise irrigation requirements. Low water requirement plants should be predominantly used and turf areas should be kept to a minimum.

5 Star Plus – Water Use in Houses Code – Stage 1

5 star plus is based around two new codes: the *Energy use in houses code* and the *Water use in houses code* The *Water use in houses code* has two stages; Stage 1 apples to new homes approved for construction after 1 September 2007. With the change in government, Stage 2 has been abandoned in favour of further national developments. Stage 1 still applies and is provided in Appendix C.

Use Only Water Efficient Fixtures and Fittings

It is proposed that only highly rated water efficient appliances and fittings are permitted within the study area. The Water Use in Houses Code Stage 1 Deem to Satisfy Provisions for water efficiency require all tap fittings other than bath outlets and gardens taps must be a minimum 4 stars Water Efficiency Labelling and Standards (WELS) rated, all showerhead must be a minimum 3 stars WELS rated and all sanitary flushing systems must be a minimum 4 stars WELS rated dual flush (DoHW, 2006).

The water-using products covered by the WELS Scheme and the proposed rating to be applied to the Redevelopment Area, are set out in Table 3.

Table 3 Specifications for Fixtures and Fittings

Product	Minimum WELS rating
Clothes washing machines	4
Dishwashers	4
Toilet (lavatory) equipment	4
Showers	3
Tap equipment	6
Urinal equipment	3

Prevent Water Loss and Use Hot Water Efficiently

The Water Use in Houses Code Stage 1 requires swimming pool cover/blankets and specifications or hot water use efficiency to prevent the excessive loss of potable water. Performance Requirements and Deem to Satisfy Provisions are detailed within the Code.

Ensure that Landscaping and Irrigation Use Water Efficiently

It is recommended that Public Open Space (POS) areas be designed to minimise irrigation requirements, with predominantly local native landscaping and keeping turf areas to a minimum. In addition POS irrigation should be restricted during the daytime between 9 am and 6 pm when evaporation is at a maximum.

Irrigation requirements for private gardens can be reduced by using subsurface irrigation, rain and soil moisture sensors, soil conditioners, wetting agents, mulches and xeriscaping (using plants with very little or no irrigation demand). Information regarding such measures will be made available to residents, through web-based information on the Mundijong / Whitby district.

5.2 Fit-for-Purpose Use Water

Ensure that non-potable water supply systems deliver a net benefit to the community

Meeting the potable water consumption target may be assisted through implementation of a fit-for-purpose use, or non-potable water supply system. Such a system cannot be established however without a detailed investigation into the associated potential risks. Possible risks associated with such systems largely relate to public health and the environment, particularly as the water is generally of poorer quality than potable water.

It is necessary to evaluate the potential public health risks, environmental impacts, financial costs, technical practicability, source viability and attitude of the local community against probable benefits of implementing a non-potable water supply system. Alternative water supply systems must therefore only be established in areas where the potential benefits outweigh the potential risks.

Further information relating to non-potable water use may be found in *Urban Non-Potable Water Use: Guidance for Developers and Consultants Considering Non-potable Water Options* (GHD, 2006), which outlines the benefits and limitations for a number of non-potable water supply options.

Ensure that non-potable water supply systems are designed as part of an integrated water supply

Non-potable water demands are only one part of the overall water demand within a development. Potable water demands and fire fighting requirements will also need to be met. The inclusion of a non-potable water supply system must not compromise the provision of other water services.

5.3 Key Design Criteria

- Consumption target for water of 100 kL/person/yr including not more than 40-60 kL/person/yr scheme water;
- Meeting 5 Star Plus provisions for all new dwellings;
- The use of native plants is to be promoted, with native species constituting a minimum of 30-35% of total POS area; and
- The use of on site rainwater tanks is to be promoted, to achieve water consumption targets whilst also having the ability to fully or partially meet on site retention requirements.

6. Stormwater Management Strategy

The key objectives for surface water management are:

- Protection of wetlands and waterways from the impacts of urban runoff; and
- Protection of infrastructure and assets from flooding and inundation.

6.1 Floodplain Management

Recommendations for floodplain management are presented in the *Floodplain management strategy* (SKM, 2007). This study developed two-dimensional modelling of the Mundijong-Whitby catchment and resulted in the identification of floodway and flood fringe areas. The proposed *Floodplain management plan* includes structural and non-structural measures for flood mitigation focussed on managing potential flooding impacts on the site and to the immediate neighbouring land and drainage infrastructure.

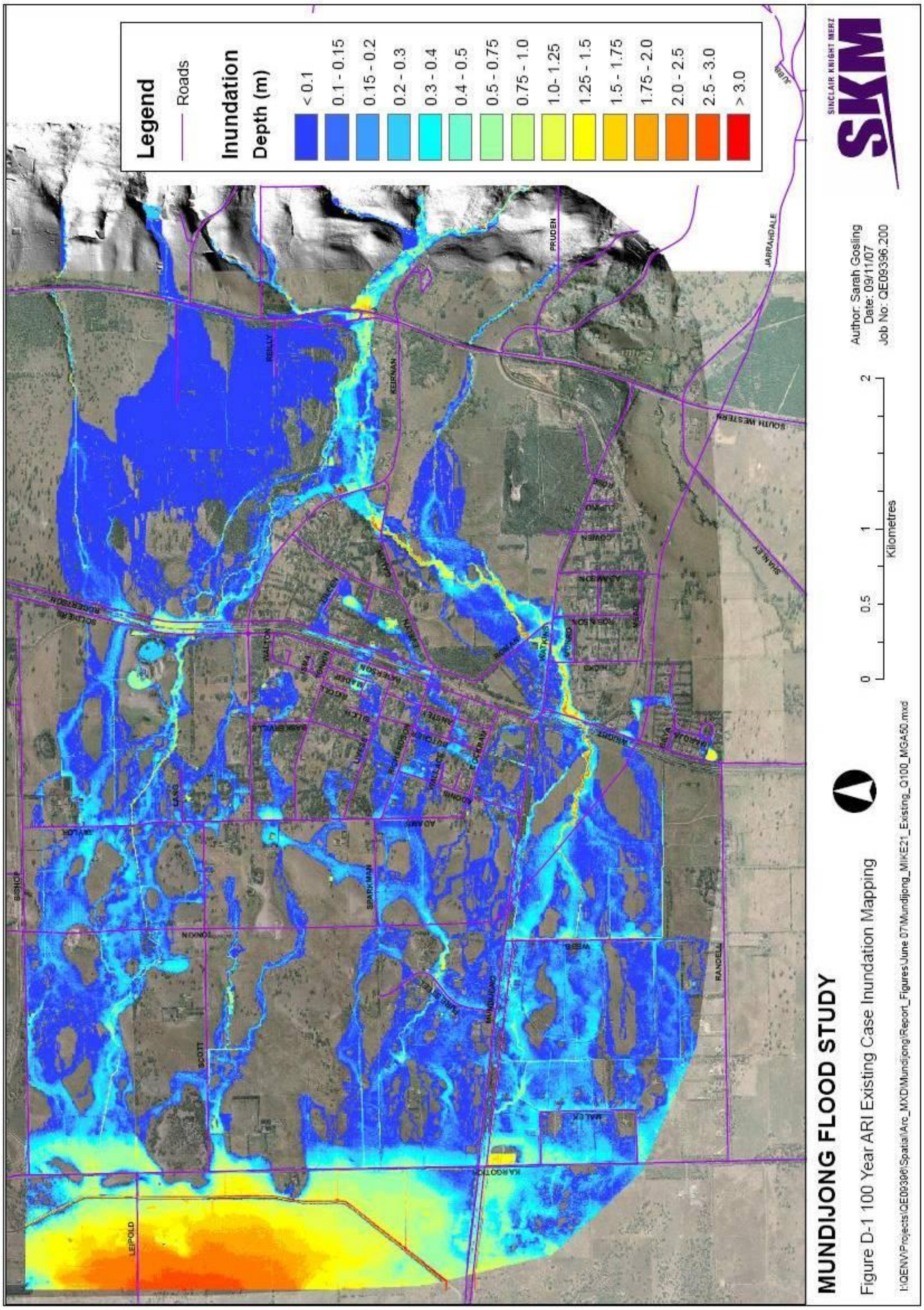
6.1.1 Flood Mitigation Measures

Flood mitigation measures are focussed on correct planning for appropriate land use in the structure plan areas and setting aside the land required for floodplain inundation depths. Existing and developed scenarios were presented within the *Floodplain Management Strategy* (SKM, 2007) and the *100-year ARI Existing Case Inundation Mapping* is reproduced in Figure 5 below. No 'developed' case investigations were undertaken in this report.

Planning measures recommended by the *Flood plain management strategy* are:

- New dwellings in proposed and existing residential areas must have their floor levels elevated 500 mm above the 100 year ARI flood level.
- New industrial or commercial premises should have their floor levels elevated 500 mm above the 100 year ARI flood level; and
- Major arterial roads with immunity to the 100-year ARI flood level that access new residential areas and can provide egress to emergency services must be identified. Other residential streets should be designed to be serviceable up to the five-year ARI flood event.

Figure 5 100 Year ARI existing case depth of inundation (SKM, 2007)



In addition, the following measures will assist flood mitigation:

- The design of the new urban areas should incorporate current best practice in water-sensitive urban design to mitigate the impacts of urbanisation in the catchments on regional water quantity and quality.
- The use of combined detention and infiltrations basins to throttle flow rates and increase groundwater recharge for flood events up to and including the 100-year ARI flood.
- Waterways within the structure plan area should be constructed to manage the flooding from the 100-year ARI flood event within their channels and floodplains without allowing flooding from the upstream catchment to enter adjacent residential areas; and
- New drainage corridors should be designed with consideration of the current practice in water-sensitive urban design by incorporating water quality management controls and riparian vegetation to allow the drainage paths to recover to a more natural state once the agricultural pressures are removed.

The Manjedal Brook floodway discharges along the northern outskirts of the existing Mundijong residential area, whilst a bifurcation of this floodway east of town causes a second floodway to discharge along the southern limits of the existing Mundijong residential area. The proposed town centre in the Planning Scheme was found by the *Floodplain Management Study* to be located between these two floodways and outside the flood fringe. A minor floodway discharges through the proposed town centre, however current modelling indicates that this risk is manageable and a strategy for addressing the flood risk for the proposed town centre is presented in Section 6.2 of this strategy.

A key recommendation within the *Floodplain Management Study* (SKM, 2007) was that emergency management planning should be undertaken to identify evacuation routes access for critical emergency services, as well as ensuring that locations are identified for temporary shelter that have sufficient floor level flood clearance.

Although located outside the study area, it is important to highlight that the proposed hospital is critical infrastructure and will need to be located outside the floodplain of the Probable Maximum Flood (PMF).

Construction of the Tonkin Highway has the potential to throttle stormwater discharging from the escarpment catchment. Assuming the highway culverts are designed for the 2% AEP flood event, less frequent flood discharges may be controlled by the highway culverts. It is assumed that the discharge from the highway itself will be discharged through detention basins to limit post development peak discharges to the predevelopment levels.

6.2 Surface Water Quantity Management

Minimise changes in hydrology to prevent impacts on receiving environments

Urbanisation results in increased impervious area. Increased rates and volumes of stormwater runoff must be managed to protect infrastructure and assets from flooding and inundation, whilst both water quantity and quality must be managed to protect wetlands and waterways from risk of increased inundation and contaminant loads. Surface water management must ensure that urban development does not increase the peak flows discharging to receiving environments.

Surface water quantity management is not only restricted to preventing runoff from increasing due to development but must also manage the maintenance or even restoration of desirable environmental flows and/or hydrological cycles where potential impacts on significant ecosystems such as wetlands are identified.

Design Objectives

- For the critical 1-year, 1-hour ARI event, the post-development discharge volume and peak flow rates shall be maintained relative to pre-development conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles as outlined in this report and approved by the Department of Water.
- Manage catchment runoff within the development area to predevelopment peak flow rates. Predevelopment critical 5- and 100-year ARI event peak flow rates are specified in Table 4 of this report and will be used for assessment of compliance with this objective.
- Water Sensitive Urban Design (WSUD) and Best Management Practices (BMPs) promoting on-site retention of events up to the 1-year 1-hour ARI form the basis of the surface water quantity management strategy for minor events.

Manage surface water flows from major events to protect infrastructure and assets

Hydrologic and Hydraulic modelling of the study area using InfoWorks CS has determined indicative subcatchment scale peak discharge flows and volumes, detention volumes required to manage surface water flows from major events, and hydraulic grade lines within the main waterways.

Detention volumes required to meet specified 5 and 100 year ARI peak flows are also presented in Table 4 of this report.

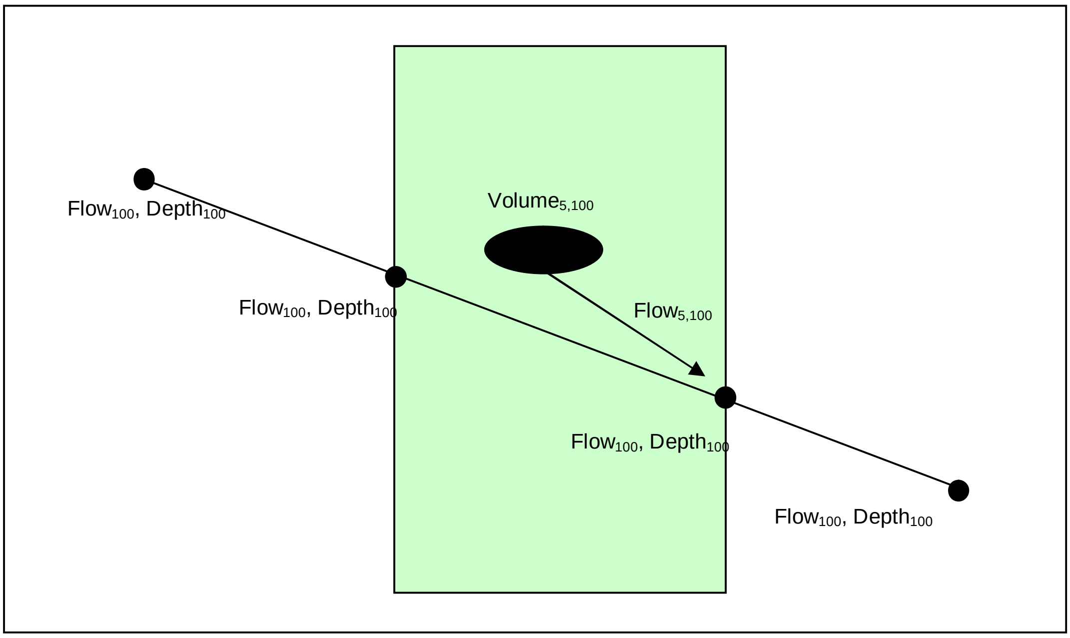
Figure A.9 in **Error! Reference source not found.** and Table 4 below present the proposed surface water management strategy for Mundijong-Whitby. Indicative 100-year annual recurrence interval flood levels, overland flow paths, subcatchment delineation (Figure A.9), and discharge flows and detention volumes (Table 4), are provided at critical locations as a guide to developers and should be refined and finalised during subdivision scale planning via the Urban Water Management Plan. Longitudinal sections of each main watercourse are available to assist with the design of subdivisional drainage and may be used to accurately determine flows and levels as the waterways pass specific locations that are not necessarily indicated in Figure A.9.

For each subcatchment, the critical 5- and 100-year ARI event pre-development discharge flow rates are presented in Table 4 along with an indicative post-development storage volume required to maintain that flow rate. The five-year ARI event is recommended by the Department of Water as the appropriate event for assessing the serviceability of local drainage, while flow paths and storage areas for the 100-year ARI event should be provided for flood management purposes in accordance with the *Australian Rainfall and Runoff* (IEA,2001) concept of a minor/major drainage system.

It is important to note that the DWMS model assumes that the 1-year 1-hour ARI event (from allotments and also from the road network) is retained at source, so this volume is not included in the indicative flood detention volumes provided in Table 4. Flows from the road network in a one-year ARI event should be retained (or detained for the duration of the 1-year ARI event) within the road reserve network in a manner that mitigates pollutant export.

Discharge flow rates quoted in Table 4 are not within main waterways and do not include flows generated by upstream subcatchments. Discharge criteria are set for whole subcatchments at the point at which they connect to main waterways as indicated by Figure 6 below.

Figure 6 Schematic presentation of information provided for subcatchments and main waterways



Where a proposed development forms a part of one or more of the subcatchments presented in Figure A.9, the storage volume to be provided by that development should be calculated based on the proposed development surface area as a percentage of the total subcatchment surface area.

Where there is an inconsistency between the drainage planning criteria presented in this report (Table 4) and a previous approval, then the previous approval, and associated developers' obligations, should prevail. However, in a case where greater detention volumes are required by this report (Table 4) than those previously approved, an assessment will need to be made of the impact on public and private amenity for the determining event and a judgement made on whether remedial work is required. The issue of who has responsibility for investigation and any remedial work need to be discussed and determined.

A summary of peak flows, levels and indicative floodway widths at critical locations at ultimate development (Figure A.9) is presented in Table 5 below.

Table 4 Subcatchment Drainage Planning Criteria – Ultimate Development

Sub-catchment ID	Area	Peak discharge flow (m^3/s)		Detention volume (m^3)	
	(ha)	5 year	100 year	5 year	100 year
B1	56.8	1.03	2.11	12400	18500
B7	44.6	1.5	2.15	6900	12600
B10	27.7	0.13	0.32	8300	13900

B17	66	0.37	1	19800	30000
B20	83	1.18	1.79	19700	32200
B27	65.2	0.27	0.77	20700	33400
B30	36	0.79	2.15	10600	18100
B34	29.8	0.14	0.21	10100	18600
B40	46.3	1	1.42	7700	13200
B42	41.6	0.51	0.78	9300	15200
B45	20.7	0.06	0.18	6100	11200
B56	154.4	1.77	2.71	33500	57200
B57	79.9	1.32	2.06	13600	22400
B57A	90.3	1.93	3.15	10800	17500
B57C	30.5	0.34	0.51	7500	13100
B59	39.1	0.91	1.96	6400	8000
B59A	48.5	0.74	1.26	8700	14100
B60	71.4	1.39	2.48	7700	12700
B61	43.7	1.05	1.62	5700	9200
B62	83.7	2.11	4.23	13700	18600

Table 5 Flows, Levels and Floodway Widths at Critical Locations – Ultimate Development

Location	Peak flows (m^3/s)		Peak levels (m AHD)		Indicative floodway width (m)
Number (Figure A.9) and description	**5 Year ARI**	**100 Year ARI**	**5 Year ARI**	**100 Year ARI**	**100 Year ARI**
M16 Creek 1 u/s of proposed Tonkin Hwy	8.89	13.77	26.13	26.14	80
M20 Manjedal Brook u/s of proposed Tonkin Hwy	27.61	41.96	27.15	27.26	160
M21 Creek 2 u/s of proposed Tonkin Hwy	2.86	5.72	26.77	26.80	230
M30 Creek 4 u/s of proposed Tonkin Hwy	5.35	9.55	25.55	27.24	40
M37 Creek 6 d/s of Wright Rd	13.43	29.83	31.48	31.63	25

M40 Creek 1 d/s of Soldiers Rd	6.34	10.76	35.06	35.12	190
M42 Creek 2 near Lang Rd	2.99	6.15	31.82	31.94	60
M43 Manjedal Brook d/s of Soldiers Rd	27.37	40.65	34.07	34.20	55
M56 Creek 1 d/s of South Western Hwy	5.89	10.82	65.01	65.12	140
M57 Manjedal Brook near Keirnan St	25.93	35.69	45.72	45.81	120
M59 Manjedal Brook d/s of South Western Hwy	9.92	18.54	56.86	56.95	110
M60 Creek 6 u/s of Watkins Rd	5.92	17.27	40.42	40.56	50
M60_01_u Creek 7 d/s of Calvin Rd	6.15	19.58	44.27	44.35	35
M60_07_u Creek 7 u/s of Calvin Rd	5.96	19.71	48.73	48.91	15
M61 Creek 6 near Keirnan St	2.02	3.44	53.67	53.84	10
M62 Creek 6 d/s of Watkins Rd	11.15	27.24	36.72	37.06	105
N10 Creek 4 d/s of Richardson St	2.37	4.29	30.79	30.84	400
N13 Creek 3 d/s of Adams St	0.9	1.76	28.34	28.37	130
N7 Creek 5 d/s of Adonis St	3.34	8.04	30.98	31.10	170

6.3 Surface Water Quality Management

The environmental values of downstream waterways within, and surrounding, the study area must be upheld.

Maintaining predevelopment discharge rates and volumes from developed catchments is expected to prevent the majority of contaminants from reaching the waterways by ensuring that the majority of flows from high frequency events are retained or infiltrated on site.

Provided that the initial flow of more significant events is subject to the same detention and treatment received by high-frequency events, surface runoff that occurs during more significant events represents a lower risk to downstream water quality. This is because nutrients and other contaminants that represent a threat to downstream water quality are typically transported within the ‘first flush’ of an event.

To minimise the average annual load of pollutants discharged by stormwater management systems into receiving environments, appropriate site-specific targets will be developed and adopted as indicated by the W*ater quality improvement plan for the rivers and estuary of the Peel-Harvey system, Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992* (Government of Western Australia) and other investigations underway.

The *Water quality improvement plan* has been developed to address catchment management measures and control actions relating to phosphorus, but does not specify site-specific design criteria. Until the outcomes of other investigations are known, and site-specific targets have been developed, interim targets will be adopted and are presented in section 6.5 of this DWMS.

The water quality objectives of the plan are:

- Median loadings of total phosphorus to estuarine waters should be less than 75 tonnes per annum in an average year;
- The median load of total phosphorus flowing in the estuary from the Serpentine River being less than 21 tonnes; and
- Water qualities in streams in winter are to meet mean concentrations of 0.1 mg/L TP at current mean flows.

In the Upper Serpentine catchment, the plan found that winter concentrations were in the range 0.1-0.2 mg/l and total winter loads were in the range 15-20 tonnes.

The *Water quality improvement plan* specifies that reductions of 30-40 per cent for both TP load and concentration are required in the upper Serpentine catchment to meet its objectives and recommends the following best management practices for urban areas:

Table 6 Recommended Best Management Practices

Best management practices	Definition of recommended action
Landscaping and application of fertiliser	Practise Xeriscaping (use of appropriate local native species) to minimise the need for fertiliser and irrigation
	Practise Hydrozoning (grouping plants with similar watering requirements) to reduce irrigation demand
	Use low water soluble fertiliser applied to sandy textured soils, applied sparingly to gardens and turf.
	Minimise lawn areas or plant an alternative lawn.
	Fertilise only when symptoms of nutrient deficiency occur e.g. yellowing.
	Use a complete lawn fertiliser containing nitrogen, phosphorus and potassium, if fertiliser is required.
	Apply fertiliser at the maximum individual application rate that is 25 grams per square metre for couch and 12 grams per square metre for kikuyu and buffalo grass.
	If fertiliser is required apply in spring or early autumn (Sept, Oct, Nov, Mar and Apr).
	Do not fertilise during summer or winter months.
	Do not over-water.

Full sewerage connection	Connect all new urban developments to sewerage. Build into approvals conditions by decision-making authorities for all new subdivisions and new homes to be connected to reticulated sewerage.
Soil remediation	Ensure all new urban developments in areas with sandy soils undergo soil remediation at the estate scale.
	At the lot scale blend or apply a layer of higher PRI soil 0-50 cm beneath the finished ground level to provide increased phosphorus retention.
	Use soil amendment materials such as yellow Spearwood sands, Karrakatta soils or brown loams.
	Remediate soil in accordance with Peel-Harvey coastal catchment water-sensitive urban design technical guidelines.
	Take care to maintain soil permeability.
Water and nutrient sensitive principles	Decision-making authorities should take a lead planning role in incorporating best management practices including water-sensitive urban design principles, criteria and outcomes in its strategic land use planning, policies structure plans and subdivision conditions.
Water-sensitive urban design	Comply with environmental quality criteria should be incorporated in local planning policy
	Ensure design complies with stormwater management policies
	Apply water-sensitive urban design treatment trains
	Prepare water management strategies
	Undertake soil amendment.
	Ensure total phosphorus and total nitrogen import and export criteria are met.
	Meet the minimum percentage area of deep-rooted perennial vegetation
	Impose building and landscaping covenants
	Ensure sound construction and building site management.
Drainage reform	Modify drainage management practices to reduce in-channel sediment movement as opportunities arise.
	Manage drainage as part of the total water cycle with the dual objectives of optimising stormwater runoff and reducing nutrient flows into the rivers and streams

The *Water quality improvement plan* has been developed to address catchment management measures and control actions relating only to phosphorus loads to the waterways. The Environmental Protection Authority recognises that there are other problems within the Peel-Harvey system. These include the nitrogen concentrations in estuarine waters; estuarine and riverine habitat loss; acid soil drainage; and bacteria concentrations – animal and human effluent. All of these problems require action.

Water quality treatment systems and water-sensitive urban design structures to meet these objectives must be designed, implemented and managed in accordance with the *Stormwater management manual for Western Australia* (Department of Water, 2007) and *Australian runoff quality* (Engineers Australia, 2006). This applies to the runoff from the proposed Tonkin Highway extension also. Management and containment of major spills from a tanker at critical locations is required to avoid ecological damage of the waterways.

6.4 Mosquito Control

Mosquito breeding sites can occur where there is standing water. Mosquito breeding can be controlled by ensuring:

- Detention basins drain within 3 days of filling;
- Detention basins are free from depressions, potholes, and related irregularities;
- Detention basins do not seep to other low lying areas;
- Stream water depths are adequate to support natural predators (e.g. fish) to consume the larvae;
- Bank gradients are steep enough not to trap pockets of stagnant water;
- Weeds are controlled in basins and streams;
- Stream water quality supports fish life;
- Residents are informed about mosquito breeding grounds and are advised to:
  - Dispose of all containers which hold water;
  - Keep ornamental ponds stocked with mosquito-eating fish, e.g. goldfish;
  - Empty pot plant drip trays once a week or fill with sand;
  - Empty and clean animal and pet drinking water once a week;
  - Keep swimming pools well chlorinated and filtered and free of dead leaves;
  - Fill or drain depressions in the ground that hold water;
  - Prevent leaking taps which can maintain semi-permanent pools;
  - Avoid over watering lawns. This can lead to high water tables or run off to storm water drains and create permanent pools;
  - Vent pipes on septic tank systems must be fitted with mosquito proof cowls. Seal all gaps in the lid, and ensure leach drains are completely covered;
  - Screen rainwater tanks and/or add paraffin oil to cover surface;
  - Ensure roof guttering does not hold water; and
  - Some plants (especially bromeliads) hold water in their leaf axils. These should be emptied of water once a week.

Chemical larviciding and adulticiding may be used if preventative measures are ineffective. In addition, mosquito monitoring traps may be set up to assess the numbers of mosquitoes in an area, for targeted control.

6.5 Key Design Criteria

6.5.1 Surface Water Quantity

- The 1-year 1-hour ARI event shall be retained at source through the use of retention (soakage) or storage devices. Refer to Chapter 9 of the Stormwater Management Manual for WA (DoW, 2007) for devices suited to the soil types for this catchment. The Stormwater

Management Manual for WA (DoW, 2007) contains guidance for the appropriate design of retention systems;

- The post-development critical 1-year ARI peak flow and volume and the 100-year ARI peak flow shall be consistent with pre-development flows at:
  - The discharge points of all subdivisions into waterways;
  - The discharge points from the Structure Plan study area; and
  - The discharge points of each subcatchment.
- Flows from developed areas must be attenuated, in accordance with Table 4 which protects the regional system, in flood detention/storage areas incorporated into POS within the subdivision and located outside defined floodways (Figure A.9);
- Post development flows for all ARI events must be discharged at flow rates which are consistent with predevelopment flow rates for those same events;
- Floodways are defined on Figure A.9 and contain the regional 100 year ARI event flow. Floodways may not be developed or obstructed in any way, and are entirely separate from the storage volumes presented in Table 4;
- Development outside of the Floodway should ensure finished floor levels at a minimum of 0.5 m above the 100 year flood level;
- The existing cross sectional area of waterways must be maintained. Restoration of waterways is essential and in some cases channel realignments and channel profile modifications may be carried out, provided it is demonstrated that the predevelopment cross-sectional area has been preserved. A permit may be required to alter the beds and banks of waterways under the *Rights in Water and Irrigation Act 1914;*
- Public open space and retention basins should operate as dry basins with a minimum clearance of 0.3 m between the controlled groundwater level and the invert of the basin. Wet basins are not recommended by the Department of Water and are unlikely to be approved by the Serpentine Jarrahdale Shire;
- Defined major arterial roads should remain passable in the 100-year ARI event;
- Minor roads should remain passable in the 5-year ARI event;
- Emergency evacuation areas defined at least 2.0 m above 100-year ARI event level; and
- Water Quality treatment systems and Water Sensitive Urban Design structures must be designed in accordance with the Stormwater Management Manual for Western Australia (DoW, 2007) and Australian Runoff Quality (Engineers Australia, 2006).

6.5.2 Surface Water Quality

The Department of Water is currently developing water quality targets that will be finalised in 2008. In the interim, designs may be based on the methodology established in the *Stormwater management manual for Western Australia* (Department of Water 2007).

Targets are to be achieved through adopting a treatment train approach including:

- Non-structural measures to reduce applied nutrient loads;
- On-site retention of one-year one-hour annual recurrence interval events; and

- Bioretention structures/systems, (also referred to as 'rain gardens') to be sized at approximately 2% of connected impervious areas.

As compared with a development that does not actively manage water quality, developments must achieve:

- At least 80% reduction of total suspended solids;
- At least 60% reduction of total phosphorus;
- At least 45% reduction of total nitrogen; and
- At least 70% reduction of gross pollutants.

Proponents shall develop and present the strategies for water quantity and quality management in the local water management strategy and urban water management plans to support the planning approvals required for the development to proceed.

Engineering drawings submitted to council for approval must be supported by clear and auditable documentation, providing details of proposed staging and implementation of the surface and groundwater quantity and quality management strategy.

It is strongly recommended that consultants meet with the local authority to discuss proposed surface and groundwater management strategies and to gain further guidance on site-specific requirements of the local authority at commencement of any local water management strategy or urban water management plan.

6.5.3 Design Standards

In addition to the manual and guides listed in sections 6.5.1 and 6.5.2 above, Council require that:

- Road reserves using bioretention structures/systems to be a minimum of 20m wide;
- Swales should only be installed on active frontages where the road reservation widths are conducive for the provision of such structures;
- Any stormwater generated within a subdivision parcel of land that is to be developed be attenuated within that parcel of land, and not passed on to other parcels. All lots are to attenuate and store water to meet the attenuation and storage requirements for the sub catchment;
- "Wet" basins and open water bodies are to be avoided; and
- Landscaping is to be integrated into the design of the water quality devices.

7. Groundwater Management Strategy

The key objectives for groundwater management are:

- Protection of infrastructure and assets from flooding and inundation by high seasonal groundwater levels, perching and/or soil moisture;
- Protection of groundwater dependent ecosystems from the impacts of urban runoff; and
- Managing and minimising changes in groundwater levels and groundwater quality following development/redevelopment.

7.1 Glossary of groundwater terms

Controlled groundwater level

Controlled groundwater level is a groundwater level endorsed by the Department of Water. Sub-surface drainage may not be installed below the controlled groundwater level.

The actual level selected will vary according to availability of data and/or modelling results. Commonly, when a modelling approach is used, the rainfall record for a year with close to average rainfall for the current climate is run and the winter maximum groundwater level for this scenario becomes the controlled groundwater level. Alternatively, where a historical groundwater record is available, the average of recorded maxima for a selected period of record that is representative of the current climate may be chosen.

Maximum groundwater level

Maximum groundwater level is a groundwater level endorsed by the Department of Water. The actual level selected will vary according to availability of data and/or modelling results, but is commonly the maximum recorded groundwater level for a high rainfall condition.

Developments will be required to make the development surface level 1.2 m above the maximum groundwater level, if subsurface drainage is not installed.

Phreatic line

The phreatic line is the modified (post-development) maximum groundwater level following the installation of subsurface drainage and is in fact an arc in between subsurface drainage lines, as indicated on the diagram below.

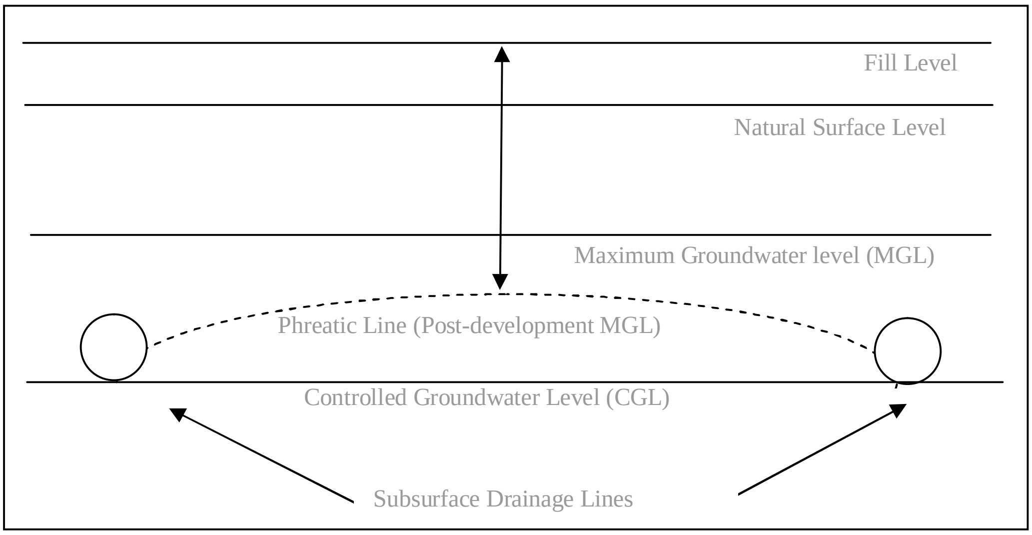
When subsurface drainage is installed the phreatic line becomes the level from which building floor level clearance to groundwater is measured.

Meeting the groundwater clearance and subsurface drainage criteria

Examples of different ways in which the groundwater clearance and subsurface drainage criteria may be met under different conditions are presented below.

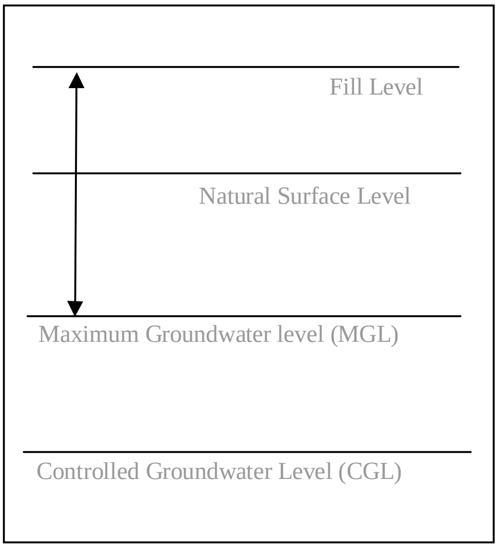
Case 1: The natural surface is less than 1.2 m above maximum groundwater level. Subsurface drainage is installed at controlled groundwater level to control the maximum groundwater level. However, because the natural surface is less than 1.2 m above the resultant phreatic line, some additional fill has also been provided to meet the minimum clearance requirement.

Figure 7 Groundwater Case 1



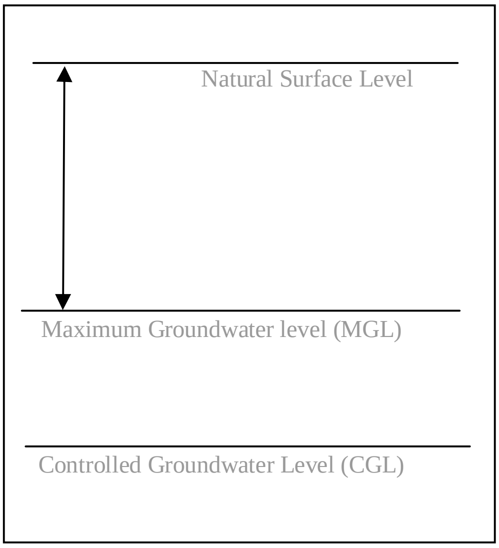
Case 2: The natural surface is less than 1.2 m above maximum groundwater level. Fill is provided to meet the minimum clearance requirement.

Figure 8 Groundwater Case 2



Case 3: The natural surface is greater than 1.2 m above maximum groundwater level. No fill or subsurface drainage is required to meet the minimum clearance requirement.

Figure 9 Groundwater Case 3



7.2 Groundwater quantity management

7.2.1 Manage groundwater levels to protect infrastructure and assets

To protect housing from flooding and damage from groundwater, the predicted maximum groundwater level must be determined, through modelling and/or measurement. Where this information is not available, local studies shall be undertaken and endorsed by the Department of Water. Where the predicted maximum groundwater level is at or within 1.2 m of the surface the importation of clean fill and/or the provision of sub surface, drainage will be required to ensure that adequate separation of building floor slabs from groundwater is achieved. In such instances, the sub-surface drainage will need to be placed at a Department of Water/Department of Environment and Conservation approved controlled groundwater level.

Groundwater modelling (CyMod Systems, 2007) included three scenarios – no development under average rainfall conditions (current climate) and proposed development under both average and wet rainfall conditions. Dry conditions were not selected as a post-development groundwater model.

Further information regarding the selection of pre- and post-development model scenarios and the construction and calibration of the groundwater model may be gained by requesting a copy of the *Groundwater modelling report* (CyMod Systems, 2007) from the Department of Water.

The district scale predicted maximum groundwater level has not been defined at this time for the study area. Localised perching that is common within this catchment cannot be accurately represented by district scale modelling and must be considered when determining the local scale predicted maximum groundwater level, which is important for the protection of urban infrastructure.

The district scale controlled groundwater level adopted for the study area and presented in Figure A-5 is the pre-development average rainfall scenario as modelled by CyMod Systems (2007).

Further investigations will be required to determine local scale predicted maximum groundwater level for individual developments to determine whether subsurface drainage is required for protection of urban infrastructure. This drainage should always be located at or above the district scale controlled groundwater level as presented in Figure A-5.

7.2.2 Maintain groundwater regimes for the protection of groundwater-dependent ecosystems

To ensure protection of groundwater dependent ecosystems, local studies to model and/or measure groundwater levels and refine the district scale controlled groundwater level shall be undertaken and endorsed by the Department of Water.

It has been identified that localised perching of groundwater is quite extensive within the development area. Where there is a groundwater-dependent ecosystem that is reliant on this seasonal perched groundwater, it will be necessary to maintain this regime. Investigations to derive a local scale controlled groundwater level shall be undertaken and endorsed by the Department of Water.

Local controlled groundwater levels must be developed with consideration of ecological water requirements for groundwater-dependent ecosystems, such as wetlands. Determination of ecological water requirements of groundwater-dependent ecosystems is outlined in the *Urban development and determination of ecological water requirements of groundwater-dependent ecosystems* (Department of Water, in preparation).

Once the ecological water requirements have been determined, controlled groundwater levels can then be finalised in accordance with the requirements of the *Decision process for stormwater management in WA* (Department of Environment and Swan River Trust, 2005). Controlled groundwater levels should always aim to meet ecological water requirements. However, if ecological water requirements cannot be met, the likely impacts on the groundwater-dependent ecosystems values should be outlined.

Any proposals to control the seasonal or long-term maximum groundwater levels through a controlled groundwater level approach should demonstrate through adequate field investigations, to the satisfaction of the Department of Water, how any local and regional impacts are to be managed.

7.2.3 Manage the shallow aquifer to protect the value of groundwater resources

Groundwater in the area is currently used for domestic and commercial purposes and is potentially an important source of water for new development in the area.

Groundwater modelling (CyMod Systems, 2007) has indicated that unmanaged future bore usage will result in long-term lowering of groundwater levels. Results for both of the proposed development scenarios predict decreases in groundwater levels when compared to the pre-development case. These results indicate that the level of bore usage assumed for the purposes of groundwater modelling cannot be supported. The post-development wet rainfall sequence scenario predicts groundwater levels of 0.40 m higher than those predicted for the average rainfall scenario, although they are still lower than those in the pre-development scenario.

In addition, the introduction of subsurface drainage may result in reduced aquifer recharge as a result of the loss of seasonal perching and its slow subsidence. Therefore it is proposed to provide infiltration systems as discussed in section 8.

If groundwater abstraction is to be supported for new development in the area, a water balance should be prepared as a part of a local water management strategy to identify the potential long-term impacts. Ongoing monitoring and control will be essential.

7.3 Groundwater quality management

The environmental values of groundwater within, and surrounding, the study area must be upheld.

> *Maintain groundwater quality at pre-development levels (median winter concentrations) and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the (sub) catchment in which the development is located.*

Water sensitive urban design and best management practices must not only promote infiltration to aid in prevention of possible local flooding from increased runoff due to urbanisation; but they must also treat the water prior to its discharge to waterways, wetlands and to groundwater. This is particularly important given the high variability in phosphorus retention capacity of the soils in the study area and the anticipated increase in nutrient load due to urbanisation.

Where subsoil drainage is installed for groundwater level or soil moisture control, a 'treatment system' (swale/bioretention etc) at each subsoil drain outlet point will be required. The *Stormwater management manual for Western Australia* (Department of Water 2004-07) contains guidance for the design of subsoil drainage, appropriate to calculated flow rates.

Where appropriate, field investigations must be undertaken to identify acid sulphate soils. Any reduction in groundwater level should not expose acid sulphate soils to the air, as this may cause groundwater contamination. If field investigations identify acid sulphate soils, further advice should be sought from the Department of Environment and Conservation.

Contaminated sites must be managed in accordance with the *Contaminated Sites Act 2003*.

7.4 Key design criteria

- Where a perched water table exists or the predicted maximum groundwater level is at or within 1.2 m of the natural ground level, the importation of clean fill and/or the provision of sub-surface drainage will be required to ensure that adequate separation of building floor slabs from groundwater is achieved. In such instances, the sub-surface drainage will need to be placed at or above the approved controlled groundwater level.
- The bio-retention system and drainage inverts are set at or above controlled groundwater level although existing inverts below the level may remain.
- Subsurface drainage is to be installed at or above controlled groundwater level.
- Subsurface drainage must be designed with free-draining outlets.

- Development should ensure finished lot levels at a minimum of 0.8 m above the phreatic line.
- The clean fill imported onto the site is to incorporate a band of material that will reduce phosphorus export via soil leaching, whilst also meeting soil permeability and soil compaction criteria specified by the local government authority.
- Where development is associated with any new or existing waterway or open drain that intersects the shallow water table, and that may discharge pollutants from the shallow groundwater to receiving environments, the following interim targets will be adopted until such time as appropriate site-specific targets are developed:

As compared with a development that does not actively manage water quality, the following should be achieved:

- At least 60 per cent reduction of total phosphorous; and
- At least 45 per cent reduction of total nitrogen.

Where development is associated with an ecosystem that is dependent on a particular hydrologic regime for survival, the water quality discharged to the groundwater must be in accordance with the requirements of the Department of Environment and Conservation.

Engineering drawings submitted to council for approval must be supported by clear and auditable documentation, providing details of proposed staging and implementation of the surface and groundwater quantity and quality management strategy.

It is strongly recommended that consultants meet with the local authority to discuss proposed surface and groundwater management strategies and to gain further guidance on site-specific requirements of the local authority at commencement of any local water management strategy or urban water management plan.

8. Commitment to Best Management Practice

8.1 Recommended Strategy

In order to meet the design criteria of reductions in TP, TN, TSS and gross pollutants as compared to developments in which water treatment is not undertaken, it is necessary to utilise a combination of Best Management Practice (BMP) strategies.

In addition, BMP strategies risks of flooding on housing and infrastructure whilst maximising the potential for stormwater to be treated as a resource.

The hierarchy of BMP principles is as follows:

- Implement controls at or near the source to prevent pollutants entering the system and/or treat stormwater;
- Install in-transit measures to treat stormwater and mitigate pollutants that have entered the conveyance system; and
- Implement end-of-pipe controls to treat stormwater, addressing any remaining pollutants prior to discharging to receiving environments.

Structural and non-structural BMP strategies must be used in combination to achieve the required stormwater treatment outcomes.

Recommended BMPs in increasing order of scale include:

- Residential lot scale:
  - On site soakage devices, with overflow outlets (Detention);
  - Water-wise and Nutrient-wise landscaping;
  - Porous pavements;
  - Amended topsoils; and
  - Rainwater tanks for harvesting, detention and re-use;
- Commercial lot scale:
  - On-site Detention and/or Retention;
  - Water-wise and Nutrient-wise landscaping;
  - Maximise permeable surfaces;
  - Porous pavements;
  - Amended topsoils;
  - Landscaped infiltration structures;
  - Hydrocarbon management and sediment traps; and

- Rainwater tanks for harvesting, detention and re-use.
- Street scale:
  - Infiltration measures;
  - Sediment traps;
  - Porous pavements (car parking); and
  - Conveyance bioretention systems.

- Estate Scale
  - Retention/detention (including water quality treatment) areas integrated within POS, in accordance with the objectives and requirements of Elements 4 (Public Parkland) and 5 (Urban Water Management) of Liveable Neighbourhoods Edition 4;

  - Using imported fill material with a high phosphorous retention capability;
  - Retain existing waterways and aim to restore a pre-development ecology and channel morphology in new and existing waterways; and
  - Non-structural BMPs such as interpretive signage, garden education programs, publishing a WSUD web-page for the estate, and inviting residents to engage with existing community catchment groups.
- Area scale:
  - Non-structural BMPs such as public education campaigns, support of local community catchment groups, installation of interpretive signage and webpages, and the adoption of appropriate planning principles including local laws for On-site Detention and Retention.

Typical drawings of online and offline infiltration basins, biofiltration pockets at verges and road nibs, and vegetated median swales are provided in Appendix A.

The above practices may be limited by several factors, including: local soil and hydrological conditions, the depth and type of fill imported, public safety and public health standards, design life/reliability requirements, maintenance/management costs, legal authority and streetscape aesthetics. Advice should be sought from the local authority on the practices most appropriate for adoption within the Mundijong / Whitby district.

8.2 Landscaping

To ensure that WSUD features perform well, look attractive, require low maintenance, and to extend their design life, it is important to choose appropriate plant species for the construction of the WSUD feature. The choice of plant species for use is a function of:

- Size of WSUD feature;
- Location of WSUD feature in relation to roads and public open space;
- Prevailing soils and climate;
- Ability of the plant to absorb nutrients;
- Ability of the plant to meet hydraulic requirements;
- Ability of the plant to undergo periodic inundation, if required;

- Water/ irrigation demand of plant and ability to withstand drought;
- Prevailing salinity;
- Local representation of plant species;
- Root structure and behaviour;
- Plant size; and
- Visual appeal of plant;

Based on the above criteria, Table 7 and Table 8 list the recommended species for use in the proposed WSUD features. Additional information about the species and their suitability for use is provided in Appendix F.

Table 7 Recommended Plant Species for Infiltration/ Detention Basins

Botanical Name		Common Name
Melaleuca	preissiana	Stout paperbark
Melaleuca	rhaphiophylla	Freshwater paperbark
Melaleuca	cuticularis	Saltwater paperbark
Melaleuca	lateritia	Robin redbreast bush
Banksia	littoralis	Swamp banksia
Banksia	seminuda	River banksia
Carex	appressa	Tall sedge
Carex	fascicularis	Tassel sedge
Carex	inversa	Knob sedge
Dianella	caerulea	King Alfred
Dianela	revoluta	Little Rev
Lomandra	histrix	Tropic Belle
Lomandra	longifolia	Lomandra

Juncus	caespiticius	Grassy rush
Juncus	holoschoenus	Jointleaf rush
Juncus	kraussii	Sea rush
Juncus	pallidus	Pale rush
Juncus	pauciflorus	Loose flower rush
Juncus	subsecundus	Finger rush
Goodenia	pulchella	subsp. Coastal Plain
Eucalyptus	occidentalis	Flat-topped-yate
Eucalyptus	rudis	Flooded gum
Casuarina	cunninghamiana	Casuarina
Ficinia	nodosa	Knotted club rush
Lepidosperma	gladiatum	Coastal sword-sedge

Table 8 Recommended Plant Species for Bioretention Swales/ Biofiltration Pockets

Botanical Name		**Common Name**
Carex	appressa	Tall sedge
Carex	appressa	Tassel sedge
Carex	inversa	Knob sedge
Juncus	caespiticius	Grassy rush
Juncus	holoschoenus	Jointleaf rush
Juncus	kraussii	Sea rush
Juncus	pallidus	Pale rush
Juncus	pauciflorus	Loose flower rush
Juncus	subsecundus	Finger rush
Ficinia	nodosa	Knotted club rush
Dianella	caerulea	King Alfred
Dianela	revoluta	Little Rev
Lomandra	histrix	Tropic Belle
Lomandra	longifolia	Lomandra
Lepidosperma	gladiatum	Coastal sword-sedge

9. Implementation

9.1 Requirements for following stages

State planning policy 2.9: water resources (Government of WA, 2006) requires that planning should contribute to the protection and wise management of water resources through local and regional planning strategies, structure plans, schemes, subdivisions, strata subdivisions and development applications. *Better Urban Water Management* (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts by Essential Environmental Services, 2008) provides guidance on implementation of *State planning policy 2.9.* It identifies the requirements for water management strategies and plans that must be developed to accompany the land use planning and approvals process in the *Mundijong-Whitby DWMS* area at each stage of the planning process

In summary, all local structure planning should incorporate a local water management strategy consistent with the strategies and objectives of this *Mundijong-Whitby DWMS*. Subsequent subdivision applications should be accompanied by an urban water management plan where required by the Department of Water and Serpentine Jarrahdale Shire, and/or should be consistent with any approved local water management strategy and with the strategies and objectives of this *Mundijong-Whitby DWMS.* Guidelines for local water management strategies and urban water management plans are in preparation by the Department of Water. In the interim the Department of Water regional office can be contacted for guidance on the requirements of these documents. Developers are encouraged to contact the Department of Water and Serpentine Jarrahdale Shire early in the planning process to discuss specific water management requirements for proposals

9.2 Review of District Water Management Strategy

It is intended that the *Mundijong-Whitby DWMS* be reviewed within ten years or earlier if deemed necessary until development has occurred consistent with the Mundijong-Whitby Structure Plan.

The review should be undertaken by the Department of Water, with agreement from the Environmental Protection Authority, Western Australian Planning Commission, Serpentine Jarrahdale Shire and the Water Corporation. The review should cover, but not be limited to the following:

- Assessment of impacts of development
- Design objectives
- Requirements for District Water management strategies and urban water management plans; and
- Cost-recovery mechanisms

9.3 Budget Estimates

9.3.1 Funding

Funding for the design and construction of both flood management measures and water quality measures can be sourced from a variety of stakeholders depending on the type of work being undertaken, and the point in time in which the funding is required. For example, bioretention swales and biofiltration pockets form part of the road reserve and are a substitute for hard engineering pit and pipe networks. Such capital works may therefore be funded by the developer of the road infrastructure as they are simply an alternative drainage solution and not an additional structure to what would normally be required. Maintenance and renewal of the bioretention swales and biofiltration pockets will be required after the developer's involvement in the area has concluded, so funding and responsibility for this work will need to be decided in advance.

Funding sources and methodologies for the flood management measures and water quality measures within the Byford release area is currently being investigated by Serpentine Jarrahdale Shire and the Western Australian Planning Commission. One of the methods being considered is a developer contribution scheme. A similar scheme may be viable for the Mundijong-Whitby area, but will need further investigation.

9.3.2 Life Cycle Cost Estimates

Life cycle cost estimates have been prepared for the flood management measures and water quality measures in accordance with the MUSIC model life cycle cost estimating relationships, based on parameters provided in Table 9 below. Life cycle cost estimate relationships are provided in Appendix E.

Table 9 Life Cycle Cost Estimate Calculation Parameters

Parameter	Value
Start Year	2010
Life Cycle (Term)	50 years
Real Discount Rate	5.5% p.a.
Inflation Rate	2.0% p.a.
Average Basin Depth	1.5 m
Bioretention Treatment Area as a percentage of impervious catchment surface area	1.5%
Percentage of total impervious catchment that is treated by bioretention swales	50%
Average Lot Yield	12 lots/Ha
Percentage of lots that will have a rainwater tank	50%
Average Tank Size	5 kL

Parameter	Value
Land Value[3]	$17.42 /m^2

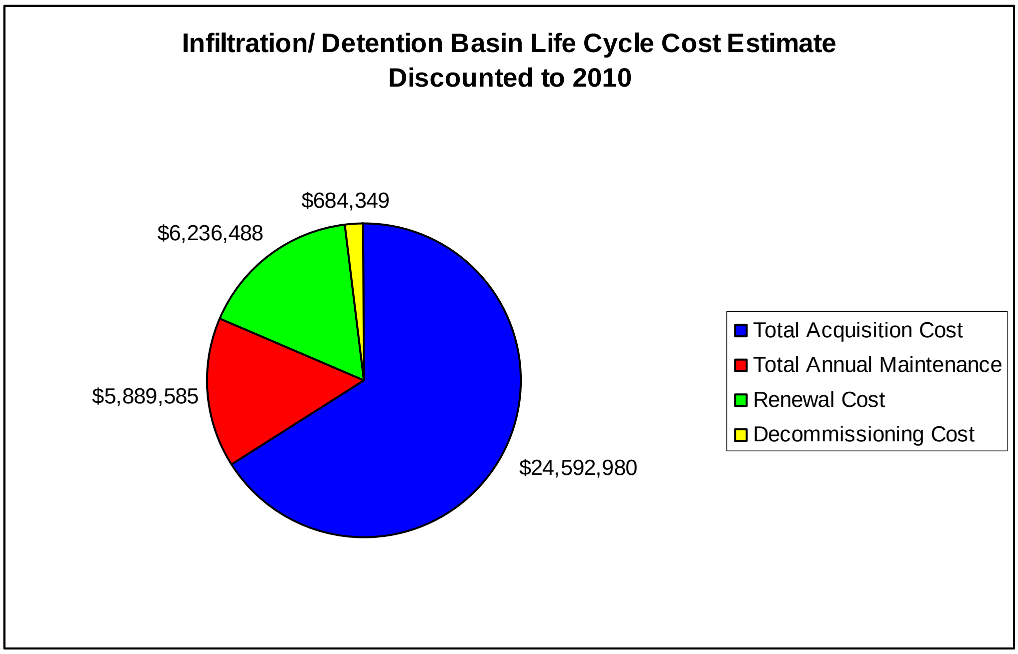
The cost estimates presented in this section have been developed solely for the purpose of comparing and evaluating competing options. They are sufficiently accurate to serve this purpose. They cannot be used for budget-setting purposes because, while allowances for common elements have been made, they may or may not include all the works required under this project. Further design work is recommended if a budget estimate is required.

Infiltration/ Detention Basins

Infiltration/ Detention Basins are primarily a flood mitigation measure with the ability to improve water quality. Approximately 65% of the total life cycle cost is the capital expenditure of the basin, with most of the remaining expenditure related to maintenance and renewal.

Benefits have not been calculated, but typically arise from savings in flood damage (structural damage, contents damage, infrastructure damage, indirect and intangible damages), the ability to develop flood prone land, and broader social and environmental benefits associated with reduced flooding and water quality improvements.

Figure 10 Infiltration/ Detention Basin Life Cycle Cost Estimate



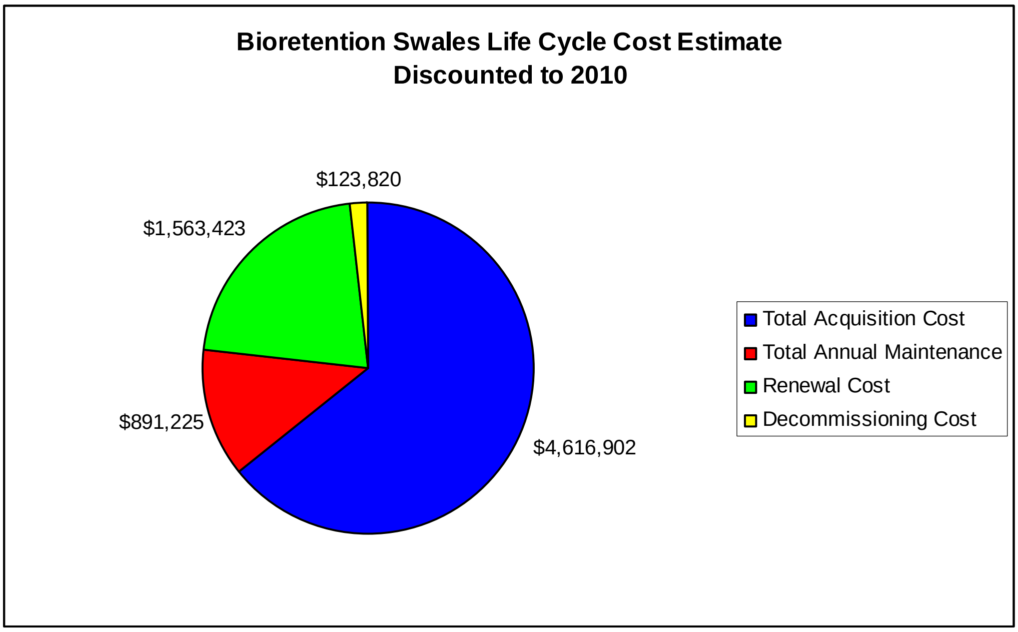
Bioretention Swales and Biofiltration Pockets

Bioretention Swales are a WSUD alternative to traditional pit and pipe networks, providing stormwater drainage and treatment. They have a similar life cycle cost breakdown to infiltration basins, with less spent on maintenance and more on renewal.

[3] Based on Asking price for Lot 200, 52 Adamson St, Mardella (http://www.homehound.com.au/lot+200+52+adamson+street+mardella+wa+6125/)

Benefits have not been calculated but would typically arise from savings in cost of traditional pit and pipe systems, and broader social and environmental benefits associated with an improved natural environment.

Figure 11 Bioretention Swales Life Cycle Cost Estimate



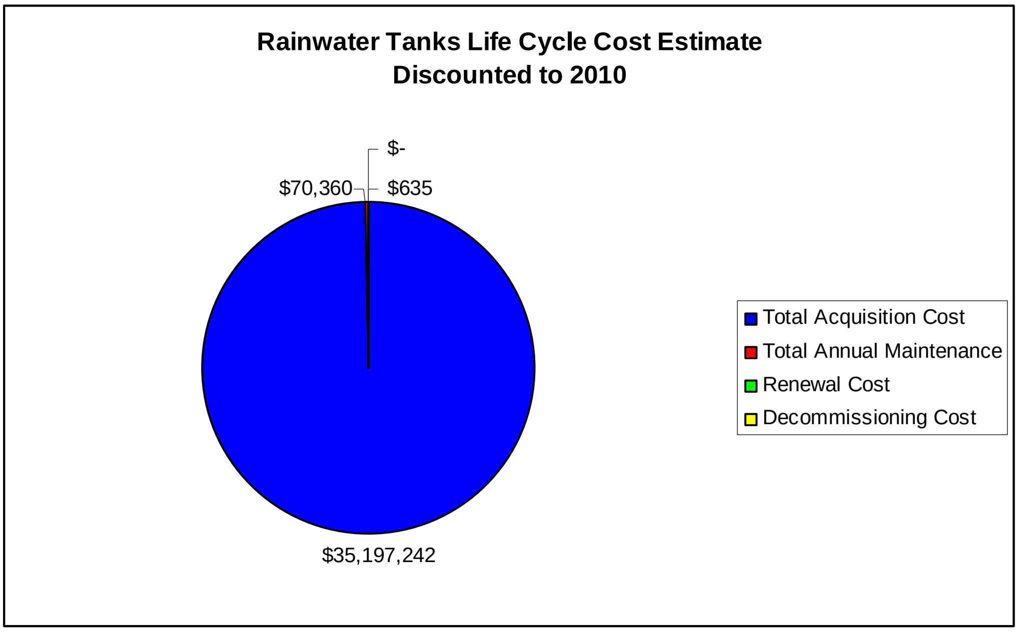
Rainwater Tanks

Rainwater Tanks provide residents and/or businesses with an alternative water source, reducing demand on potable water. With minimal maintenance and decommissioning, and no renewal, expenditure is almost 100% capital acquisition costs.

Benefits have not been calculated but would typically arise from savings to the water authority in the cost of supplying additional potable water, and savings to the water consumer from a reduced potable water demand. Ignoring environmental and social costs and benefits, the Net Present Value of a 5 kL tank catching a 200 m^2 roof in Perth is approximately -$2700[4]. Depending on how the tanks are configured, there could also be benefits of reduced runoff on associated infrastructure.

[4] Interpolated from "The cost effectiveness of rainwater tanks in urban Australia", March 2007, Marsden Jacob Associates

Figure 12 Rainwater Tanks Life Cycle Cost Estimate



9.4 Monitoring strategy

A groundwater and surface water monitoring program should be designed as part of the local water management strategy to assess the hydrological impacts of the proposed development and to establish a contingency action plan with associated trigger values for specified parameters.

The baseline monitoring program should be conducted for at least three years prior to development to characterise the sites hydrology and hydrogeology. However in some cases it may be acceptable to provide 18 months of pre-development monitoring with a minimum of two winters where the monitored hydrology and hydrogeology is considered suitably reflective of the long-term environment, and approval has been given by the Department of Water. The results of the baseline monitoring strategy should be presented in the final local water management strategy.

The post-development monitoring program should be tailored to the development, quantifying the development's impact on surfaces water quality, surface water flows, groundwater levels seasonal fluctuation and quality.

The monitoring results can then provide:

- pre-development baseline data
- post-development comparison to target design objectives and criteria
- a trigger for contingency action, as per the contingency plan
- an interim internal assessment tool of the monitoring programme

All monitoring results should be provided to the Department of Water in an agreed format. A report on these results is not usually required; however where a trigger for contingency action has been reached, it will be necessary to report on the action taken.

Standards

Monitoring sampling should follow Australian Standards AS/NZ 5667 series of *Water quality sampling* guidance notes and a National Association of Testing Authorities accredited laboratory is required to perform water quality testing.

Monitoring network

The groundwater monitoring bore network's extent and density should spatially represent the hydrogeology of the local area, to the satisfaction of the local government and Department of Water.

Surface water monitoring sites should capture inflows and outflows for the whole site, all detention or retention storages, and any water dependent ecosystems.

Monitoring parameters

Monitoring of groundwater levels should be initially on a monthly basis to establish water level fluctuations. Surface water monitoring requirements are site-specific and must meet the regulatory bodies' recommendations.

Samples should be analysed for at least the following water quality parameters:

- *in-situ* pH, electrical conductivity and temperature
- heavy metals - arsenic, cadmium, chromium, copper, lead, nickel, zinc, mercury
- total suspended solids
- total nitrogen and total kjeldahl nitrogen
- ammonia (NH4)
- nitrate and nitrite (NO_x)
- total phosphorus (TP)
- orthophosphate (PO_4^{3-})

The following additional parameters are recommended in locations where drainage intercepts shallow groundwater systems:

- total titratable acidity and total alkalinity
- major anions (chloride, bromide and sulphate)
- major cations (calcium, magnesium, sodium and potassium)
- iron and aluminium

The effective management of urban stormwater quality typically focuses on the treatment of frequent, low-intensity stormwater events. These small but frequent flows account for the majority of nutrient loads and represent the best opportunity for water quality improvement.

The process of infiltration filters the stormwater and is effective in the removal of particulate nutrients. Dissolved nutrients cannot be filtered and are therefore more difficult to treat. Urban runoff is a combination of dissolved and particulate nutrients.

If the treatment measure is infiltration, then filtered and unfiltered samples of total nutrient concentrations should be measured to quantify the proportion of dissolved and particulate nutrients generated within the development site, and the method recorded.

Program

A summary of an example monitoring program is presented in Table 10 below. The format and frequency of post-development reporting should be proposed within the local water management strategy and approved by the local government and Department of Water. Where a trigger for contingency action, as specified in the local water management strategy is reached, it will be necessary to report on the action taken.

Table 10 Monitoring programme summary

	Sites	Frequency	Parameters
Surface water	Developments inflow and outflow locations Detention storages inflow and outflow Water bodies	Site specific	-Flows -Water levels
		Monthly grab samples while flowing, to be reviewed after the first year of monitoring	-**In-situ** pH, EC and temperature. -**Unfiltered sample**: pH, EC, TN, FRP, TKN, ammonia, TP, heavy metals -**Filtered sample**: nitrate/nitrite and PO4,
Groundwater	Network of monitoring bores providing a suitable spatial representation of the study area.	Monthly	Water level
		Quarterly (typically Jan, Apr, July, Oct)	-**In-situ** pH, EC and temperature. -**Unfiltered sample**: pH, EC, TN, FRP, TKN, ammonia, TP, heavy metals -**Filtered sample**: nitrate/nitrite and PO4

A summary of monitoring requirements and responsibilities is provided in Table 11.

Table 11 Assessment requirements of development proposals - monitoring

Responsible Agency	Timing	Monitoring Requirement
Developers	Period of 3 years pre-development (minimum of 18 months with at least 2 winters with approval of DoW)	Monitor key criteria for maintenance of hydrologic regimes, buffers and ecological corridors/linkages of environmental assets Monitor local superficial aquifer groundwater levels Monitor flow and water quality (including nutrients, TSS, and gross pollutants) at regular intervals (monthly) Monitor peak flows (snapshots) within developments and wetlands
	Period of 3 years post-development, including at least 1 year following completion of the majority (80%) of developments	Monitor key criteria for maintenance of hydrologic regimes, buffers and ecological corridors/linkages of environmental assets Monitor local superficial aquifer groundwater levels Monitor flow and water quality (including nutrients, TSS, and gross pollutants) at regular intervals (monthly) Monitor peak flows (snapshots) within developments and wetlands Monitor behavioural patterns with respect to non-structural measures for water quality management Monitor performance of new drainage systems

DoW	Ongoing	Monitor efficacy of water conservation measures and achievement of water consumption targets Monitor regional surface water flows and quality Monitor confined aquifer groundwater levels and regional superficial aquifer groundwater levels and quality Monitor groundwater abstraction in the DSP area Monitor surface water quality and flows at strategic locations in main drains and waterways Monitor structural BMPs for efficacy with advice from the BMP technical reference group Monitor performance of new drainage systems across catchments and property boundaries
SJ Shire – with funding from developer contributions scheme	From 3 years post-development	Monitor key criteria for maintenance of hydrologic regimes, buffers and ecological corridors/linkages of environmental assets Monitor local superficial aquifer groundwater levels Monitor water quality and flows within developments and wetlands Monitor behavioural patterns with respect to non-structural measures for water quality management
DEC	Ongoing	Evaluate health of significant environmental assets

9.5 Action plan

Table 12 presents the key actions necessary to implement the proposed DWMS, identifying the responsible agency and proposed time for completion. “SJ Shire” refers to Serpentine-Jarrahdale Shire.

Table 12 Actions and responsibilities for implementation of the DWMS

Strategy	Action	Lead agency	Timing
Protection of environmental assets			
Minimise changes to hydrology to prevent impacts on watercourses and wetlands	Establish a process for ongoing evaluation of the impacts of development on significant environmental assets and review of the strategy	DoW	As part of the planning process
	Identify land required for protection of environmental assets and to allow for the management of their hydrologic regimes	DEC	As part of the planning process
	Incorporate environmental assets as a key part of community planning	DPI and SJ Shire	Through assessment of planning proposals
Assess and manage impacts on native flora and fauna	Provide appropriate buffers and ecological corridors/linkages in local structure plans	WAPC and SJ Shire	Through assessment of planning proposals
	Establish responsibilities for ongoing management of natural areas	DEC and SJ Shire	As part of the planning process
	Undertake more detailed fauna assessments at the local structure plan stage, including details of management measures to deal with issues such as	WAPC and SJ Shire	Through assessment of planning proposals

	habitat protection, fauna relocation and non-native animal control		
Assess and manage impacts on sites of indigenous significance	Undertake more detailed assessments at the local structure plan stage, including details of management measures as required	Developers in consultation with DIA and SJ Shire	Through local structure planning
Surface water management			
Minimise changes in hydrology to prevent impacts on receiving environments	Ensure development complies with the stormwater design objectives for flooding and ecological protection	DoW	Through assessment of LWMS/UWMP
Manage surface water flows from major events to protect infrastructure and assets	Ensure development in the DSP area complies with the stormwater design criteria for flood management in this DWMS	SJ Shire	Through assessment of LWMS/UWMP
	Secure land that might be required for arterial drainage in the Mundijong town site catchment	WAPC and SJ Shire	Through local structure planning
	Design and construct regional flood management infrastructure	SJ Shire with funding from developer contribution scheme	Through local structure planning
Apply the principles of water sensitive urban design	Seek opportunities to include environmental and social objectives in planning of stormwater management, such as incorporation of multiple use corridors to provide habitat values and opportunities for recreation	SJ Shire	Through assessment of local structure plans
	Retain existing natural waterways and drainage lines in the design of stormwater management systems for urban development – requires modification of existing BSP	SJ Shire	Through modification of BSP and assessment of LWMS/UWMP
Adopt nutrient load reduction design objectives for stormwater runoff	Ensure development in the DSP area complies with the design objectives for stormwater quality	SJ Shire	Through assessment of LWMS/UWMP
Floodplain management and urban drainage	Ensure hydraulic properties of WSUD structures are maintained	SJ Shire	Commencing post development and ongoing
Groundwater management			
Manage groundwater levels to protect infrastructure and assets	Monitor superficial aquifer groundwater levels pre- and post-development at the local scale	Developers' data to be passed by SJ Shire to DoW for collation	3 years each pre- and post-development
	Monitor confined aquifer groundwater levels and regional superficial aquifer groundwater levels	DoW	Commencing immediately and ongoing
	Investigate potential changes to local water balance and implications for groundwater rise	DoW	Through assessment of LWMS/UWMP
	Manage groundwater levels within ranges reported in this *DWMS* via a combination of subsoil drainage at local CGLs, imported fill and groundwater abstraction as appropriate for management of groundwater rise, and via recharge mechanisms for falling	Developers for 3 years post-development, after that time responsibility of SJ Shire	Commencing immediately and ongoing

	groundwater levels		
Maintain groundwater regimes for groundwater dependent ecosystems	Review developers' investigations of local groundwater regime to establish local groundwater management criteria near GDEs	DoW	Through assessment of LWMS/UWMP
Protect the value of groundwater resources	Prepare a groundwater allocation plan for the DSP area	DoW	Commencing immediately and ongoing
Adopt nutrient load reduction design objectives for discharges to groundwater	Ensure development in the DSP area complies with the design objectives for groundwater quality	DoW	Through assessment of LWMS/UWMP
Monitoring and implementation			
Adopt an adaptive management approach	Monitor water quality and flows pre- and post-development, within developments and at strategic locations in waterways This includes both regular (monthly) sampling for flow and water quality and targeted peak flow during storm events Locations to include key outlets to waterways	At the local scale: developers then SJ Shire, data to be passed to DoW for collation At the regional scale (sub-catchment outlets): DoW	3 years pre- and post-development, then ongoing
	Collate and analyse monitoring data to establish baseline water quality data throughout DSP area	Developer to pass data to DoW, DoW to collate and organise data, CSIRO's real-time data collection system to support the data analysis	Commencing immediately and ongoing
	Assess behavioural patterns with respect to non-structural measures and the effectiveness of non-structural measures, using a method such as community-based social marketing	Developer to implement with guidance from local government, local government to take over responsibility 3 years post-development	Ongoing
	Determine efficacy of structural BMPs, provide feedback to developers and allow for alteration of practices if necessary	DoW and local government with advice from the BMP technical reference group	Ongoing
	Engage the research community in the process of evaluation and feedback	DoW with advice from the BMP technical reference group	Ongoing
Maintain drainage and treatment structures	Maintain the drainage and treatment structures implemented, in particular during the initial construction and building development phase for the subdivision.	Developer	During infrastructure construction and building works
Water Conservation			
Adopt drinking water consumption target	Ensure that residential development complies with the water conservation design objectives	DoW	Through assessment of LWMS/UWMP
	Ensure scheme water substitution does not lead to an overall increase in water consumption	DoW	Through assessment of LWMS/UWMP

Ensure that non-potable water supply systems deliver a net benefit to the community	The impact of a non-potable water supply system on the local water balance must be assessed as part of the local water management strategy	DoW	Through assessment of LWMS/UWMP
	The design of a non-potable water supply system must be subject to a sustainability assessment as part of the local water management strategy to determine the net benefit or cost of the scheme	DoW	Through assessment of LWMS/UWMP
Ensure that non-potable water supply systems are designed as part of an integrated water supply	Non-potable water supply systems must be designed in conjunction with potable water supply systems, to ensure that fire-fighting requirements can be met from one or both of the systems and that both systems are designed for efficiency (e.g. minimising pipe sizes and pumping requirements where possible)	DoW	Through assessment of LWMS/UWMP
	Reach agreement between the developer, SJ Shire and licensed service provider (e.g. Water Corporation) on the design, operation and management of a non-potable water supply system, including arrangements for use in public open space and appropriate level of water quality, to ensure that all water demands are met appropriately	DoW	Through assessment of LWMS/UWMP

10. List of shortened forms

ADS	Arterial drainage scheme
AHD	Australian height datum
ARI	Average recurrence interval
BFS	Bush Forever site
CCW	Conservation category wetland
CGL	Controlled groundwater level
DEC	Department of Environment and Conservation
DoW	Department of Water
DPI	Department of Planning and Infrastructure
DRF	Declared rare flora
DSP	District structure plan
DWMP	Drainage and water management plan
DWMS	District water management strategy
EWR	Environmental water requirement
GDE	Groundwater-dependent ecosystem
HGL	Hydraulic grade line
LWMS	Local water management strategy
MUW	Multiple use wetland
PWSA	Public water supply area
REW	Resource enhancement wetland
SJ Shire	Serpentine Jarrahdale Shire
TEC	Threatened ecological community
ToK	Town of Kwinana
TN	Total nitrogen
TP	Total phosphorous
TWG	Technical working group
TWL	Top water level
UWMP	Urban water management plan
UWPCA	Underground water protection control area

WAPC	Western Australian Planning Commission
WDE	Water-dependent ecosystem

11. References

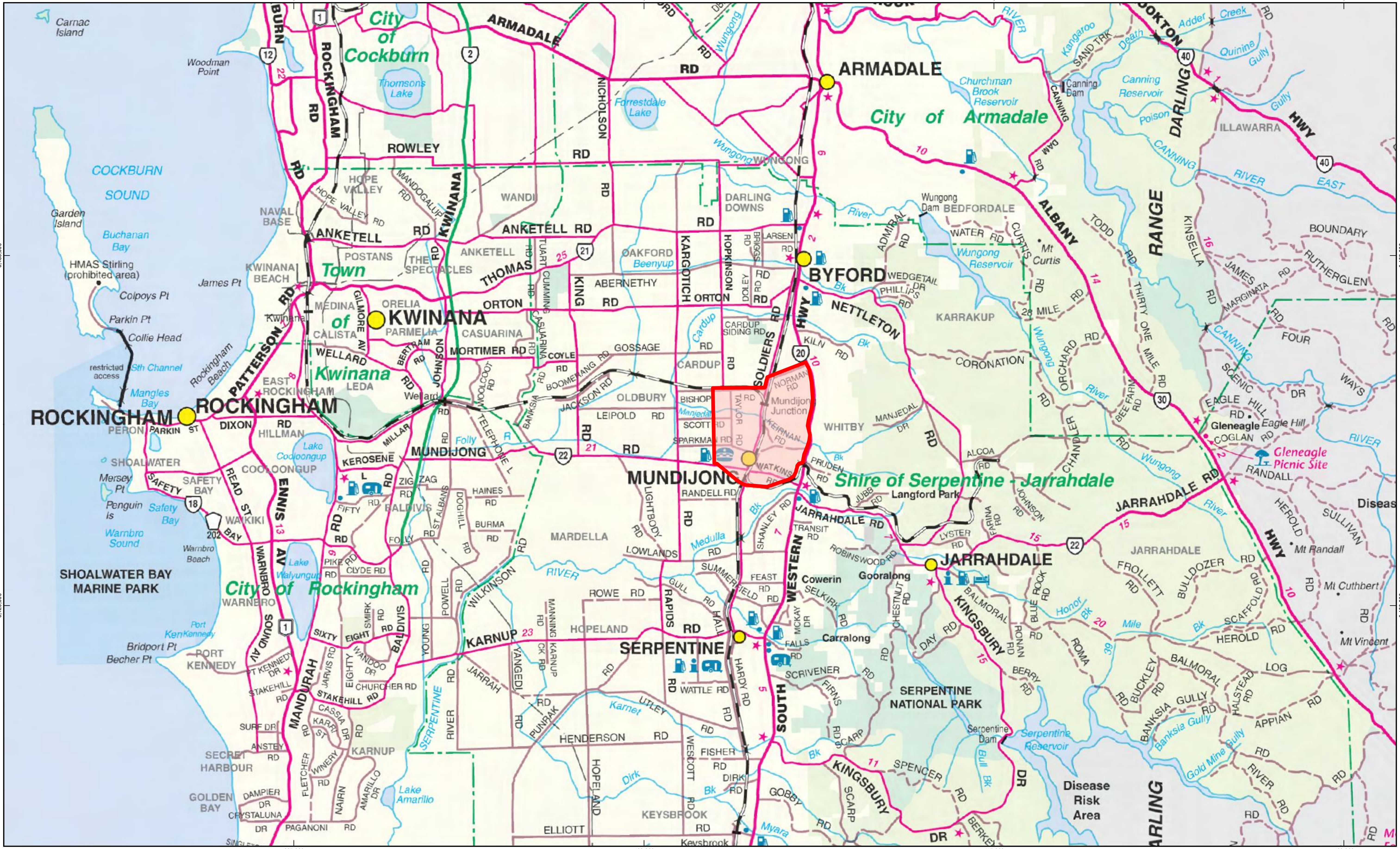
- CALM, 2003. Lambertia multiflora var. multiflora, photograph by M. Kealley.
- CyMod Systems Pty Ltd. 2007, Local Scale Groundwater Modelling to Assess Effects of Climatic Variations and Planned Development, Department of Water.
- Department of Water, 2004-07. Stormwater Management Manual for Western Australia, Perth.
- Department of Water, 2007. Interim Position Statement: Constructed Lakes, Perth.
- Department of Water, 2008. Urban Water Management Conditions – Guidelines for Compliance, Perth.
- Department of Environment & Swan River Trust, 2005. Decision Process for Stormwater Management in WA, Perth.
- Department of Housing and Works, 2007. 5 Star Plus, Energy Use in House Code, Water Use in House Code, Perth.
- Environmental Protection Authority, 2004. Revised Draft Environmental Protection (Swan Coastal Plain Wetlands) Policy 2004, Perth.
- Environmental Protection Authority, 2008. Water Quality Improvement Plan for the Rivers and Estuary of the Peel-Harvey System, Perth.
- GHD, 2006. Urban Non-potable Water Use: Guidance for Developers and Consultants Considering Non-potable Water Options, Water Corporation.
- Government of Western Australia, 1992. Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992,Government Gazette Perth.
- Government of Western Australia, 2007. State Water Plan [online], available from:<http://portal.water.wa.gov.au/portal/page/portal/PlanningWaterFuture/StateWaterPlan> [27 August 2007].
- SCARM, 2000. Floodplain Management in Australia – best practice principles and guidelines, Agriculture and Resource Management Council of Australia and New Zealand, Standing Committee on Agriculture and Resource Management Report No 73, CSIRO Publishing, Collingwood Victoria.
- Statewest Surveying & Planning, Chris Antill Planning & Urban Design, McDowall Affleck, Thompson Partners and Landform Research, 2005. Byford Townsite Detailed Area Plan, Shire of Serpentine Jarrahdale.
- SKM, 2007. Mundijong Floodplain Management Study, Department of Water.
- Western Australian Planning Commission, 2008. Liveable Neighbourhoods Edition 4, Perth.
- Western Australian Planning Commission, 2008. Better Urban Water Management, Perth.
- Western Australian Planning Commission, 2003. Planning Bulletin No. 64: Acid Sulphate Soils, Perth.
- Western Australian Planning Commission, 2004. Statement of Planning Policy No 2.9: Water Resources Policy, Perth.

- Water Sensitive Urban Design (WSUD) in the Sydney Region, 2006. WSUD in the Sydney Region [online], available from: <http://wsud.org> [31 July 2007].

Appendix A

Figures

{Blank Page for Double Sided Printing}



1:150,000 (at A3)

0 0.75 1.5 3 4.5 6 7.5

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

LEGEND

Study Area - GHD - 20080616

Shire of Serpentine-Jarrahdale
Mundijong Whitby
District Water Management Strategy

Job Number	6122035
Revision	0
Date	09 Sep 2009

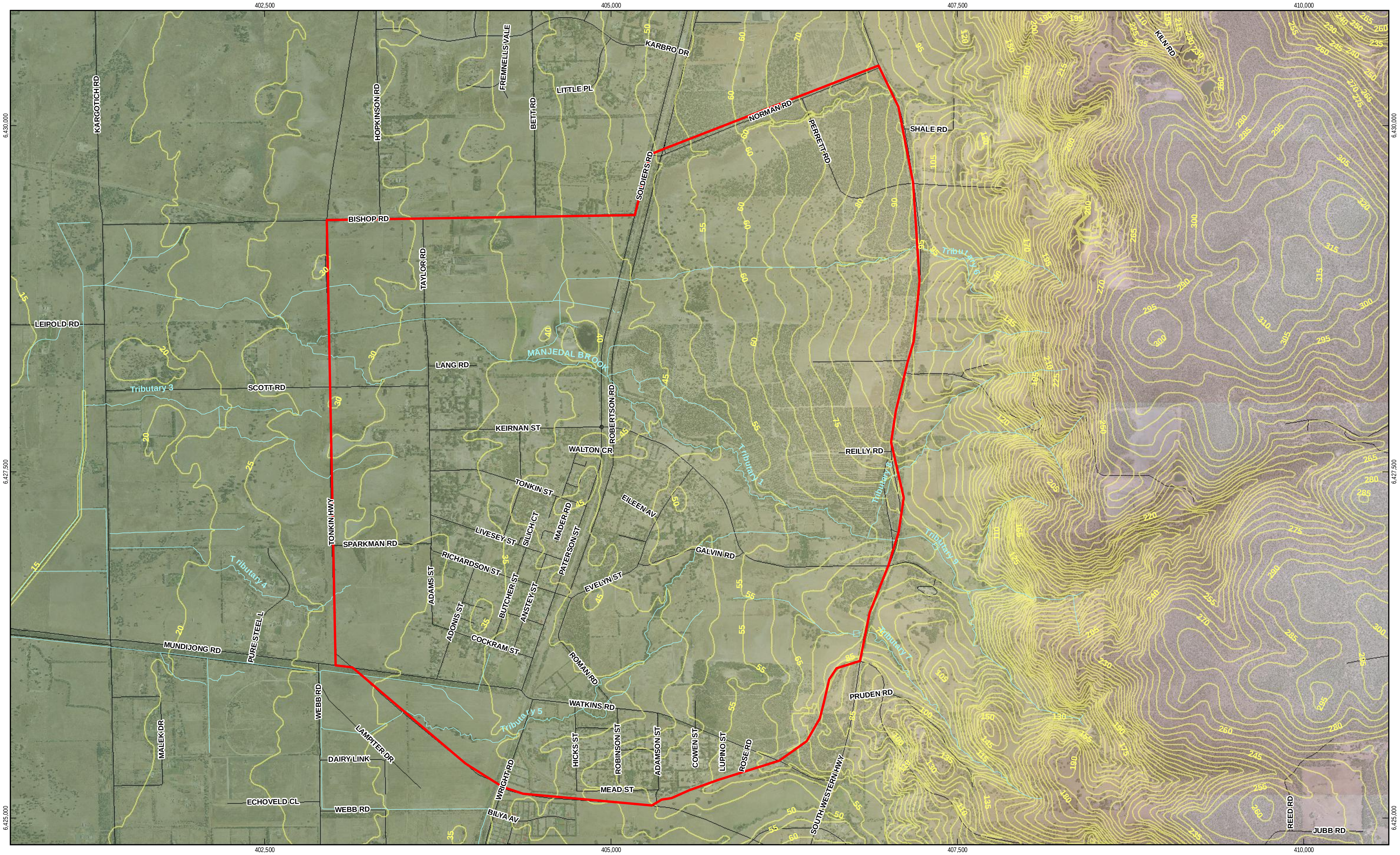
Locality Map

Figure A.1

G:\61\22035\GIS\mxds\6122035-G001.mxd

© 2009. While GHD has taken care to ensure the accuracy of this product, GHD and DATA SUPPLIER(S) make no representations or warranties about its accuracy, completeness or suitability for any particular purpose. GHD and DATA SUPPLIER(S) cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.
Dataset names include published date where available. Background taken from Travellers Atlas 2004 Edition, produced 2003. Created by: N Tan. Modified by: N Deeks

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



1:25,000 (at A3)

0 125 250 500 750 1,000 1,250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

LEGEND

- Study Area - GHD - 20080616
- Waterways - SKM - 20070315
- Contours (1m) - Landgate - 20080428
- Roads - Landgate - 20080429

Elevation - GHD - 200811

m

High : 341

Low : 9

Shire of Serpentine-Jarrahdale
Mundijong Whitby
District Water Management Strategy

Job Number	6122035
Revision	0
Date	09 Sep 2009

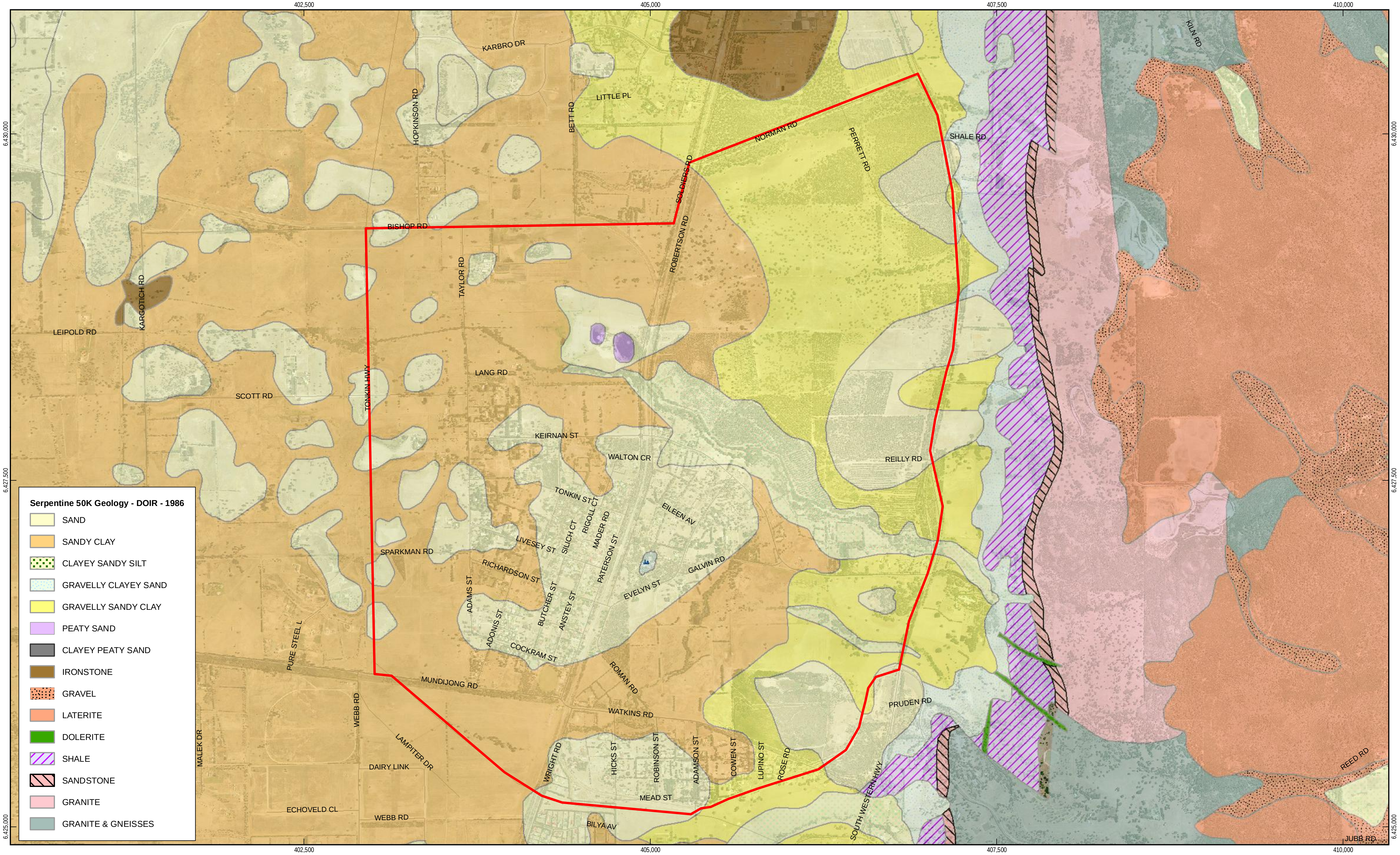
Topography and Drainage

Figure A.2

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

G:\61\22035\GIS\mxds\6122035-G002.mxd

© 2009. While GHD has taken care to ensure the accuracy of this product, GHD and DATA SUPPLIER(S) make no representations or warranties about its accuracy, completeness or suitability for any particular purpose. GHD and DATA SUPPLIER(S) cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.
Dataset names include published date where available. Aerial photography Metro Central 2007 Mosaic sourced from Landgate April 2008. Created by: N Tan. Modified by N Deeks, N Tan



1:25,000 (at A3)

0 125 250 500 750 1,000 1,250

Metres

N

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

LEGEND

Study Area - GHD - 20080616

Roads - Landgate - 20080429

Shire of Serpentine-Jarrahdale
Mundijong Whitby
District Water Management Strategy

Job Number	6122035
Revision	0
Date	09 Sep 2009

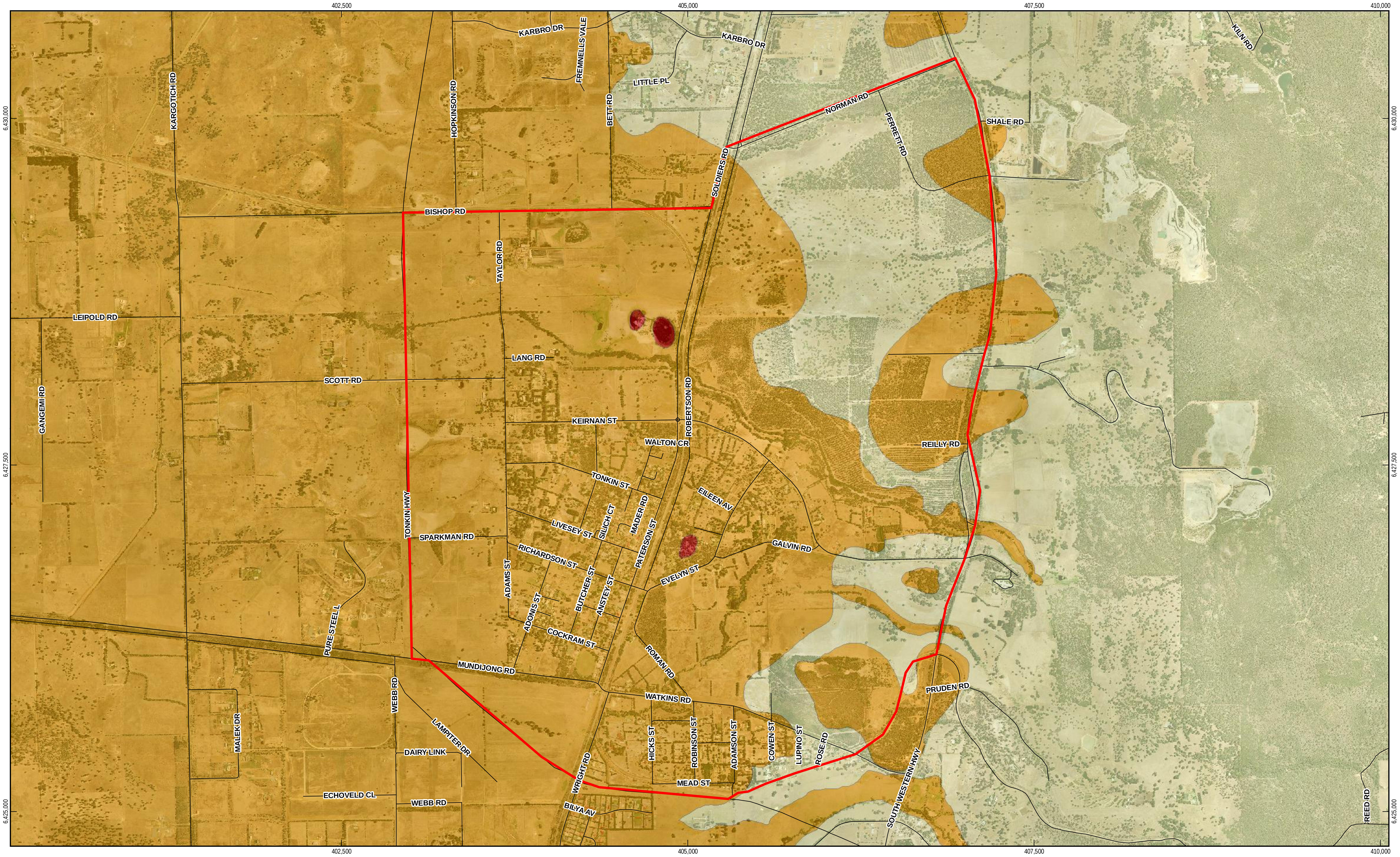
Soils and Geology

Figure A.3

G:\61\22035\GIS\mxds\6122035-G003.mxd

© 2009. While GHD has taken care to ensure the accuracy of this product, GHD and DATA SUPPLIER(S) make no representations or warranties about its accuracy, completeness or suitability for any particular purpose. GHD and DATA SUPPLIER(S) cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.
Dataset names include published date where available. Aerial photography Metro Central 2007 Mosaic sourced from Landgate April 2008. Created by: N Tan. Modified by N Deeks, N Tan

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



1:25,000 (at A3)

0 125 250 500 750 1,000 1,250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

LEGEND

Study Area - GHD - 20080616

Roads - Landgate - 20080429

Acid Sulfate Soils Risk - DEC - 20060807

- High to moderate ASS disturbance risk (<3m from surface)
- Moderate to low ASS disturbance risk (<3m from surface)
- No known ASS disturbance risk (<3m from surface)

Shire of Serpentine-Jarrahdale
Mundijong Whitby
District Water Management Strategy

Job Number	6122035
Revision	0
Date	09 Sep 2009

Acid Sulphate Soils Risk

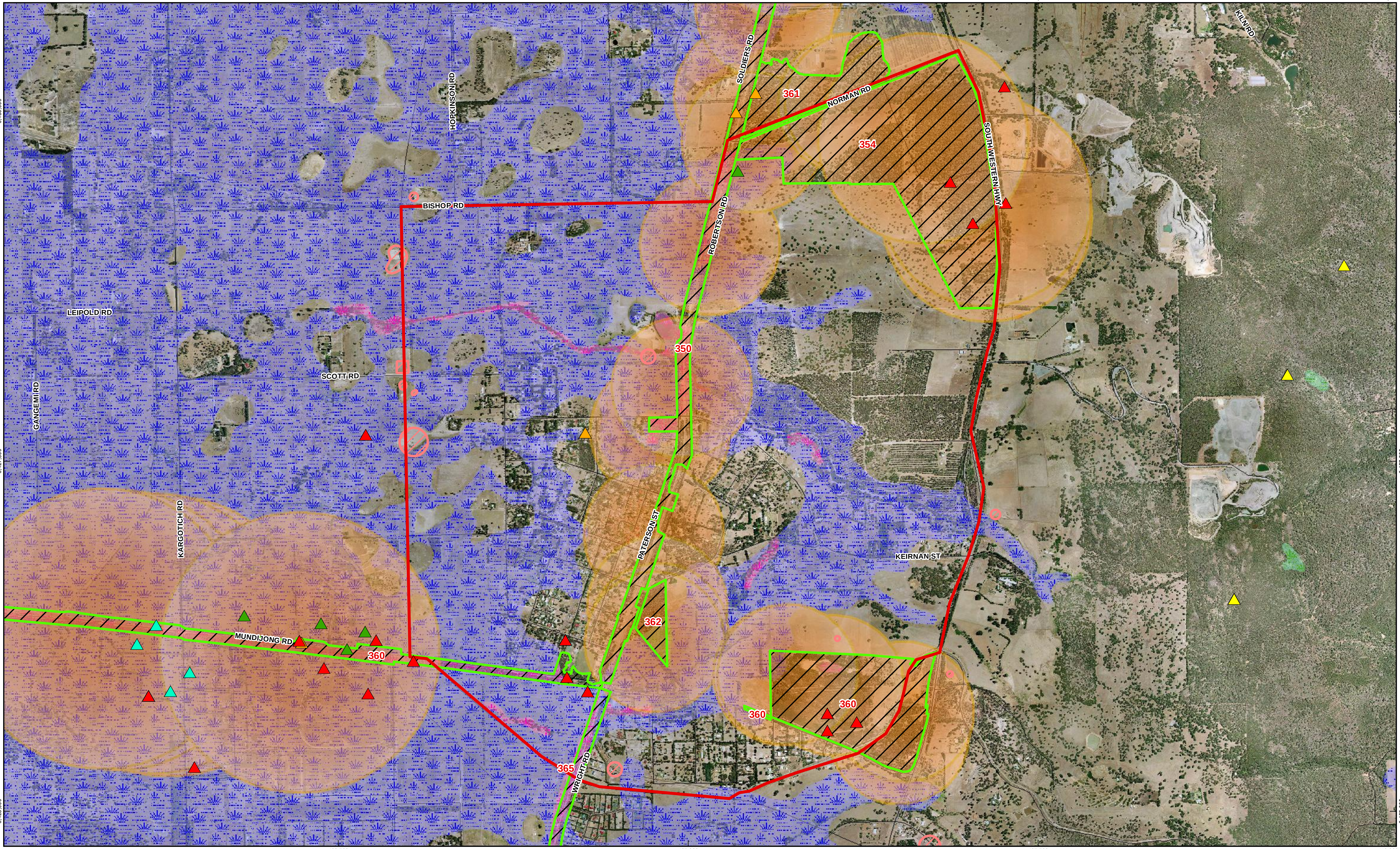
Figure A.4

G:\61\22035\GIS\mxds\6122035-G004.mxd

© 2009. While GHD has taken care to ensure the accuracy of this product, GHD and DATA SUPPLIER(S) make no representations or warranties about its accuracy, completeness or suitability for any particular purpose. GHD and DATA SUPPLIER(S) cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.

Dataset names include published date where available. Aerial photography Metro Central 2007 Mosaic sourced from Landgate April 2008. Created by: N Tan. Modified by: N Deeks, N Tan

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



1:25,000 (at A3)

0 125 250 500 750 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

LEGEND

- Study Area - GHD - 20080616
- Threatened/Priority Ecological Community Buffer - DEC - 20080527
- Bush Forever 2007 Boundaries - DPI - 200711
- Aboriginal Heritage Sites - DIA - 20090107
- Roads - Landgate - 20080429

Geomorphic Wetlands - DEC - 20081006

- Conservation
- Resource Enhancement
- Multiple Use
- Not Assessed

Declared Rare & Priority Species - DEC - 20080527

- (R) Declared Rare Flora - Extant Taxa
- Priority 1 - Poorly Known Taxa
- Priority 2 - Poorly Known Taxa
- Priority 3 - Poorly Known Taxa
- Priority 4 - Rare Taxa

GHD

Shire of Serpentine-Jarrahdale
Mundijong Whitby
District Water Management Strategy

Job Number	6122035
Revision	0
Date	09 Sep 2009

Environmental and Social Considerations

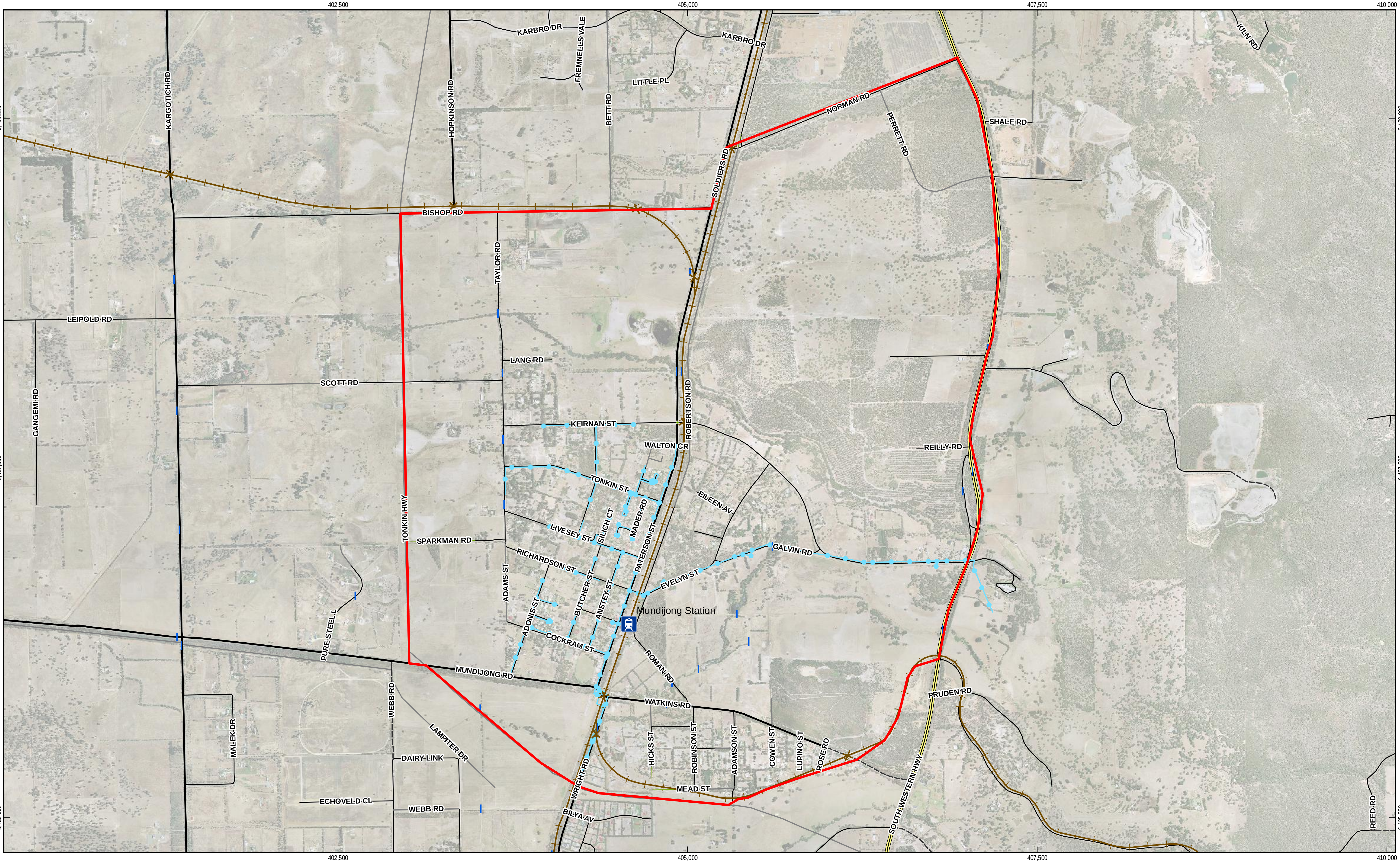
Figure A.5

G:\61\22035\GIS\mxds\6122035-G005.mxd

© 2009. While GHD has taken care to ensure the accuracy of this product, GHD and DATA SUPPLIER(S) make no representations or warranties about its accuracy, completeness or suitability for any particular purpose. GHD and DATA SUPPLIER(S) cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.

Dataset names include published date where available. Aerial photography Metro Central 2007 Mosaic sourced from Landgate April 2008. Created by: N Deeks, Updated by: S.Lee, N Tan

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



1:25,000 (at A3)

0 125 250 500 750 1,000 1,250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

LEGEND

- Study Area - GHD - 20080414
- Railway Station - GHD - 200811
- Railway - Landgate - 20021028
- Stormwater Culverts - GHD - 200807
- Potable Water - Water Corporation - 20080729

Roads - Landgate - 20080428

- Highway/ Freeway
- Main Road
- Minor Road
- Connector Road
- Track
- Surveyed
- Unsurveyed

Shire of Serpentine-Jarrahdale
Mundijong Whitby
District Water Management Strategy

Job Number	6122035
Revision	0
Date	09 Sep 2009

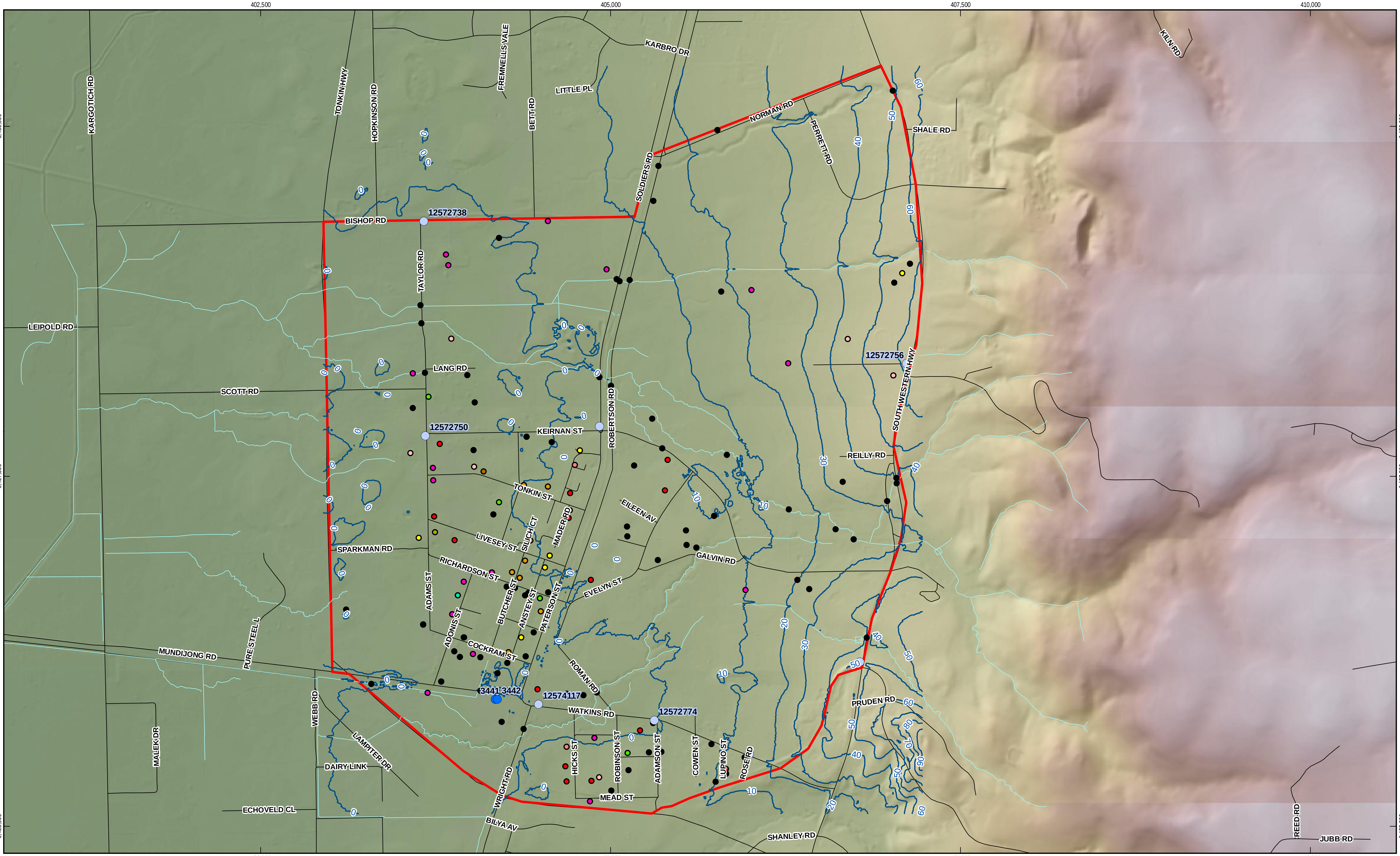
Existing Infrastructure

Figure A.6

G:\61\22035\GIS\mxds\6122035-G006.mxd

© 2009. While GHD has taken care to ensure the accuracy of this product, GHD and DATA SUPPLIER(S) make no representations or warranties about its accuracy, completeness or suitability for any particular purpose. GHD and DATA SUPPLIER(S) cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.
Dataset names include published date where available. Aerial photography Metro Central 2007 Mosaic sourced from Landgate April 2008. Created by: N Deeks, N Tan

239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au



1:25,000 (at A3)

0 125 250 500 750 1,000 1,250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

LEGEND

- Study Area - GHD - 20080616
- Waterways - SKM - 20070315
- Roads - Landgate - 20080429
- Groundwater Depth Contour - GHD - 200811

Elevation - GHD - 200811
m
High : 341
Low : 9

Bore Purpose - GHD - 200811
- Unknown
- Domestic/Household
- Domestic/Household/Irrigation
- Domestic/Household/Livestock
- Garden Irrigation
- Garden Irrigation/Livestock
- Horticulture
- Industry
- Irrigation
- Irrigation/Livestock
- Livestock
- Monitoring
- Observation

Shire of Serpentine-Jarrahdale
Mundijong Whitby
District Water Management Strategy

Job Number	6122035
Revision	0
Date	09 Sep 2009

Groundwater Bores

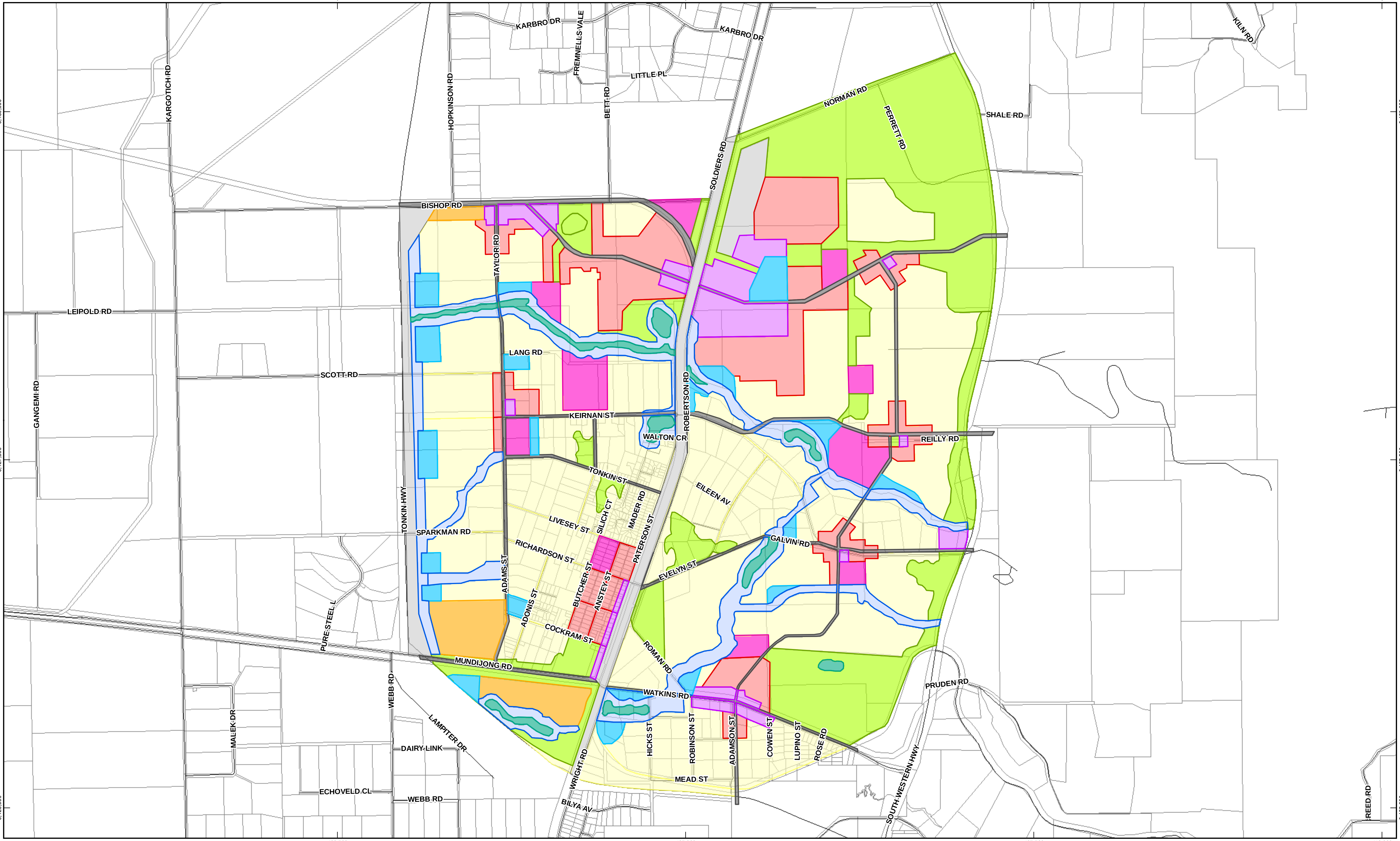
Figure A.7

G:\61\22035\GIS\mxds\6122035-G007.mxd

© 2009. While GHD has taken care to ensure the accuracy of this product, GHD and DATA SUPPLIER(S) make no representations or warranties about its accuracy, completeness or suitability for any particular purpose. GHD and DATA SUPPLIER(S) cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.

Dataset names include published date where available. Relief layer created from Landgate contour information. Created by: N Deeks Updated by: N Tan

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



1:25,000 (at A3)

0 125 250 500 750 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

LEGEND

Land Use - GHD - 20090513

- Basin
- Commercial
- Industrial
- Low
- Med
- School
- Public Open Space
- Drainage
- Wetland
- Major Road
- Road/Rail
- Roads - Landgate - 20090429
- Cadastre - Landgate - 20090429

CLIENTS | PEOPLE | PERFORMANCE

serpentine jarrahdale shire

Shire Of Serpentine-Jarrahdale
Mundijong Whitby
Draft Water Management Strategy

Job Number	61-22035
Revision	0
Date	09 SEP 2009

Land Use Plan

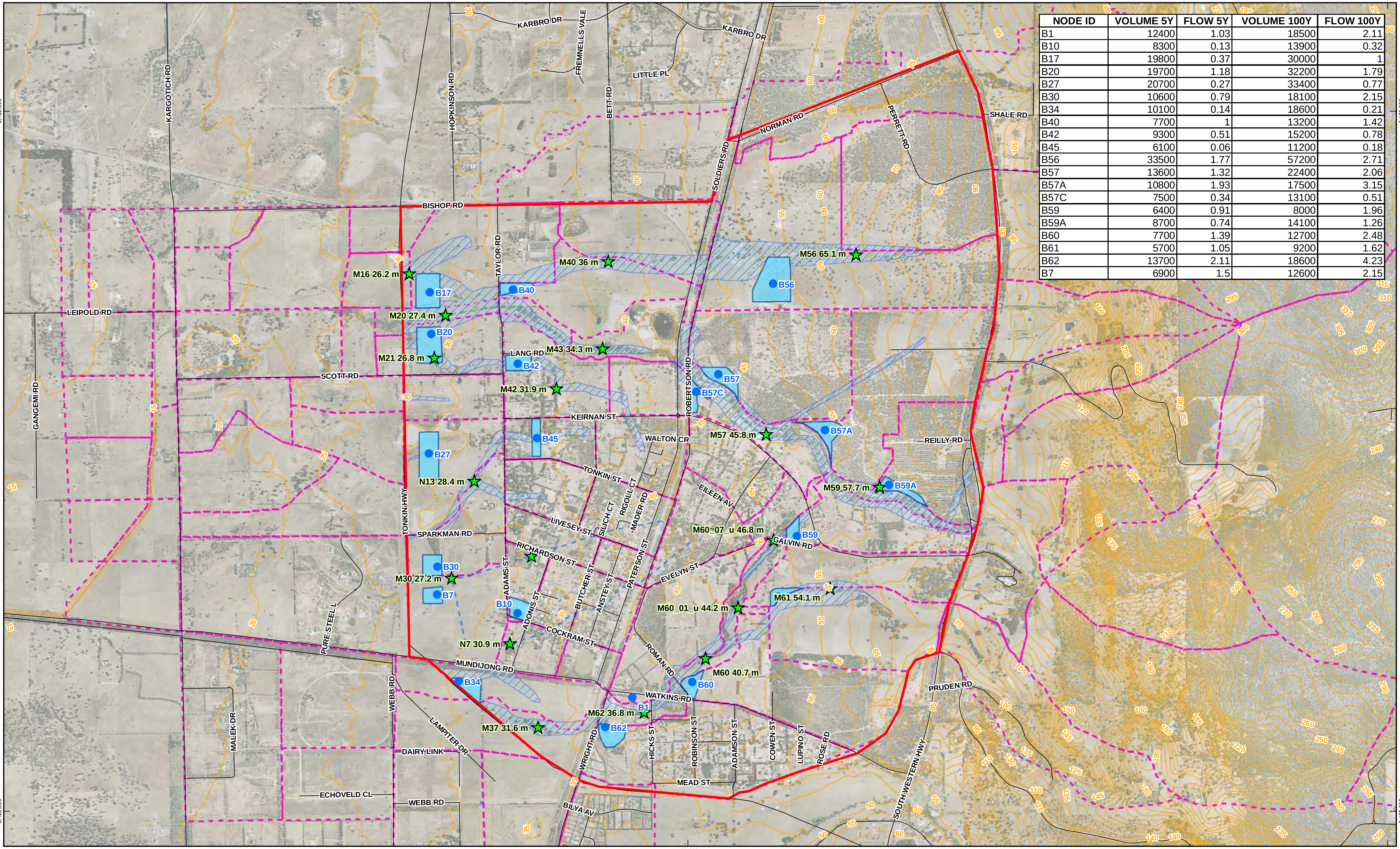
Figure A.8

G:\61\22035\GIS\mxds\6122035-G009.mxd

GHD House, 239 Adelaide Terrace Perth WA 6004 T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

© 2009. While GHD has taken care to ensure the accuracy of this product, GHD and LANDGATE make no representations or warranties about its accuracy, completeness or suitability for any particular purpose. GHD and LANDGATE cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.

Data Source: MRWA: Roads - 200804; Landgate: Cadastre - 200804; GHD: Land Use Plan - 20090513. Created by: xntan, ndeeks, slee2, mbusbridge



NODE ID	VOLUME 5Y	FLOW 5Y	VOLUME 100Y	FLOW 100Y
B1	12400	1.03	18500	2.11
B10	8300	0.13	13900	0.32
B17	19800	0.37	30000	1
B20	19700	1.18	32200	1.79
B27	20700	0.27	33400	0.77
B30	10600	0.79	18100	2.15
B34	10100	0.14	18600	0.21
B40	7700	1	13200	1.42
B42	9300	0.51	15200	0.78
B45	6100	0.06	11200	0.18
B56	33500	1.77	57200	2.71
B57	13600	1.32	22400	2.06
B57A	10800	1.93	17500	3.15
B57C	7500	0.34	13100	0.51
B59	6400	0.91	8000	1.96
B59A	8700	0.74	14100	1.26
B60	7700	1.39	12700	2.48
B61	5700	1.05	9200	1.62
B62	13700	2.11	18600	4.23
B7	6900	1.5	12600	2.15

1:25,000 (at A3)

0 125 250 500 750 1,000 1,250

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 50

N

LEGEND

- Study Area - GHD - 20080816
- Reporting Location - GHD - 20080731
- Basin Location - GHD - 20090716
- Proposed Basin Reserve - GHD - 20090515
- Indicative Flood Extents 100-year ARI - GHD - 20080731
- Subcatchments - GHD - 20090716
- Overland Flow Path - GHD - 20080730
- Existing Culvert - GHD - 20080729
- Contour - Landgate 1m - 20080428
- Roads - Landgate - 20080429

GHD

serpentine jarrahdale shire

Shire of Serpentine-Jarrahdale
Mundijong Whitby
District Water Management Strategy

Job Number	6122035
Revision	1
Date	10 February 2010

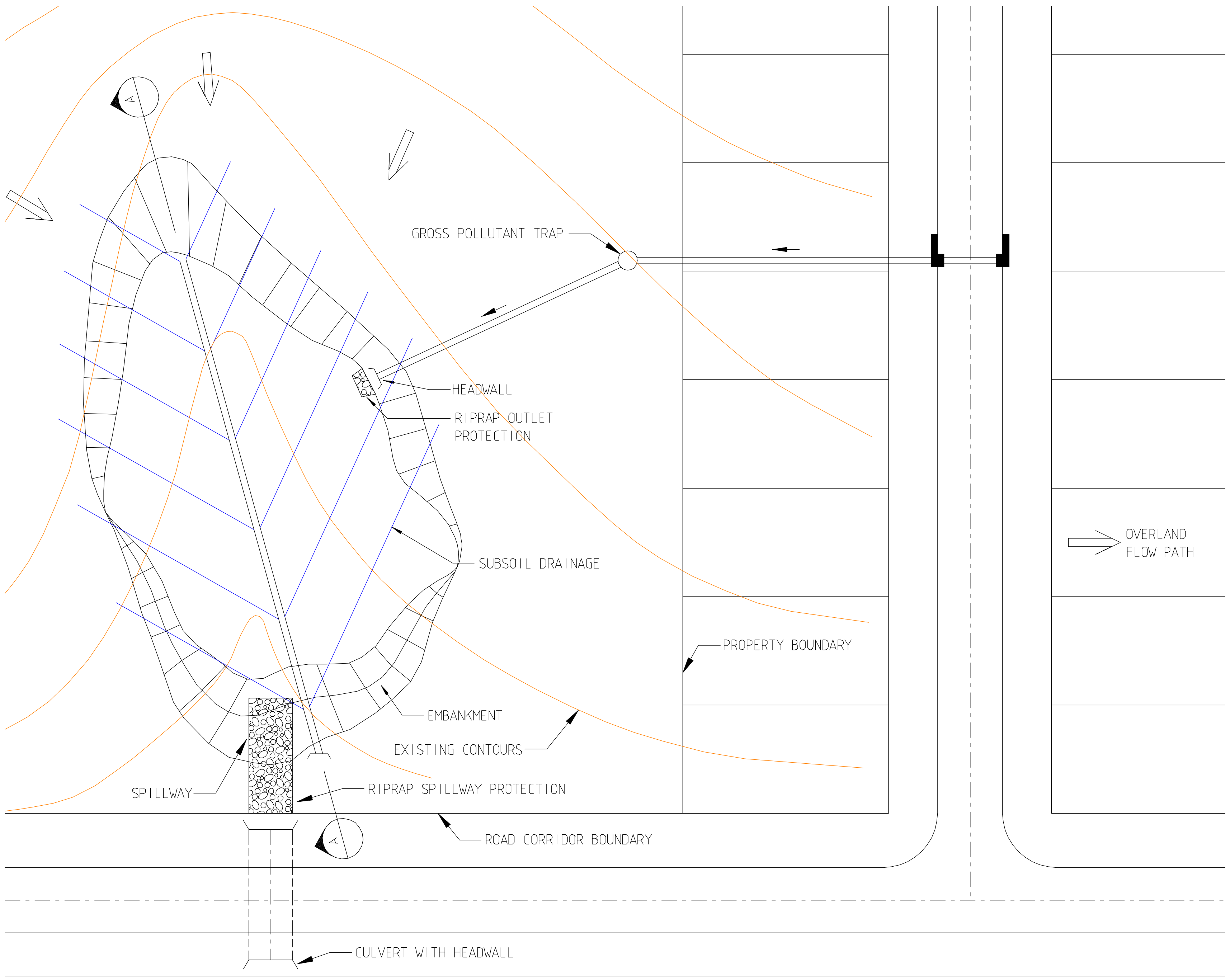
Stormwater Management Strategy
Basin & Reporting Locations

Figure A.9

G:\61\22035\GIS\mxds\6122035-G010_Rev1.mxd

© 2010. While GHD has taken care to ensure the accuracy of this product, GHD Pty Ltd and DATA SUPPLIER(S) make no representations or warranties about its accuracy, completeness or suitability for any particular purpose. GHD and DATA SUPPLIER(S) cannot accept liability of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incurred as a result of the product being inaccurate, incomplete or unsuitable in any way and for any reason.
Dataset names include published date where available. Aerial photography Metro Central 2007 Mosaic sourced from Landgate April 2008. Created by: N Deeks, Modified by N Tan, KIralu

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



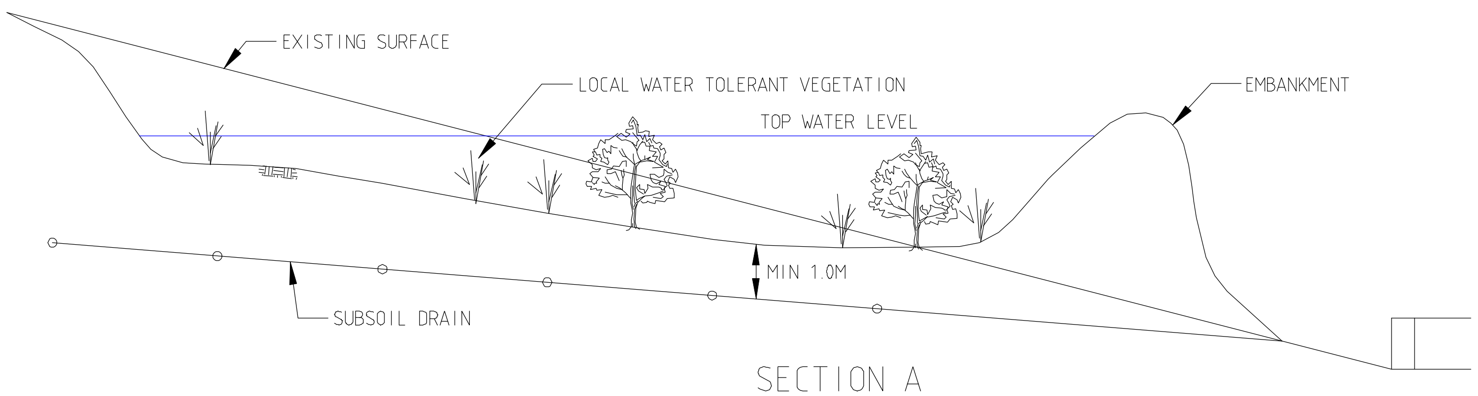
TYPICAL ONLINE INFILTRATION BASIN

NTS

PHOTO OF TYPICAL INFILTRATION BASIN

NOTES

1. SUBSOIL DRAINAGE REQUIRED WHERE BASIN LOCATED IN A HIGH WATER TABLE ZONE



SECTION A

NTS

GHD CLIENTS | PEOPLE | PERFORMANCE

MUNDIJONG WHITBY UWMS

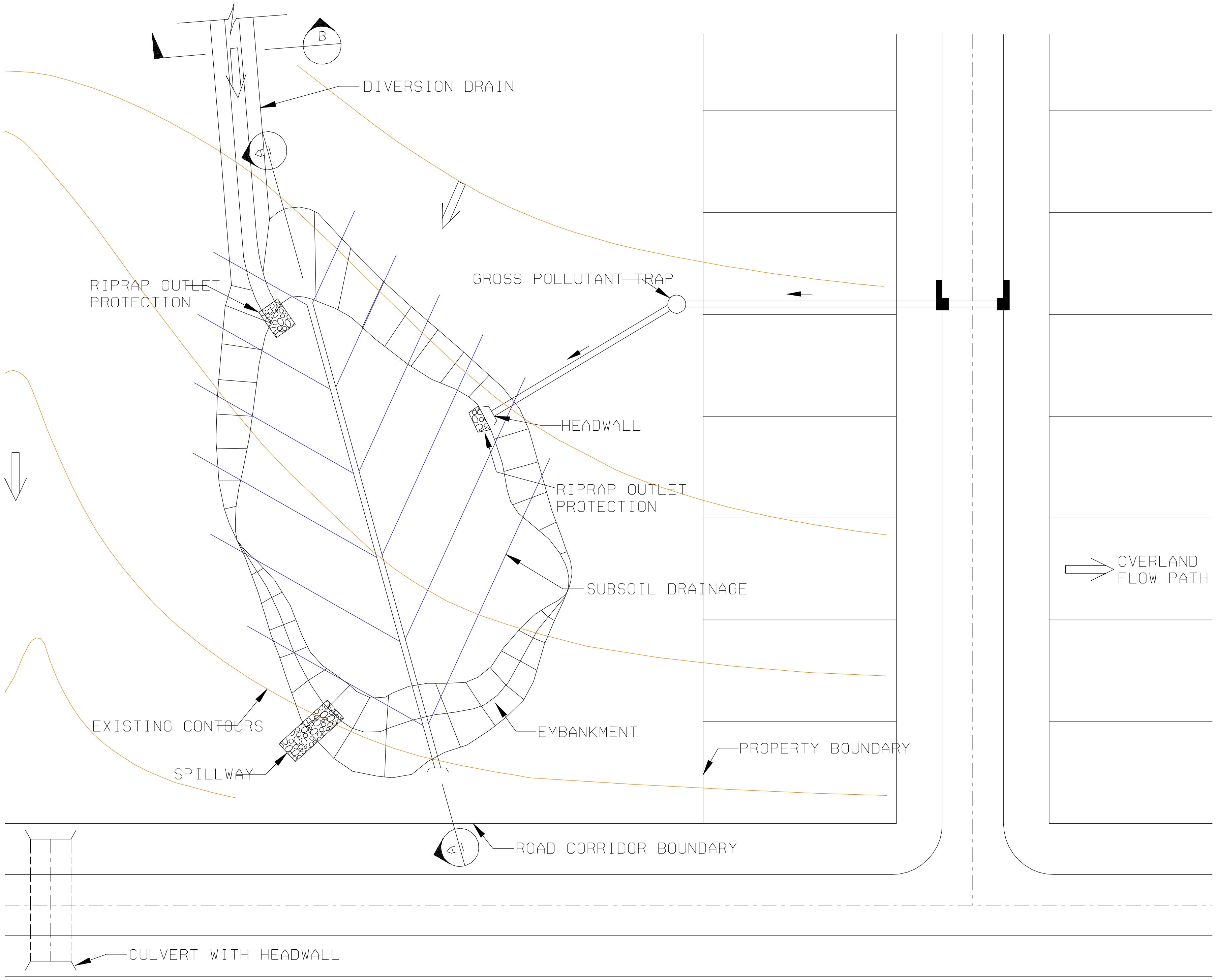
TYPICAL ONLINE INFILTRATION BASIN

scale | 1:500 for A3 date | OCT 2008

job no. | 61-22035
rev no. | A

Figure A10

GHD HOUSE 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



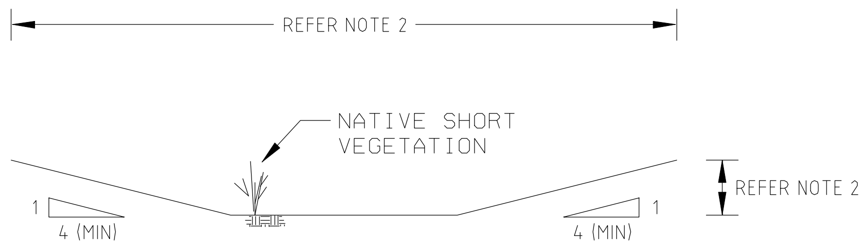
TYPICAL OFFLINE INFILTRATION BASIN

NTS

PHOTO OF TYPICAL INFILTRATION BASIN

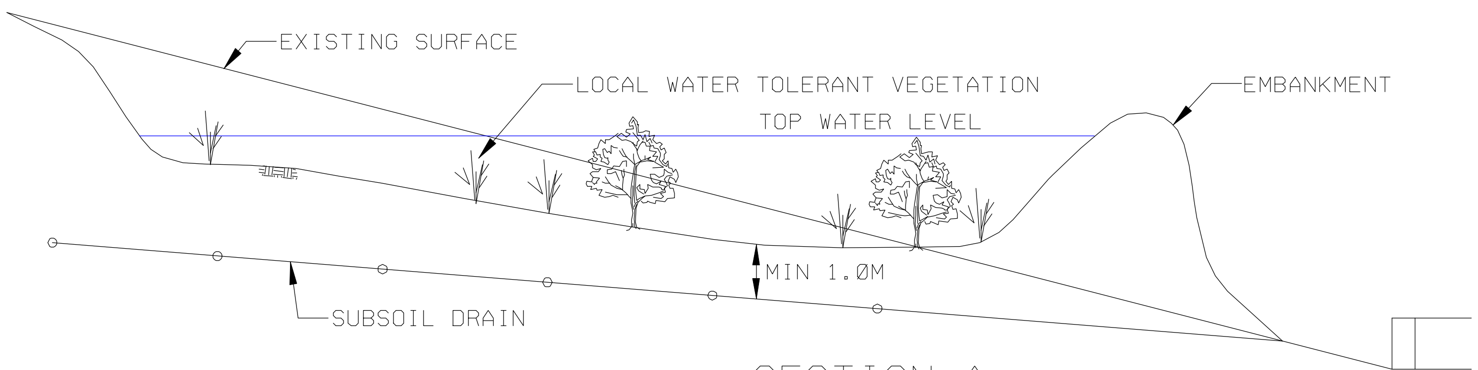
NOTES

1. SUBSOIL DRAINAGE REQUIRED WHERE BASIN LOCATED IN A HIGH WATER TABLE ZONE
2. HEIGHT AND WIDTH OF SWALE TO CONVEY 100 YEAR ARI FLOOD



SECTION B

NTS



SECTION A

NTS

GHD

CLIENTS | PEOPLE | PERFORMANCE

MUNDIJONG WHITBY UWMS

TYPICAL OFFLINE INFILTRATION BASIN

scale | 1:500 for A3 date | OCT 2008

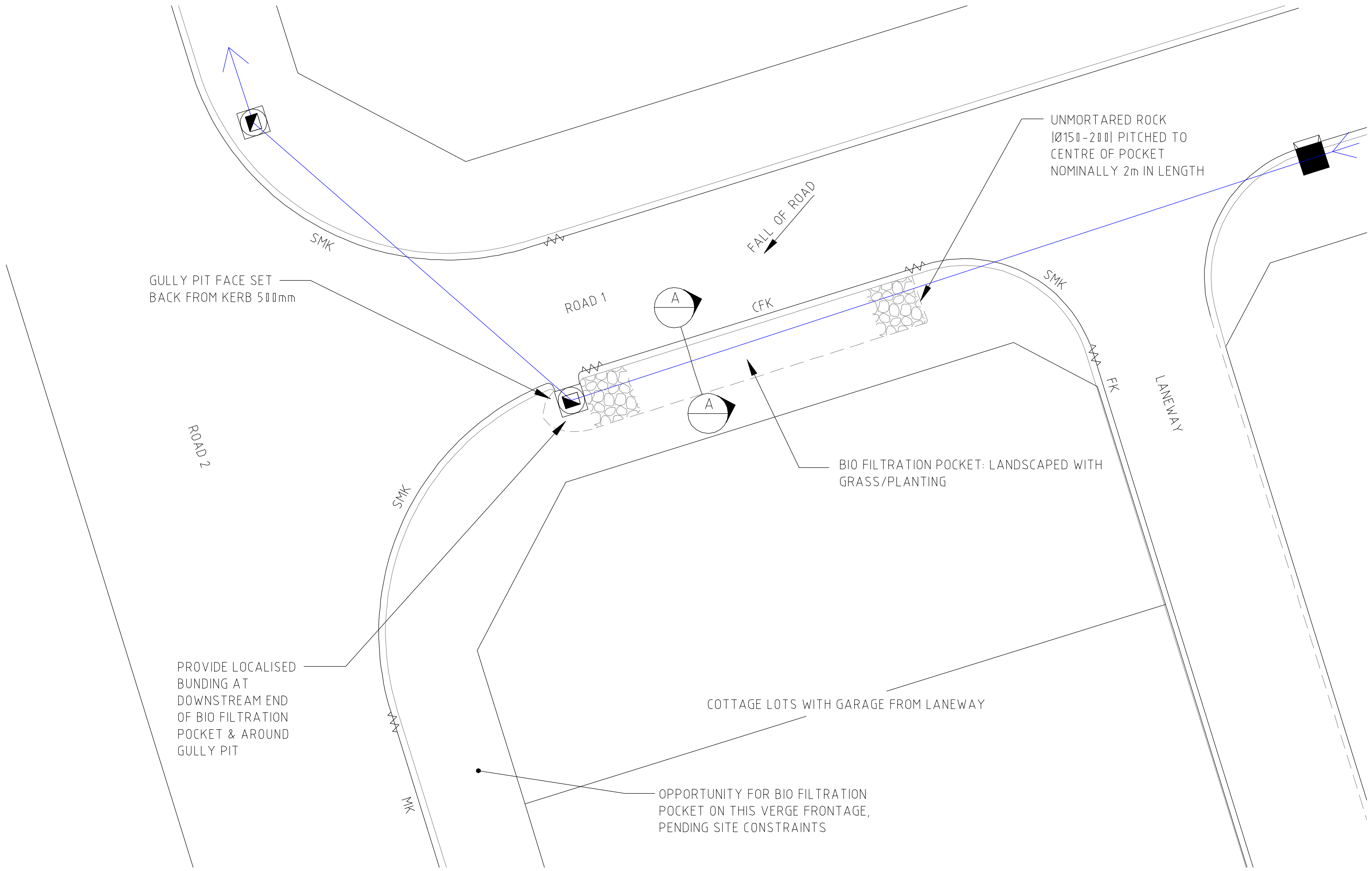
job no. | 61-22035
rev no. | A

Figure A11

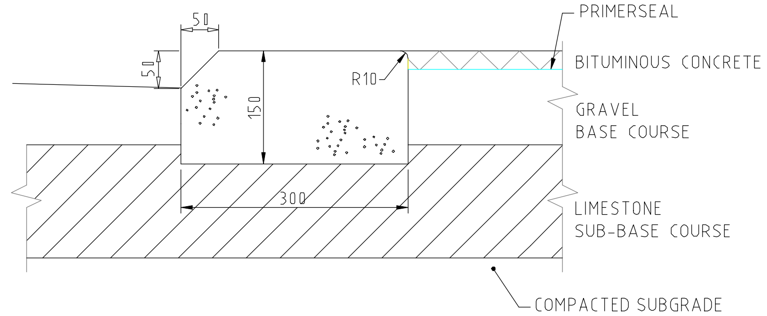
GHD HOUSE 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

17/02/2010 1:12:01 PM

Cad File No: $(GETVAR, DWGNAME) (G:\6122035\CAD\FIGURES\FIGURE A14.DGN)

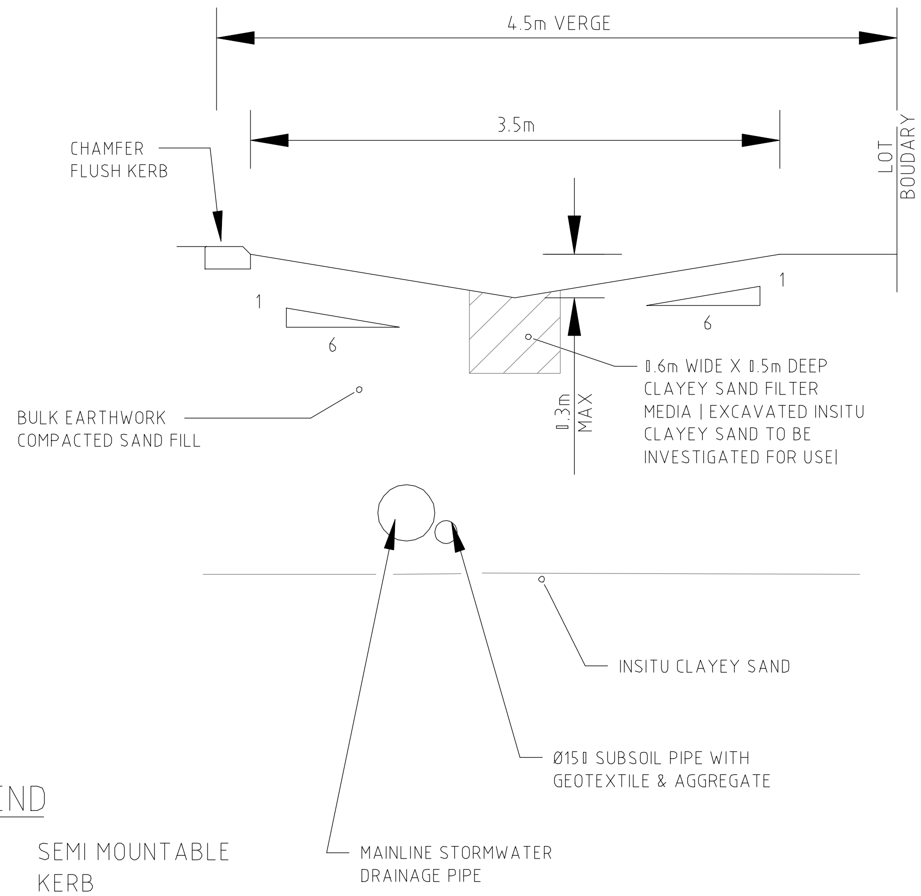


BIO FILTRATION POCKETS CAN BE EASILY EMPLOYED TO VERGES THAT ARE NOT LIKELY TO HAVE DRIVEWAY CROSSOVERS



TYPICAL CHAMFER FLUSH KERB

NTS



LEGEND

SMK	SEMI MOUNTABLE KERB
MK	MOUNTABLE KERB
FK	FLUSH KERB
CFK	CHAMFER FLUSH KERB
—^^—	KERB TRANSITION

SECTION A - BIO FILTRATION POCKET

NTS

PHOTO EXAMPLE OF VERGE PLANTED SWALE

GHD CLIENTS | PEOPLE | PERFORMANCE

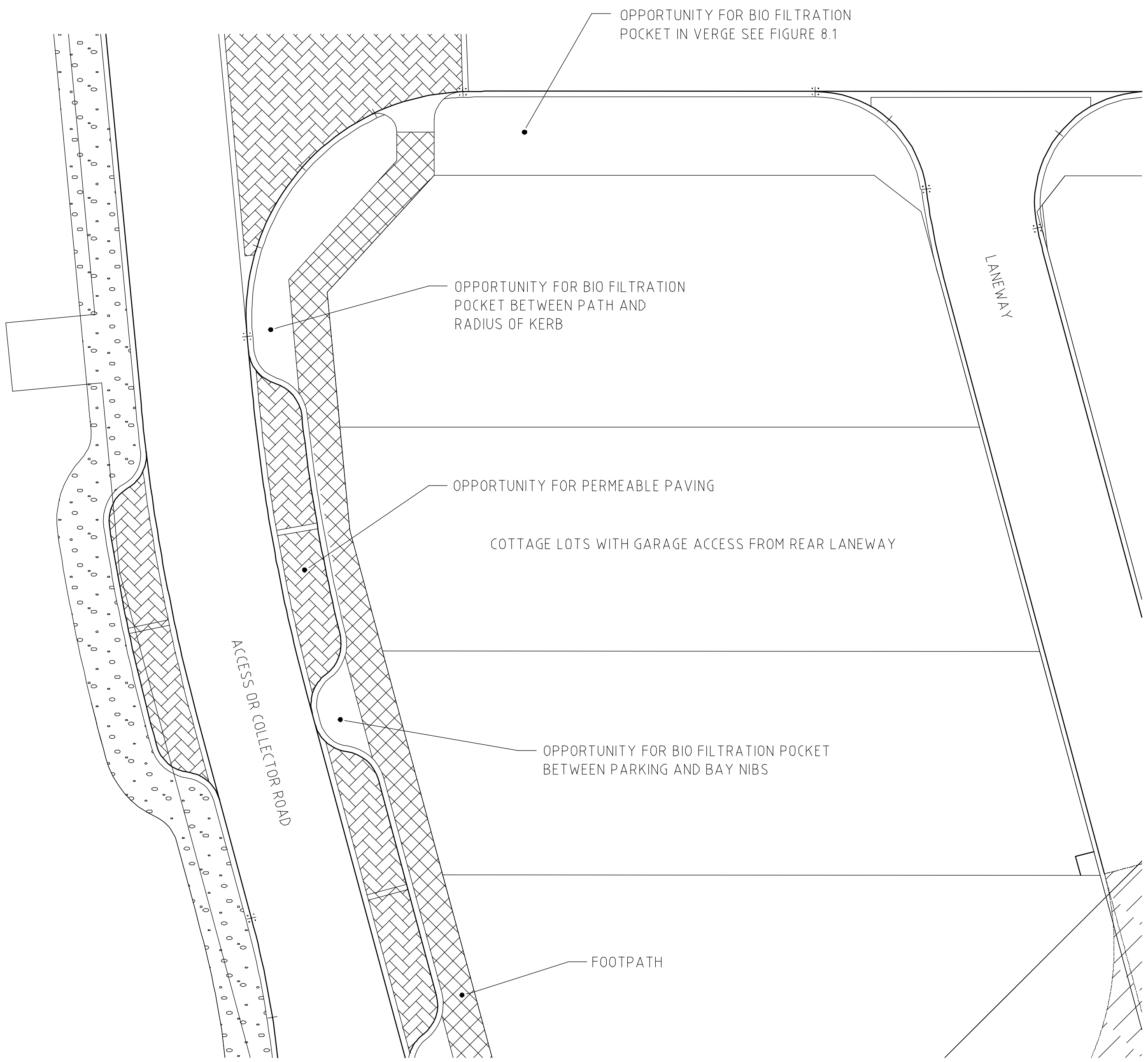
MUNDIJONG WHITBY UWMS
TYPICAL BIO FILTRATION POCKET

scale 1:250 for A3 date OCT 2008

job no. 61 22035
rev no. A

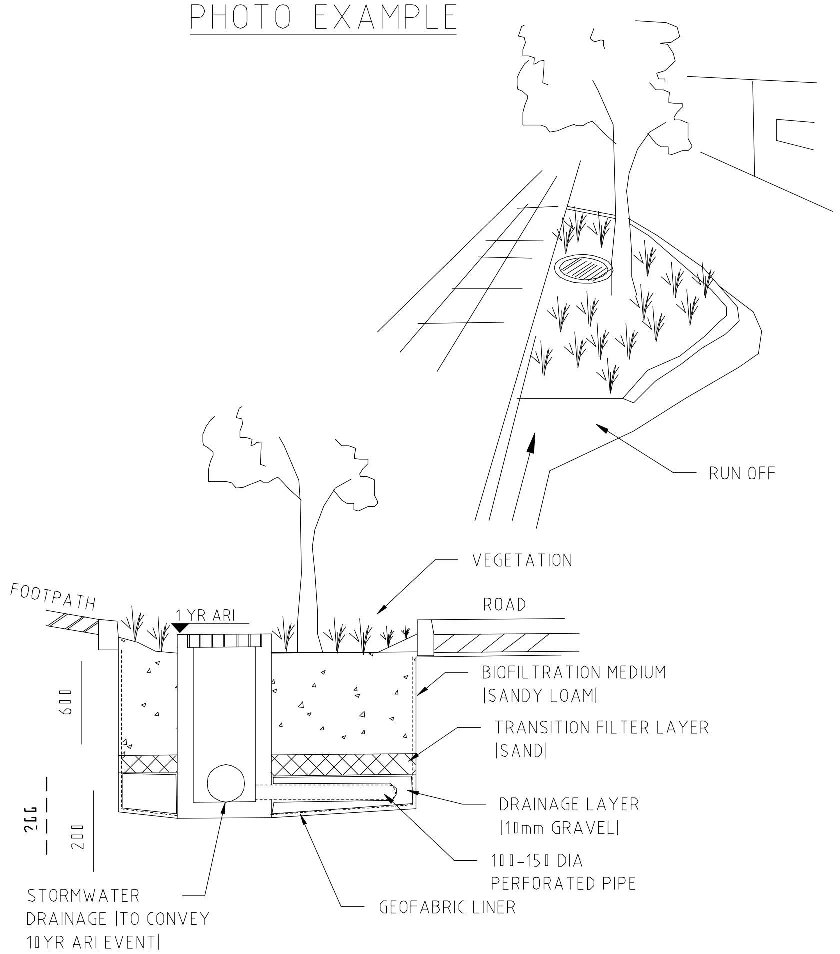
Figure A12

GHD HOUSE 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au



EXAMPLE OPPORTUNITIES FOR BIO FILTRATION POCKETS

PHOTO EXAMPLE



TYPICAL DETAIL

CLIENTS | PEOPLE | PERFORMANCE

MUNDIJONG WHITBY UWMS

TYPICAL BIO FILTRATION POCKETS TO ROAD NIBS

scale | 1:500 for A3 date | OCT 2008

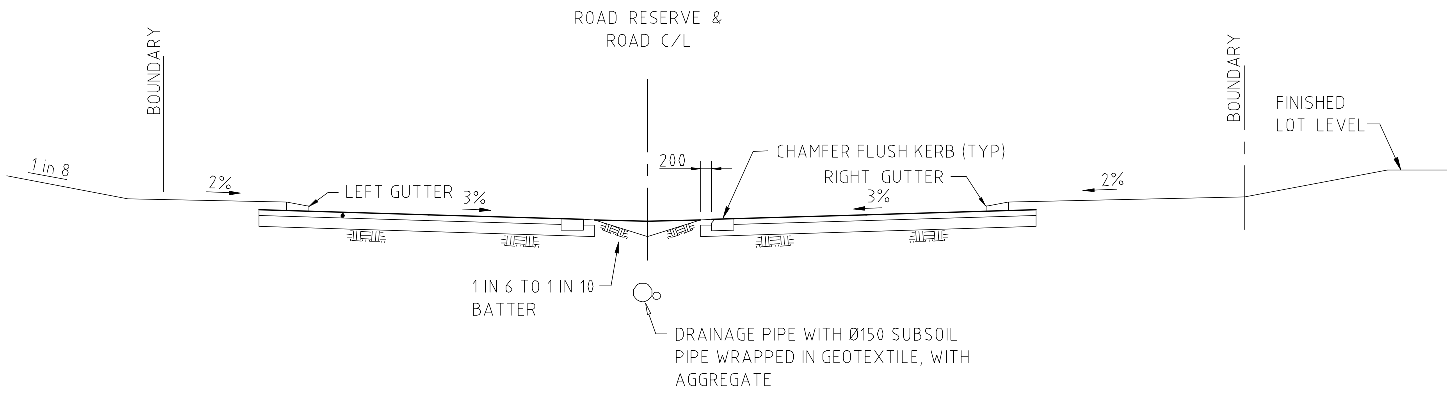
job no. | 61-22035
rev no. | A

Figure A13

GHD HOUSE 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

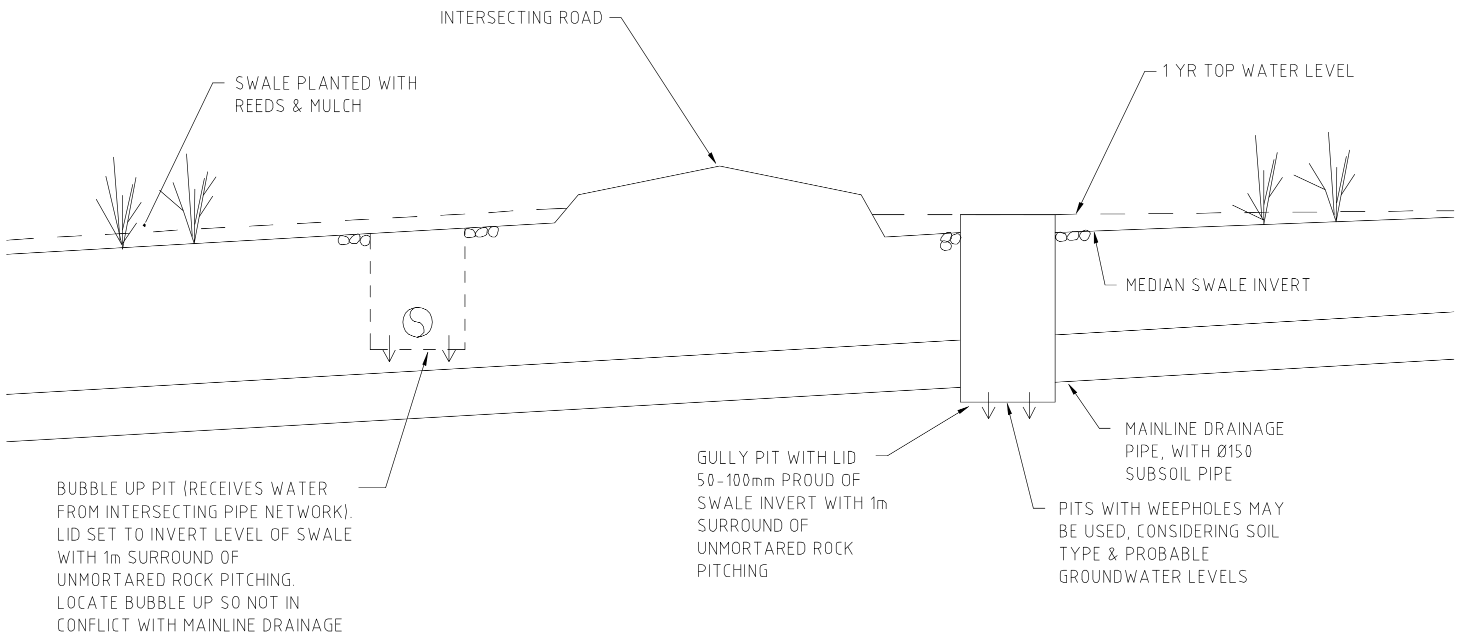
10/09/2009 9:45:54 AM Cad File No: $(GETVAR, DWGNAME) IG:\6122035\CAD\Figures\Figure A16.dgnl

PHOTO OF TYPICAL VEGETATED SWALE TREATMENT



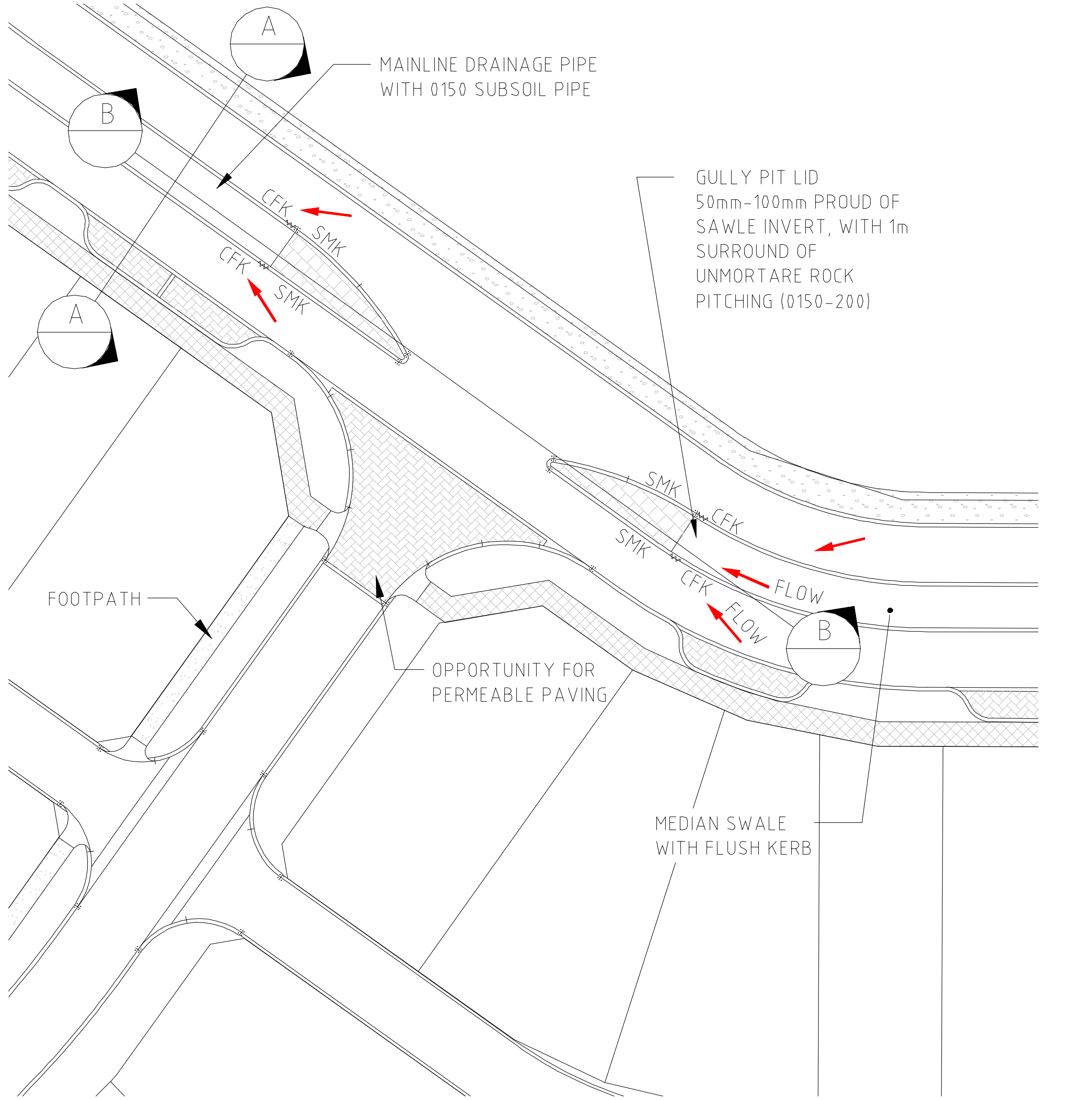
SECTION A – TYPICAL VEGETATED MEDIAN SWALE ROAD CROSS SECTION

NTS

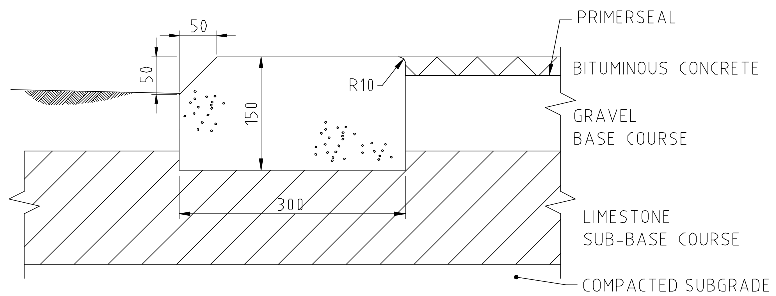


SECTION B – TYPICAL LONG SECTION OF VEGETATED MEDIAN SWALE & ROAD INTERSECTION

NTS



PLAN – TYPICAL MEDIAN SWALE



TYPICAL CHAMFER FLUSH KERB

NTS

LEGEND

SMK	SEMI MOUNTABLE KERB
MK	MOUNTABLE KERB
FK	FLUSH KERB
CFK	CHAMFER FLUSH KERB
-^^-	KERB TRANSITION

GHD CLIENTS | PEOPLE | PERFORMANCE

MUNDIJONG WHITBY UWMS

TYPICAL VEGETATED MEDIAN SWALE TREATMENT

scale | 1:500 for A3 date | OCT 2008

job no. | 61-22035
rev no. | A

Figure A14

GHD HOUSE 239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Appendix B

Stormwater Modelling in InfoWorks CS

B.1 Hydraulic Modelling in InfoWorks CS

InfoWorks CS is a hydraulic modelling package used to simulate stormwater drainage systems. The software package is capable of hydrological modelling of the complete urban water cycle, including stormwater drainage master planning or studies, assessments of flooding in urban drainage systems and hydraulic response of the stormwater network infrastructure to the changes in the land use. The hydraulic software component can resolve open channel and closed conduit flows, model the effect of backwater effect and reverse flow. The model is used predominantly for calculations of event-based simulations; therefore the initial conditions are usually set to the worst-case scenario.

Time-varying surface runoff generated by the runoff routing model discharges into the hydraulic network. The hydraulic network consists of interconnected nodes (manholes, outfalls and storage basins) and links (weirs, pipes, culverts and open channels).

Mannings roughness coefficients applied to conduits are summarised in Table B.1.

Table B.1 Culverts Roughness Coefficients (Manning's "n")

Drain type	Manning's coefficient of roughness
Maintained Open Drain	0.030
Unmaintained Open Drain	0.050
Circular Culvert	0.012
Rectangular Culvert	0.013
Over Road Flood Route	0.015
Over Land Flood Route	0.035

Combined detention/ infiltration basins were sized according to the principles outlined in Chapter 6. The numerical model is run for pre-development land use to determine maximum discharge from each subcatchment for critical 5-, 10- and 100-year ARI rainfall events. The peak predevelopment discharge flow rates of the subcatchments are to be maintained in the post-development scenario.

The detention storage size is tested by running critical 5-, 10- and 100-year ARI rainfall events for the post-development scenario. The peak discharge from the detention basin should not exceed the pre-development level, the storage volume should also be fully utilised. If the storage volume is inadequate, the basin is resized to achieve required volume utilisation, discharge out of the basin and the shape of the hydrograph.

Groundwater levels in drains and basins were not modelled in Infoworks due to the unrealistic groundwater levels reported in west Mundijong (up to 5.8 m *above* ground).

B.2 Modelling Assumptions

The following assumptions used for modelling of Mundijong-Whitby:

- Peak winter groundwater levels (controlled groundwater levels) applied as starting water levels in basins and as baseflows in drains.

- Average recurrence interval rainfall events applied to whole catchment with a universal start time.
- 100-year flood levels taken from the Mundijong floodplain management strategy (SKM, 2007) applied as constant tailwater at the Hopkinson Road end of each modelled waterway.
- Infiltration modelled at a constant rate of 4 mm/hour.
- Catchment parameterisation for existing catchments (pervious/impervious breakdown, catchment slope, roughness and losses) adopted from the Mundijong floodplain management strategy (SKM, 2007).

B.3 Surface Runoff Parameters

Recorded stream flow information was not available for the Mundijong-Whitby catchments to enable calibration of the loss parameters adopted within runoff routing models of the catchments. When deciding on the appropriate loss parameters applicable to the Mundijong-Whitby catchments, the Department of Water considered:

- Adopted parameters for calibrated runoff routing models of nearby similar catchments;
- Incorporation of antecedent flow from the catchment (baseflow);
- Adopted parameters during modelling for other major infrastructure projects on the Swan Coastal Plain;
- Catchment soil characteristics;
- Vegetation coverage;
- Future expansion of Tonkin Highway;
- Uncertainty in design rainfall depths and temporal patterns;
- Uncertainty due to the impact of climate change; and
- Uncertainty in upper catchment land use/vegetation coverage into the future.

The Floodplain management strategy adopted runoff coefficients of 10 mm initial loss and 50 per cent continuing proportional loss for the upper catchments and 10 mm initial loss and 4 mm/hr continuing loss on the flatter heavy soils downstream of South Western Highway.

The InfoWorks CS model of Mundijong-Whitby study area uses a constant infiltration model to generate rainfall runoff and the SWMM single non-linear reservoir routing model to provide inflows to the hydraulic component of the model. Each subcatchment in the study area is subdivided into pervious and impervious areas that have surface roughness, initial losses and infiltration losses applied according to land use (Table B.2).

The land use of the existing catchments was adopted from the SKM flood management strategy. The distinct structure plan (Table B.3) provided the land use breakdown for the ultimate development. The effective Fi of residential areas was reduced in areas where infiltration was relatively high primarily East of Soliders Road. The percentage of surface types for individual catchments was calculated from the existing land use and draft district structure plan; the results are summarised in Table B.4 (pre-development scenario) and Table B.5 (post-development scenario).

Design rainfall events for the 1h, 3h, 6h, 12h, 24h, 48h and 72h durations were run for 5y, 10y and 100y ARI storms.

Table B.2 InfoWorks model runoff area properties

Land use	Surface roughness (Mannings N)		Initial loss (mm)		Infiltration loss (mm/hour)		Fixed runoff coefficient	
	Perv	Imperv	Perv	Imperv	Perv	Imperv	Perv	Imperv
Upper scrub	0.05	0.015	0	1.5	N/A	N/A	0.25 (5y) 0.5 (100y)	1.0
Upper forested	0.080	0.015	0	1.5	N/A	N/A	0.25 (5y) 0.55 (100y)	1.0
Rural pasture	0.050	0.015	10	1.5	4	0	N/A	N/A
Existing urban	0.025	0.015	10	1.5	4	0	N/A	N/A
Constructed urban	0.025	0.015	10	15	4	0	N/A	N/A

Table B.3 InfoWorks model land use surface breakdown

Land use category	Pervious area 1 (%)	Effective impervious area 2 (%)
Drainage Basin (POS)	95%	5%
Road	30%	70%
Mixed Business	25%	75%
Neighbourhood Centre	45%	55%
Low Density Residential	50%	50% (40% if Deep Groundwater)
Medium Density Residential	40%	60% (48% if Deep Groundwater)
High Density Residential	25%	75%

Notes: Effective impervious areas presented in this table are for modelling at the catchment scale and are not to be used for individual lot runoff calculations.

Table B.4 InfoWorks model catchment properties for pre-development scenario

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
M01	14.89	1.00	290.3	0.00
M02	30.52	1.50	415.6	0.00
M03	14.77	2.70	289.1	0.00
M04	29.27	1.20	406.9	0.00
M05	11.75	3.90	257.8	0.00

M06	27.73	0.80	396.1	0.00
M07	13.63	3.80	277.8	0.00
M08	25.92	0.80	382.9	0.00
M09	17.90	0.80	318.3	0.00
M10	16.84	2.80	308.7	0.00
M11	33.65	1.90	436.4	0.00
M12	15.48	1.20	296	0.00
M13	56.47	1.30	565.3	0.00
M14	21.52	1.30	349	0.00
M15	17.50	0.90	314.7	0.00
M16	35.08	1.50	445.6	0.00
M17	20.89	1.20	343.8	0.00
M18	57.92	1.50	572.5	0.00
M19	11.94	1.80	259.9	0.00
M20	23.11	1.50	361.6	0.00
M21	22.48	1.70	356.7	0.00
M22	33.34	1.60	434.4	0.00
M23	49.94	1.10	531.6	0.00
M24	29.93	1.70	411.5	0.00
M25	25.69	2.30	381.3	0.00
M26	48.54	1.40	524.1	0.00
M27	27.73	1.80	396.1	0.00
M28	27.54	1.90	394.8	0.00
M29	124.66	1.30	839.9	0.00
M30	69.13	1.30	625.5	0.00
M31	92.65	1.50	724.1	5.00
M32	57.51	1.50	570.5	0.00
M33	15.58	1.30	296.9	0.00
M34	22.73	1.70	358.6	0.00
M35	41.01	1.00	481.8	0.00
M36	24.06	1.30	369	0.00

M37	26.54	2.40	387.5	0.00
M38	46.63	1.40	513.7	0.00
M39	42.52	1.70	490.5	0.00
M40	116.54	1.90	812.1	5.00
M41	17.88	1.80	318.1	0.00
M42	21.89	2.00	352	20.00
M43	29.87	3.50	411.1	0.00
M44	30.60	1.90	416.1	0.00
M45	20.75	2.20	342.6	20.00
M46	23.69	2.00	366.1	20.00
M47	16.95	2.30	309.7	20.00
M48	12.23	1.70	263.1	5.00
M49	32.77	2.60	430.6	20.00
M50	25.25	2.70	378	40.00
M51	9.53	2.60	232.2	40.00
M52	15.23	2.20	293.5	20.00
M53	19.49	2.10	332.1	40.00
M54	10.27	1.70	241	5.00
M55	10.25	1.90	240.8	20.00
M56	177.08	3.30	1490	0.00
M57	169.59	3.00	1379.6	0.00
M58	76.06	1.00	656.1	5.00
M58A	1.93	2.00	104.6	5.02
M59	104.80	3.70	1070.1	0.00
M59A	18.46	20.00	323.2	0.00
M60	122.20	2.60	1197.5	0.00
M61	130.25	3.80	1288	0.00
M62	84.64	3.00	696.3	20.00
M63	97.35	15.10	742.2	0.00
M64	61.71	12.90	602.3	0.00
M65	111.14	15.20	960.4	0.00

M66	56.67	7.20	566.3	0.00
M67	77.93	13.70	883.2	0.00
M68	32.84	23.20	412.2	0.00
M69	102.84	21.10	1014.6	0.00
M70	246.47	15.00	1663.4	0.00
M71	592.63	7.10	2644	0.00
M72	213.78	5.40	1262.8	0.00
M73	377.08	5.00	1842.8	0.00
M74	19.92	2.50	385.7	0.00
M75	37.76	2.60	462.2	0.00
M76	45.63	17.80	588.2	0.00
M77	16.33	6.70	304	0.00
M80	85.38	1.9	695.1	0.00
M81	79.83	3.3	672.1	0.00
M8	324.22	14.6	1354.5	0.00

Table B.5 InfoWorks model catchment properties for post-development scenario

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
B1	56.77	2.10	566.80	41.86
B57	79.76	0.40	671.80	52.93
B59	39.11	1.50	470.40	45.79
B7	44.64	0.50	422.10	83.50
M01	14.91	1.00	290.30	0.00
M02	30.56	1.50	415.60	0.00
M03	14.79	2.70	289.10	0.00
M04	29.30	1.20	406.90	0.00
M05	11.76	3.90	257.80	0.00
M06	27.76	0.80	396.10	0.00
M07	13.65	3.80	277.80	0.00
M08	25.95	0.80	382.90	0.00

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
M09	17.93	0.80	318.30	0.00
M10	16.86	2.80	308.70	0.00
M11	33.69	1.90	436.40	0.00
M12	15.50	1.20	296.00	0.00
M13	56.54	1.30	565.30	0.00
M14	17.44	1.30	314.20	21.07
M15	17.52	0.90	314.70	0.00
M16A	18.56	0.50	324.30	9.10
M17	66.06	0.40	611.40	53.53
M18	57.99	1.50	572.50	0.00
M19	11.95	1.80	259.90	0.00
M20B	28.37	0.50	400.70	39.50
M20C	10.74	0.60	246.50	7.67
M21A	5.63	0.20	197.00	0.00
M22	33.38	1.60	434.40	0.00
M23	50.00	1.10	531.60	0.00
M24	29.96	1.70	411.50	0.00
M25	23.05	0.60	361.20	47.94
M26	49.38	1.40	524.10	0.00
M27	42.16	0.50	488.40	42.84
M29	124.50	1.30	839.90	0.00
M30	82.29	0.50	609.10	22.21
M31	92.77	1.50	724.10	0.00
M32	57.58	1.50	570.50	0.00
M33	9.80	1.30	296.90	
M34	29.75	0.50	410.30	58.02
M35	41.06	1.00	481.80	0.00
M36	30.65	1.30	369.00	
M37	19.32	0.60	330.60	15.74

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
M38	46.68	1.40	513.70	0.00
M39	40.84	1.70	490.50	0.00
M40	51.16	0.70	538.10	45.25
M40B	46.33	0.70	512.00	48.83
M41	8.10	0.60	214.10	6.29
M42B	41.62	0.50	485.30	49.50
M43	26.06	1.00	384.00	11.48
M44	21.88	1.00	351.90	50.43
M45	20.74	0.80	342.60	32.58
M46	23.73	0.70	366.50	50.63
M47	17.06	1.30	310.70	50.66
M48	12.54	0.60	266.40	44.30
M49	32.81	0.90	430.90	47.59
M50	25.25	1.20	378.00	48.50
M51	9.54	0.10	232.30	41.36
M52	15.15	0.10	292.80	50.00
M53	20.28	0.80	338.70	65.17
M54	13.82	0.90	279.70	48.81
M55	11.16	1.00	251.30	32.27
M56	100.38	2.10	753.70	12.77
M56B	154.62	1.40	935.40	44.30
M57	90.39	1.00	715.20	28.53
M57A	30.49	2.10	415.40	28.43
M58	32.00	0.90	425.60	36.90
M58A	30.52	0.60	415.60	40.90
M59	8.49	1.70	219.20	6.03
M59A	12.64	0.60	267.50	30.72
M59B	48.54	0.90	524.10	32.88
M60	18.53	0.70	323.80	6.34

Subcatchment ID	Total area (ha)	Vector slope (%)	Catchment width (m)	% Impervious
M60B	71.49	0.80	636.10	21.48
M61	63.08	0.20	597.50	29.80
M61B	43.22	2.00	494.50	33.68
M62_02_u	9.75	0.50	234.80	7.61
M62B	83.78	6.00	688.50	47.26
M63	98.53	15.10	742.20	0.00
M64	62.14	12.90	602.30	0.00
M65	111.28	15.20	960.40	0.00
M66	58.23	7.20	566.30	0.00
M67	79.65	13.70	883.20	0.00
M68	32.88	23.20	412.20	0.00
M69	102.97	21.10	1014.60	0.00
M70	246.78	15.00	1663.40	0.00
M71	593.37	7.10	2644.00	0.00
M72	214.05	5.40	1262.80	0.00
M73	377.56	5.00	1842.80	0.00
M74	19.83	2.50	335.70	0.00
M75	31.62	2.60	462.20	0.00
M76	45.69	17.80	588.20	0.00
M77	15.51	6.70	304.00	0.00
M80	84.97	1.90	695.10	0.00
M81	75.55	3.30	653.80	3.32
M82	324.68	14.60	1354.50	0.00

B.4 Hydrologic model validation

Peak and total pre-development catchment runoff generated by the InfoWorks model was compared to peak and total catchment output from the RAFTS model used in the SKM floodplain management study.

In general, the fit is good, though at high flows the peak flows generated by InfoWorks are somewhat smaller than those generated by RAFTS. Figure B.1 shows the peak outputs of each model plotted against each other (the 1:1 line is provided for comparison, Figure B.2) for the critical 6h 100y event.

A comparison of total generated runoff volume has also been carried out for the six-hour hour 100-year ARI event and shows a good calibration between the RAFTS and InfoWorks models. The results are presented in Figure B.3 below.

Figure B.1 Hydrologic model validation – peak flow: 6h 100y

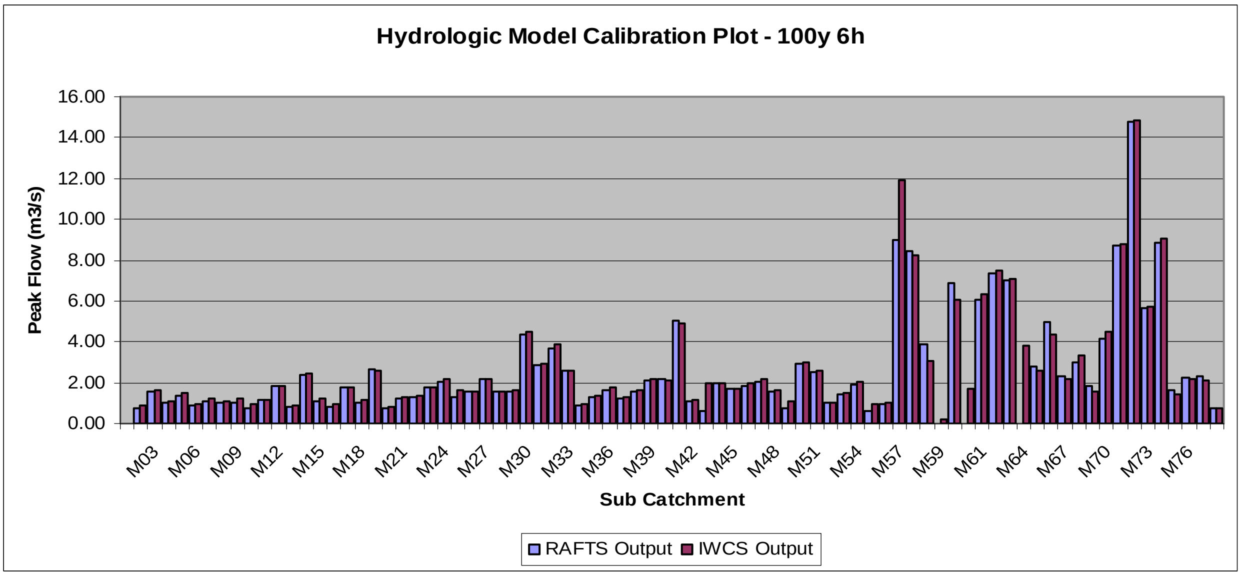


Figure B.2 Hydrologic model validation – peak flow: 6h 100y

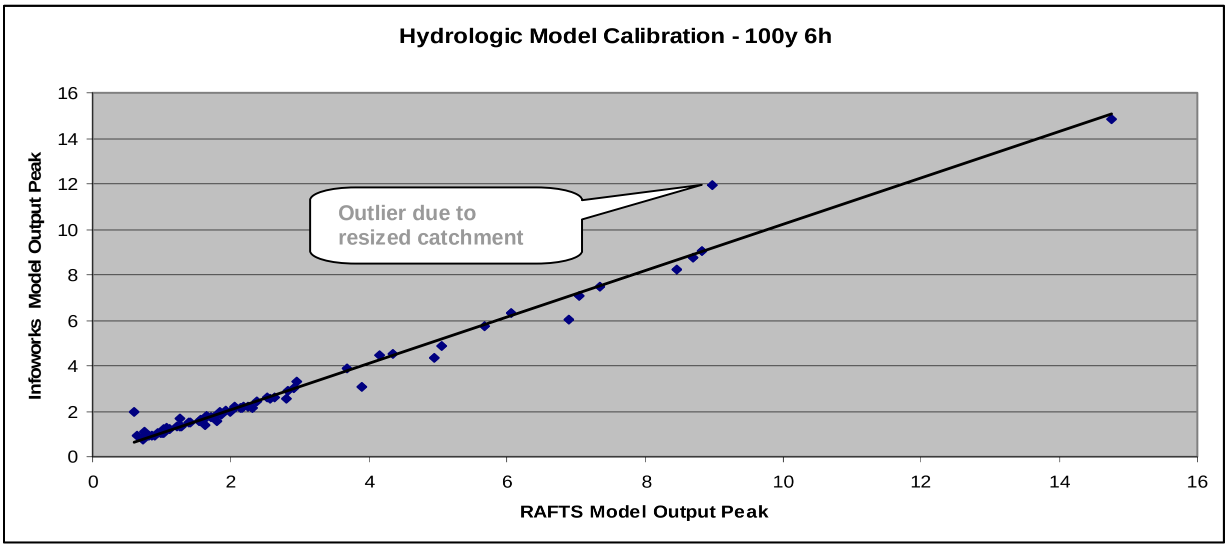
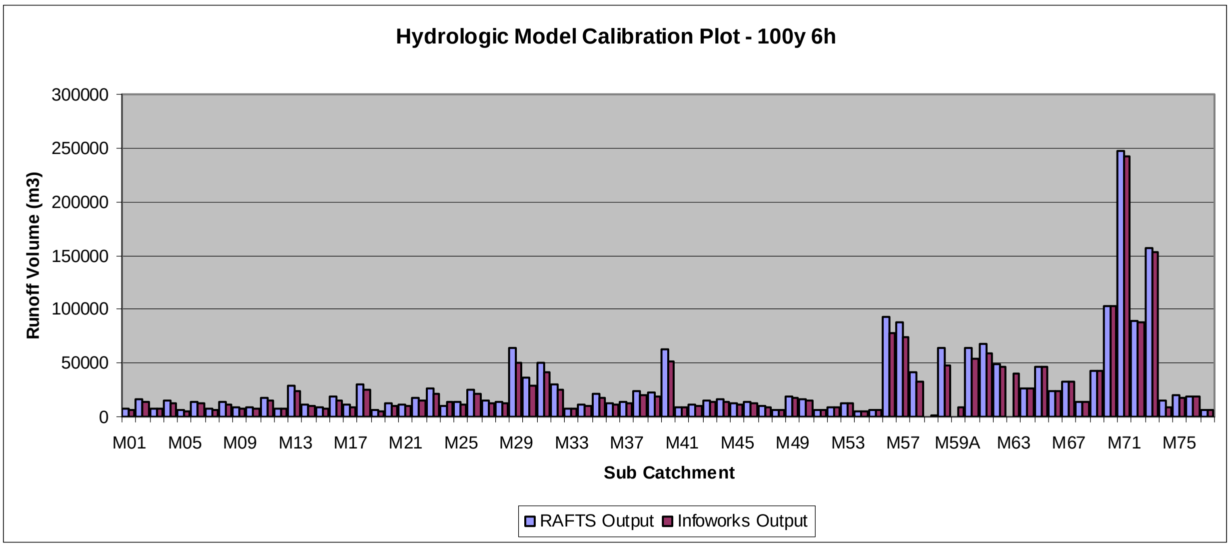


Figure B.3 Hydrologic model validation – total volume: 6h 100y



B.5 Hydraulic model validation

Peak pre-development flows generated by the InfoWorks model at various critical locations within the major waterways were compared to peak flows reported in the Floodplain management study (SKM, 2007) and are presented in Table B. below.

In general the InfoWorks model flows compare well to those generated by the flood model (SKM, 2007). Some sites within the Infoworks model experience flows less than the flood model produced by SKM. In particular upstream of Wright Rd at the Railway and at the Intersection of Kargotich Rd and Mundijong Rd experience flows less than predicted, a result of a revision to the upstream flow paths within the Infoworks model. Mapping of the preferred flow paths identified flow bifurcates of upstream of Keirnan St, thus reducing the flow experienced upstream of Wright Rd at Railway. Similary it was indentified that the Mundijong town site drains via Pure Steel Lane not Webb Rd, thereby reducing the flow experienced at the Intersection of Kargotich Rd and Mundijong Rd. The findings from this terrain analysis were confirmed with a site inspection.

Table B.6 Pre-development peak flow comparison between SKM flood study and DWMS InfoWorks CS Model

Location	**10 Year ARI Peak Flows (m^3/s)**		**100 Year ARI Peak Flows (m^3/s)**	
	Flood Study	DWMP model	Flood Study	DWMP model
U/S of Wright Rd at the Railway (M62)	18.55	11.1	59.0	25.9
Intersection of Kargotich Rd and Mundijong Rd (M11)	32.6	7.6	77.9	24.8
U/S of South Western Hwy just	8.1	10.4	37.7	40.5

Location	10 Year ARI Peak Flows (m^3/s)	100 Year ARI Peak Flows (m^3/s)
north of Keirnan St (M66)		

Table B.7 presents the significant hydraulic structures that have been included within the InfoWorks model of the Mundijong-Whitby catchment.

Table B.7 Modelled hydraulic structures

Location (MGA 1994)		Shape	Diameter/ width (mm)	Height (mm)	Invert level (m AHD)	Number of barrels
Easting	Northing					
401334.6	6428848.4	CIRC	1200	1200	15.765	2
401354.1	6427909	CIRC	900	900	15.717	1
401371.6	6427057.1	CIRC	900	900	15.825	1
401355.7	6426292.6	CIRC	500	500	16.495	1
403650.3	6428603.9	CIRC	1200	1200	27.142	3
403682.7	6428179.6	CIRC	500	500	28.742	1
403686	6427703.4	RECT	600	500	29.184	1
402629.7	6426585.9	CIRC	400	400	21.503	1
401386.4	6426233.3	RECT	1200	1200	15.653	3
403522.8	6425779.1	CIRC	600	600	28.926	1
403528.2	6425063.6	CIRC	600	600	28.04	1
404035.5	6424735.3	CIRC	400	400	33	1
405023.8	6428902.5	RECT	1500	800	39.956	1
404926.1	6428191.3	CIRC	1200	1200	37.335	6
404963.5	6428189.8	RECT	1200	1200	37.478	3
403693.6	6427240.8	CIRC	400	400	29.303	1
406974	6427336.3	RECT	2800	300	64.521	1
405358.6	6426457.7	CIRC	600	600	43.482	1
405084.2	6426063.7	CIRC	600	600	39.338	1
404895.8	6425962.8	CIRC	1800	1800	37.1	1
404855.9	6425814.8	CIRC	1800	1800	35.88	1

405613.1	6426939	CIRC	800	800	45.615	2
406829.3	6426345.9	CIRC	1100	1100	70.221	2
405444.7	6426260.1	CIRC	600	600	42.055	1
404362	6425643.9	CIRC	600	600	32.9	3
407231.6	6429121.6	CIRC	1200	1200	92.471	2
407153.4	6428354.1	CIRC	1500	1500	97.14	1
407044.1	6427475.3	CIRC	1500	1500	69.064	1
404075	6424725.1	RECT	1200	600	33.165	1

B.6 Modified parameterisation

The original 100 -year ARI event upper catchment runoff parameter of 0.5 (or 50% continuing proportional loss) developed for the Floodplain management strategy included allowances for the following uncertainties:

- uncertainty in design rainfall depths and temporal patterns
- uncertainty due to the impact of climate change
- uncertainty in upper catchment land use / vegetation coverage into the future

These allowances provided a conservative analysis of potential flood risk for the catchment. However, it is appropriate to reduce this allowance for design purposes, and so for the design scenarios presented in the main text of this report the Department of Water have adopted runoff coefficients of:

- 10-mm initial loss and 75% continuing proportional loss for the upper catchments in the 5- and 10-year ARI events;
- 10-mm initial loss and 4-mm/hr continuing loss on the flatter heavy soils downstream of the South Western Highway

Appendix C

5 Star Plus

Energy Use in Houses Code

Water Use in Houses Code

Department of Housing and Works
Government of Western Australia

5 Star Plus

Energy Use in Houses Code
Water Use in Houses Code

Playing our part in building better communities for Western Australia

Introduction

In May 2006, Western Australia adopted the minimum 5 Star energy efficiency provisions of the Building Code of Australia for all new homes. Now the Government has gone further and introduced 5 Star Plus – that builds on the energy efficiencies from 5 Star with the added benefits of water reduction measures for all homes right across the State.

5 Star Plus is based around two new Codes:

The Energy Use in Houses Code - confirms the existing 5 Star provisions for house design and construction and adds requirements for energy efficient water heating.

The Water Use in Houses Code - aims to reduce the consumption of water in residential homes by requiring water efficient fittings, minimising the wastage of water and facilitating the appropriate use of alternative sources of water such as grey water and rain water.

5 Star Plus will be applicable to new homes approved for construction after 1 September 2007, however, existing home owners can also use these Codes to improve energy and water efficiency in their homes. During 2008, the Government will investigate measures to apply the 5 Star Plus provisions to existing homes.

The Energy Use in Houses Code and Water Use in Houses Code are written to supplement the Building Code of Australia (BCA) and adopt BCA definitions and format for consistency. The Codes are published together for the convenience of builders, plumbers and certifiers who may need a convenient reference on site.

The Codes are available online at **www.5starplus.wa.gov.au**

Energy Use in Houses Code

Application

This Code applies to all new buildings classified as Class 1 and 10 buildings by the Building Code of Australia.

Interpretation

"The Building Code of Australia" means the latest edition of the Building Code of Australia published from time to time by, or on behalf of, the Australian Building Codes Board, but not including explanatory information published with that Code.

Objective

The objective of this Code is to reduce greenhouse gas emissions.

Functional Statement

In order to reduce greenhouse gas emissions, a building, including its services, is to be capable of efficiently using appropriate sources of energy.

Compliance With This Code

A building will comply with this Code if its construction satisfies all the Performance Requirements. Compliance with the Performance Requirements can be shown by:

(a) Complying with the Deemed-to-Satisfy provisions as listed in the Acceptable Construction Practice; or

(b) Formulating an alternative solution that is shown to be equivalent to the Deemed-to-Satisfy provisions; or

(c) Formulating an alternative solution that is verified using an acceptable verification method; or

(d) Formulating an alternative solution that is based on expert judgement or supported by suitable evidence in accordance with clause 1.2.2 of the Building Code of Australia; or

(e) Any combination of the above.

Energy Use in Houses Code

Performance Requirements

PR1 – Building

A building must comply with the Building Code of Australia Performance Requirement P2.6.1.

PR2 – Services

A building's domestic services including any associated distribution system and components must have features that comply with the Building Code of Australia, Performance Requirement P2.6.2.

PR3 – Hot Water Systems

A building's hot water systems including any associated components must have features that produce low levels of greenhouse gases when heating water.

Acceptable Construction Practice

(a) Compliance with all of the Deemed-to-Satisfy provisions of DTS1 satisfy the Performance Requirement PR1 for a building.
(b) Compliance with all of the Deemed-to-Satisfy provisions of DTS2 satisfy the Performance Requirement PR2 for a building.
(c) Compliance with all of the Deemed-to-Satisfy provisions of DTS3 satisfy the Performance Requirement PR3 for a building.

Deemed to Satisfy Provisions

DTS 1 – Thermal Comfort

The building must comply with the provisions of Part 3.12 of the Building Code of Australia for Building Fabric, External Glazing, Building Sealing and Air Movement.

DTS 2 – Services

The building must comply with the provisions of Part 3.12 of the Building Code of Australia for Services.

DTS 3 – Hot Water Systems

A hot water system must be either:

(i) a solar hot water system, complying with AS 2712-2002, that has been tested in accordance with AS 4234-1994, and achieves a minimum energy saving of 60% for a hot water demand level of 38MJ per day for climate zone 3; or
(ii) a gas hot water system, complying with AS 4552-2005 that achieves a minimum energy rating of "5 stars"; or
(iii) a heat pump hot water system, complying with AS 2712-2002 that has been tested in accordance with AS 4234-1994, and achieves a minimum energy saving of 60% for a hot water demand level of 38MJ per day for climate zone 3.

Explanatory Notes:

1. **BCA Performance Requirement P2.6.1**

   A building must have, to the degree necessary, a level of thermal performance to facilitate the efficient use of energy for artificial heating and cooling appropriate to –

   (a) the function and use of the building; and
   (b) the internal environment; and
   (c) the geographic location of the building; and
   (d) the effects of nearby permanent features such as topography, structures and buildings; and
   (e) solar radiation being—
      (i) utilised for heating; and
      (ii) controlled to minimise energy for cooling; and
   (f) the sealing of the building envelope against air leakage; and
   (g) the utilisation of air movement to assist cooling.

2. **BCA Performance Requirement P2.6.2 – Services**

   A building's domestic services including any associated distribution system and components must have features that, to the degree necessary, facilitate the efficient use of energy appropriate to –

   (a) the domestic services and its usage; and
   (b) the geographic location of the building; and
   (c) the location of the domestic services; and
   (d) the energy source.

3. **AS 2712-2002** details the design and construction of solar and heat pump water heaters.
4. **AS 4234-1994** sets out the method of testing and calculation of energy consumption for domestic solar water heaters and heat pumps.
5. **AS 4552-2005** details the design of gas forced water heaters for hot water supply and/or central heating.

Water Use in Houses Code

Application

This Code applies to all new buildings classified as Class 1 and 10 buildings by the Building Code of Australia.

Interpretation

"The Building Code of Australia" means the latest edition of the Building Code of Australia published from time to time by, or on behalf of, the Australian Building Codes Board, but not including explanatory information published with that Code.

"Alternative Internal Water Supply" refers to a water supply such as collection of rainwater on site, external third pipe non-potable water source, on-site bores or the like, other than potable water supplied by a licensed water service provider, and approved for use inside a dwelling.

"Alternative External Water Supply" refers to a water supply such as collection of rainwater on site, external third pipe non-potable water source, re-cycled grey water, on-site bores or the like, other than potable water supplied by a licensed water service provider, and approved for use outside a dwelling.

"Potable Water" refers to water intended for human consumption supplied by a licensed water service provider.

Objective

The objective of this Code is to reduce water demand by efficiently using water, and minimising the wasting of water, and facilitating the appropriate use of alternative sources of water.

Functional Statement

To reduce potable water demand a building must:

(a) enable the efficient use of potable water; and
(b) prevent excessive loss of potable water; and
(c) have the capacity to connect to alternative sources of water supply; and
(d) use alternative sources in situations of high water demand or restricted availability of potable water.

Compliance With This Code

A building will comply with this Code if its construction satisfies all the Performance Requirements. Compliance with the Performance Requirements can be shown by:

(a) complying with the Deemed-to-Satisfy provisions as listed in the Acceptable Construction Practice; or
(b) formulating an alternative solution that is shown to be equivalent to the Deemed-to-Satisfy provisions; or
(c) formulating an alternative solution that is verified using an acceptable verification method; or
(d) formulating an alternative solution that is based on expert judgement or supported by suitable evidence in accordance with clause 1.2.2 of the Building Code of Australia; or
(e) any combination of the above.

Explanatory Notes:

Stage 1 of the Code will be prescribed in the Building Regulations to apply from 1 September 2007.

Stage 2 of the Code will be prescribed in the Building Regulations to apply from date to be determined.

Implementation of Stage 2 of the Code is dependent on further consultation and research to determine areas of application and on amendments to plumbing regulations and processes as well as ensuring compliance with health regulations and policies.

Water Use in Houses Code

Stage 1 - To apply from 1 September 2007

Performance Requirements

PR1 – Water Use Efficiency

A building must have features that, to the degree necessary, facilitate the efficient use of potable water appropriate to:

(a) the geographic location of the building; and
(b) the available potable water supply for the building; and
(c) the function and use of the building.

PR2 – Water Loss Prevention

A building, including any water holding structures, must have features that, to the degree necessary, prevent the excessive loss of potable water appropriate to:

(a) the geographic location of the building; and
(b) the available potable water supply for the building; and
(c) the function and use of the building; and
(d) the effects of permanent features such as topography, structures and buildings.

PR3 – Hot Water Use Efficiency

A building must have features that, to the degree necessary, facilitate the efficient use of hot water appropriate to:

(a) the geographic location of the building; and
(b) the available hot water supply for the building; and
(c) the function and use of the building.

Acceptable Construction Practice

(a) Compliance with all of the Deemed-to-Satisfy provisions of DTS1 satisfies the Performance Requirement PR1 for a building.
(b) Compliance with all of the Deemed-to-Satisfy provisions of DTS2 satisfies the Performance Requirement PR2 for a building.
(c) Compliance with all of the Deemed-to-Satisfy provisions of DTS3 satisfies the Performance Requirement PR3 for a building.

Deemed to Satisfy Provisions

DTS 1 – Water Use Efficiency

(a) all tap fittings other than bath outlets and garden taps must be minimum 4 stars WELS rated.
(b) all showerheads must be minimum 3 stars WELS rated.
(c) all sanitary flushing systems must be a minimum 4 stars WELS rated dual flush.

DTS 2 – Swimming Pool Covers and Blankets

An outdoor private swimming pool or spa associated with a Class 1 building must be supplied with a cover, blanket or the like that:

(a) is designed to reduce water evaporation; and
(b) is listed on the Smart Approved Watermark Scheme.

DTS 3 – Hot Water Use Efficiency

All internal hot water outlets (taps, showers, washing machine water supplies) must be connected to a hot water system or a recirculating hot water system with pipes installed and insulated in accordance with AS/NZS 3500:2003. Plumbing and Drainage, Part 4 Heated Water Services. The pipe from the hot water system or recirculating hot water system to the furthest hot water outlet must not exceed 20 metres in length or 2 litres of internal volume.

Explanatory Notes:

The Smart Approved Watermark Scheme is implemented through the National Water Commission as a simple identification label about water efficient products. Further information can be obtained from www.nwc.gov.au

Stage 2 - To apply from (date to be determined)

Performance Requirements

PR4 – Alternative Water Supply Use Capacity

A building, including any associated plumbing, must have features that, to the degree necessary, facilitate the future use of alternative water supplies appropriate to:

(a) the geographic location of the building; and
(b) the function and use of the building; and
(c) the soil type and ground condition; and
(d) the available alternative sources of water; and
(e) the size and type of external landscaping.

PR5 – Grey Water Use Capacity

A building including any associated plumbing, located on a lot of a size and in a location suitable for recycling of grey water, must have features that, to the degree necessary, facilitate the future use of grey water recycling appropriate to:

(a) the geographic location of the building; and
(b) the available potable water supply for landscaping; and
(c) the function and use of the building; and
(d) the soil type and ground condition; and
(e) the available alternative sources of water; and
(f) the size and type of external landscaping.

Acceptable Construction Practice

(a) Compliance with all of the Deemed-to-Satisfy provisions of DTS4 satisfies the Performance Requirement PR4 for a building.
(b) Compliance with all of the Deemed-to-Satisfy provisions of DTS5 satisfies the Performance Requirement PR5 for a building.

Deemed to Satisfy Provisions

DTS 4 – Alternative Water Supply Use Capacity

All sanitary flushing systems and washing machines must be able to be connected at a later date, to an appropriate alternative water supply without the need to break, or cut into the fabric of the building to run new pipes.

DTS 5 – Grey Water Use Capacity

All shower, bath, laundry trough and washing machine drains must be able to be connected at a later date to an appropriate grey water diversion system without the need to break, or cut into the fabric of the building to run new pipes.

Explanatory Notes:

1. Health regulations apply to the use of alternative water supplies and will, amongst other things, limit the alternative water sources suitable for various uses.
2. The DTS 4 provisions do not require rainwater tanks. They require buildings to be able to be connected to such alternative water supplies relatively easily at a later date (i.e. the buildings are to be alternative supply 'ready'). Subject to health regulations and policies, alternative water supplies could also include bore water, third pipes, and the like.
3. All plumbing work associated with these requirements must be carried out by licensed plumbers and in accordance with all relevant plumbing regulations.

Water Use in Houses Code

Performance Requirements

PR6 – Alternative Internal Water Supply

A building with more than two showers or two WC facilities must use alternative internal water supplies for internal uses appropriate to:

(a) the geographic location of the building; and
(b) the available potable water supply for the building; and
(c) the function and use of the building; and
(d) the available alternative sources of water.

PR7 – Alternative External Water Supply

A building located on a lot of a size and in a location likely to use significant potable water for landscaping use must use alternative internal or external water supplies appropriate to:

(a) the geographic location of the building; and
(b) the available potable water supply for the building; and
(c) the function and use of the building; and
(d) the soil type and ground condition; and
(e) the available alternative sources of water; and
(f) the size and type of external landscaping.

Deemed to Satisfy Provisions

DTS 6 – Alternative Internal Water Supply

All sanitary flushing systems and clothes washing facilities must be connected to an alternative internal cold water supply.

DTS 7 – Alternative External Water Supply

(a) All external garden taps and irrigation systems must be connected to an alternative external water supply; or
(b) all shower, bath, laundry trough and washing machine drains must be connected to an approved grey water diversion and recycling system.

Acceptable Construction Practice

(a) Compliance with all of the Deemed-to-Satisfy provisions of DTS6 satisfies the Performance Requirement PR6 for a building.
(b) Compliance with all of the Deemed-to-Satisfy provisions of DTS6 or DTS7 satisfies the Performance Requirement PR7 for a building.

Explanatory Notes:

1. Houses required to be "grey water ready" under PR5 are those on large enough lots to allow drains carrying appropriate water to be run outside the house before connection to other waste pipes, and where there is likely to be enough landscaped area to adequately dilute the grey water.
2. Lots where houses are required to comply with PR7 will be identified through regulations. Further research is needed with relevant stakeholders to resolve which lots will be subject to this requirement.
3. Health regulations apply to the use of alternative water supplies and will, amongst other things, limit the alternative water sources suitable for internal or external use in different localities. For example most private bore water, whilst it may be suitable for garden use, may be inappropriate for use internally.
4. Alternative water supplies can include but is not limited to, rainwater tanks, bore water, third pipes, and the like.
5. Subject to health regulations an acceptable alternative internal water supply is an appropriately sized rainwater tank harvesting the rainwater runoff from the roof.
6. Subject to health regulations an acceptable alternative external water supply is a domestic bore.
7. All plumbing work associated with alternative water supplies must be carried out by licensed plumbers and in accordance with all relevant plumbing regulations.
8. The Water Use in Houses Code is implemented in two stages to allow amendment of plumbing regulations and training of licensed plumbers to ensure alternative water supplies are appropriate and safe, and that there is no risk of cross contamination with potable water supplies.

Further information

These Codes are intended to supplement the Building Code of Australia and will be called up by the Building Regulations 1989

For further information about 5 Star Plus please visit our website at www.5starplus.wa.gov.au

This brochure has been printed on 100% recycled paper.

May 2007 - First Edition

ISBN 978-0-9775498-3-2
Published by: Department of Housing and Works
Building Industry Development
108 Adelaide Terrace,
East Perth WA 6004

Copyright in this document is reserved to the Crown in the right of the State of Western Australia. Reproduction is prohibited other than in accordance with copyright law or with the prior written consent of the Director General of the Department of Housing and Works or the Attorney General.

{Blank Page for Double Sided Printing}

Appendix D

Groundwater Borehole Data

Published Data Only

{Blank Page for Double Sided Printing}

SITE_ID	SITE_TYPE	FEATURE	AWRC_REF	AWRC_CTXT	AWRC_NAME	AQWA_REF	PURPOSE_DE	COMMENCE	CEASE	DATE_DRILL	DRILLED_DE	BORE_INLET	WATER_SUPP	WATER_LEVE	TDS_COND	SAMPLE_DAT	STATUS_DES	GEOPHYSICA
20023376	Ground	Borehole or Well	61404187	MURRAY RIVER CATCHMENT 614	112	2033-2-NE-0194	Livestock	10000101		01-01-1000 - Unknown	= 10.36 m from Ground level			Static water level 1.830 m from Ground level on 01-01-1000	TDSolids (in situ) 265.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023384	Ground	Borehole or Well	61404195	MURRAY RIVER CATCHMENT 614	120	2033-2-NE-0202				01-01-1000 - Unknown	= 14.94 m from Ground level			Static water level 6.710 m from Ground level on 01-01-1000	TDSolids (in situ) 143.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023658	Ground	Borehole or Well	61404437	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0476		28/12/1990		28-12-1990 - Known day	= 82 m from Ground level	Top of top inlet =18m, Bottom of bottom inlet =24m, from Ground level		Static water level 4.000 m from Ground level on 28-12-1990		28-12-1990 to 28-12-1990	Operating	N
20023618	Ground	Borehole or Well	61404399	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0436	Domestic/Household			19-08-1989 - Known day	= 21 m from Ground level	Top of top inlet =13m, Bottom of bottom inlet =21m, from Ground level	Borehole water supply 218.000 m3/day on 19-08-1989	Static water level 1.500 m from Ground level on 19-08-1989		19-08-1989 to 19-08-1989		N
20023608	Ground	Borehole or Well	61404390	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0426	Domestic/Household			25-04-1989 - Known day	= 26.4 m from Ground level	Top of top inlet =12.2m, Bottom of bottom inlet =24.4m, from Ground level	Borehole water supply 76.000 m3/day on 25-04-1989	Static water level 5.300 m from Ground level on 25-04-1989	TDSolids (in situ) 370.000 mg/L on 25-04-1989	25-04-1989 to 25-04-1989		N
20023544	Ground	Borehole or Well	61404336	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0362	Domestic/Household/Livestock			09-11-1987 - Known day	= 20.5 m from Ground level	Top of top inlet =8m, Bottom of bottom inlet =20.5m, from Ground level	Borehole water supply 65.000 m3/day on 09-11-1987		TDSolids (in situ) 140.000 mg/L on 09-11-1987	09-11-1987 to 09-11-1987		N
20023654	Ground	Unknown	61406615	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0472												N
20023609	Ground	Borehole or Well	61404391	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0427				03-02-1989 - Known day	= 14.6 m from Ground level	Top of top inlet =10.1m, Bottom of bottom inlet =14.6m, from Ground level		Static water level 5.000 m from Ground level on 03-02-1989		03-02-1989 to 03-02-1989		N
20023655	Ground	Borehole or Well	61404434	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0473	Domestic/Household			15-04-1991 - Known day	= 37 m from Ground level	Top of top inlet =18m, Bottom of bottom inlet =37m, from Ground level			TDSolids (in situ) 260.000 mg/L on 15-04-1991	15-04-1991 to 15-04-1991		N
20023610	Ground	Borehole or Well	61404392	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0428	Domestic/Household			30-10-1989 - Known day	= 29 m from Ground level	Top of top inlet =7.8m, Bottom of bottom inlet =25.9m, from Ground level		Static water level 1.900 m from Ground level on 30-10-1989		30-10-1989 to 30-10-1989		N
20023378	Ground	Borehole or Well	61404189	MURRAY RIVER CATCHMENT 614	114	2033-2-NE-0196				01-01-1000 - Unknown	= 24.38 m from Ground level		Borehole water supply 16.366 m3/day on 01-01-1000	Static water level 7.620 m from Ground level on 01-01-1000	TDSolids (in situ) 268.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
12574123	Ground	Borehole or Well	61414050	SOUTH EAST CORRIDOR	SED10		Observation	1/04/1996	2/04/1996	01-04-1996 - Unknown	= 9.2 m from Ground level	Top of top inlet =5m, Bottom of bottom inlet =8m, from Ground level					Not operating	N
20023651	Ground	Borehole or Well	61404431	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0469	Irrigation	12/11/1993		12-11-1993 - Known day	= 20.4 m from Ground level	Top of top inlet =8.4m, Bottom of bottom inlet =20.4m, from Ground level					Operating	N
20023383	Ground	Borehole or Well	61404194	MURRAY RIVER CATCHMENT 614	119	2033-2-NE-0201				01-01-1000 - Unknown	= 11.89 m from Ground level			Static water level 8.840 m from Ground level on 01-01-1000	TDSolids (in situ) 340.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023533	Ground	Unknown	61406602	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0351				15-03-1987 - Known day								N
20023203	Ground	Unknown	61406548	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0021												N
20023652	Ground	Borehole or Well	61404432	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0470	Domestic/Household/Irrigation	2/11/1993		02-11-1993 - Known day	= 30 m from Ground level	Top of top inlet =24m, Bottom of bottom inlet =30m, from Ground level		Static water level 6.000 m from Ground level on 02-11-1993	TDSolids (in situ) 260.000 mg/L on 02-11-1993	02-11-1993 to 02-11-1993	Operating	N
20023522	Ground	Borehole or Well	61404316	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0340				30-04-1985 - Known day	= 15 m from Ground level	Top of top inlet =6m, Bottom of bottom inlet =15m, from Ground level	Borehole water supply 54.500 m3/day on 30-04-1985	Static water level 4.000 m from Ground level on 30-04-1985		30-04-1985 to 30-04-1985	Capped	N
20023377	Ground	Borehole or Well	61404188	MURRAY RIVER CATCHMENT 614	113	2033-2-NE-0195	Livestock	10000101		01-01-1000 - Unknown	= 6.4 m from Ground level			Static water level 1.830 m from Ground level on 01-01-1000	TDSolids (in situ) 273.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023602	Ground	Borehole or Well	61404384	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0420	Domestic/Household			16-10-1990 - Known day	= 25 m from Ground level	Top of top inlet =19m, Bottom of bottom inlet =25m, from Ground level	Borehole water supply 10.900 m3/day on 16-10-1990			16-10-1990 to 16-10-1990		N
23003143	Surface	Sampling point	6142781	SERPENTINE CATCHMENT	SR18043			30/08/2000							Cond uncomp (lab) 43500.000 uS/m on 22-09-2003	31-08-2000 to 22-09-2003	Operating	N
20023202	Ground	Unknown	61406547	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0020												N
20023201	Ground	Unknown	61406546	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0019												N
12572774	Ground	Borehole or Well	61414020	SOUTH EAST CORRIDOR	SES34		Observation	29/03/1996	30/03/1996	29-03-1996 - Unknown	= 5.2 m from Ground level	Top of top inlet =0m, Bottom of bottom inlet =5.2m, from Ground level					Not operating	N
23016678	Surface	Sampling point	6140525	SERPENTINE CATCHMENT	SERPENTINE RIVER			1/08/2000									Operating	N
12574117	Ground	Borehole or Well	61414049	SOUTH EAST CORRIDOR	SED9		Observation	1/04/1996	24/06/1999	01-04-1996 - Unknown	= 10.1 m from Ground level	Top of top inlet =1m, Bottom of bottom inlet =4m, from Ground level		Static water level .660 m from Top of casing on 29-09-1998		02-10-1996 to 29-09-1998	Not operating	N
3441	Ground	Borehole or Well	61415041	ARTESIAN MONITORING	AM56	2033-2-NE-0337	Monitoring	17/05/1978		30-06-1978 - Known year	= 351 m from Ground level	Top of top inlet =246m, Bottom of bottom inlet =255m, from Ground level	Borehole water supply 21.600 m3/day on 18-11-1979	Static water level 12.570 m from Top of casing on 10-03-2008	TDSolids (calc @180ºC)-HCO3 840.000 mg/L on 08-11-1979	17-05-1978 to 10-03-2008	Operating	N
3442	Ground	Borehole or Well	61415042	ARTESIAN MONITORING	AM56A	2033-2-NE-0336	Monitoring	7/11/1983		30-06-1982 - Known year	= 85 m from Ground level	Top of top inlet =33m, Bottom of bottom inlet =44m, from Ground level		Static water level 5.800 m from Top of casing on 10-03-2008	TDSolids (calc @180ºC)-HCO3 682.000 mg/L on 07-11-1983	07-11-1983 to 10-03-2008	Operating	Y
20023531	Ground	Borehole or Well	61404325	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0349				15-02-1987 - Known day	= 30.48 m from Ground level	Top of top inlet =18.28m, Bottom of bottom inlet =30.48m, from Ground level						N
20023520	Ground	Borehole or Well	61404314	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0338				01-01-1000 - Unknown	= 28.34 m from Ground level	Top of top inlet =16.15m, Bottom of bottom inlet =28.34m, from Ground level	Borehole water supply 327.000 m3/day on 01-01-1000		TDSolids (in situ) 460.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
23016677	Surface	Sampling point	6140524	SERPENTINE CATCHMENT	SERPENTINE RIVER			1/08/2000									Operating	N
20023374	Ground	Borehole or Well	61404185	MURRAY RIVER CATCHMENT 614	110	2033-2-NE-0192	Livestock	30/06/1963		30-06-1963 - Known year	= 6.1 m from Ground level			Static water level 2.130 m from Ground level on 30-06-1963	TDSolids (in situ) 700.000 mg/L on 30-06-1963	30-06-1963 to 30-06-1963	Operating	N
23003144	Surface	Sampling point	6142782	SERPENTINE CATCHMENT	SR18044			30/08/2000							Cond uncomp (lab) 56600.000 uS/m on 22-09-2003	31-08-2000 to 22-09-2003	Operating	N
20023507	Ground	Borehole or Well	61404303	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0325	Domestic/Household			30-06-1976 - Known year	= 19.81 m from Ground level		Borehole water supply 43.642 m3/day on 30-06-1976			30-06-1976 to 30-06-1976		N
20023262	Ground	Borehole or Well	61404094	MURRAY RIVER CATCHMENT 614	56	2033-2-NE-0080				30-06-1956 - Known year	= 22.86 m from Ground level							N
20023355	Ground	Borehole or Well	61404167	MURRAY RIVER CATCHMENT 614	90	2033-2-NE-0173	Irrigation/Livestock	10000101		01-01-1000 - Unknown	= 27.43 m from Ground level			Static water level 2.740 m from Ground level on 01-01-1000	TDSolids (in situ) 1060.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023356	Ground	Borehole or Well	61404168	MURRAY RIVER CATCHMENT 614	91	2033-2-NE-0174				01-01-1000 - Unknown	= 6.4 m from Ground level			Static water level 2.740 m from Ground level on 01-01-1000	TDSolids (in situ) 1020.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023482	Ground	Borehole or Well	61404288	MURRAY RIVER CATCHMENT 614	MUNDIJONG RSVE 6 INCH	2033-2-NE-0300				30-06-1973 - Known year	= 31.7 m from Ground level		Borehole water supply 54.553 m3/day on 30-06-1973	Static water level 6.100 m from Ground level on 30-06-1973	TDSolids (in situ) 815.000 mg/L on 30-06-1973	30-06-1973 to 30-06-1973		N
12572780	Ground	Borehole or Well	61414021	SOUTH EAST CORRIDOR	SES35		Observation	29/03/1996	30/03/1996	29-03-1996 - Unknown	= 5.2 m from Ground level	Top of top inlet =0m, Bottom of bottom inlet =5.2m, from Ground level					Not operating	N
20023369	Ground	Borehole or Well	61404181	MURRAY RIVER CATCHMENT 614	104	2033-2-NE-0187				01-01-1000 - Unknown	= 6.1 m from Ground level			Static water level 2.440 m from Ground level on 01-01-1000	TDSolids (in situ) 180.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023365	Ground	Borehole or Well	61404177	MURRAY RIVER CATCHMENT 614	100	2033-2-NE-0183				01-01-1000 - Unknown	= 5.49 m from Ground level			Static water level 2.130 m from Ground level on 01-01-1000	TDSolids (in situ) 480.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023359	Ground	Borehole or Well	61404171	MURRAY RIVER CATCHMENT 614	94	2033-2-NE-0177				01-01-1000 - Unknown	= 4.27 m from Ground level			Static water level 1.520 m from Ground level on 01-01-1000	TDSolids (in situ) 200.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023336	Ground	Borehole or Well	61404148	MURRAY RIVER CATCHMENT 614	79	2033-2-NE-0154	Industry	30/06/1970		30-06-1970 - Known year	= 6.71 m from Ground level			Static water level 1.830 m from Ground level on 30-06-1970	TDSolids (in situ) 137.000 mg/L on 30-06-1970	30-06-1970 to 30-06-1970	Operating	N
20023337	Ground	Borehole or Well	61404149	MURRAY RIVER CATCHMENT 614	80	2033-2-NE-0155		30/06/1950		30-06-1950 - Known year	= 7.62 m from Ground level		Borehole water supply 54.553 m3/day on 30-06-1950	Static water level 2.440 m from Ground level on 30-06-1950	TDSolids (in situ) 490.000 mg/L on 30-06-1950	30-06-1950 to 30-06-1950	Operating	N
20023361	Ground	Borehole or Well	61404173	MURRAY RIVER CATCHMENT 614	96	2033-2-NE-0179	Livestock	10000101		01-01-1000 - Unknown	= 5.18 m from Ground level			Static water level 1.830 m from Ground level on 01-01-1000	TDSolids (in situ) 500.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023366	Ground	Borehole or Well	61404178	MURRAY RIVER CATCHMENT 614	101	2033-2-NE-0184	Garden Irrigation	10000101		01-01-1000 - Unknown	= 6.1 m from Ground level			Static water level 2.740 m from Ground level on 01-01-1000	TDSolids (in situ) 430.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023360	Ground	Borehole or Well	61404172	MURRAY RIVER CATCHMENT 614	95	2033-2-NE-0178				01-01-1000 - Unknown	= 3.05 m from Ground level			Static water level 1.830 m from Ground level on 01-01-1000	TDSolids (in situ) 520.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
23003162	Surface	Sampling point	6142800	SERPENTINE CATCHMENT	SR18122			30/08/2000							Cond uncomp (lab) 36600.000 uS/m on 22-09-2003	31-08-2000 to 13-09-2004	Operating	N
20023370	Ground	Borehole or Well	61404182	MURRAY RIVER CATCHMENT 614	105	2033-2-NE-0188	Garden Irrigation/Livestock	10000101		01-01-1000 - Unknown	= 3.96 m from Ground level		Borehole water supply 6.819 m3/day on 01-01-1000	Static water level 1.830 m from Ground level on 01-01-1000	TDSolids (in situ) 380.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023357	Ground	Borehole or Well	61404169	MURRAY RIVER CATCHMENT 614	92	2033-2-NE-0175				01-01-1000 - Unknown	= 5.18 m from Ground level			Static water level 2.590 m from Ground level on 01-01-1000	TDSolids (in situ) 580.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023358	Ground	Borehole or Well	61404170	MURRAY RIVER CATCHMENT 614	93	2033-2-NE-0176				01-01-1000 - Unknown	= 1.52 m from Ground level			Static water level 1.220 m from Ground level on 01-01-1000	TDSolids (in situ) 480.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023372	Ground	Borehole or Well	61404184	MURRAY RIVER CATCHMENT 614	107	2033-2-NE-0190				01-01-1000 - Unknown	= 13.11 m from Ground level			Static water level 2.130 m from Ground level on 01-01-1000	TDSolids (in situ) 185.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023506	Ground	Borehole or Well	61404302	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0324	Domestic/Household			30-06-1976 - Known year	= 18.59 m from Ground level		Borehole water supply 163.659 m3/day on 30-06-1976		TDSolids (evap @180ºC) 190.000 mg/L on 11-08-1977	30-06-1976 to 11-08-1977		N
20023354	Ground	Borehole or Well	61404166	MURRAY RIVER CATCHMENT 614	88	2033-2-NE-0172		30/06/1952		30-06-1952 - Known year	= 11.89 m from Ground level		Borehole water supply 13.638 m3/day on 30-06-1952	Static water level 1.830 m from Ground level on 30-06-1952	TDSolids (in situ) 519.000 mg/L on 30-06-1952	30-06-1952 to 30-06-1952	Operating	N
20023343	Ground	Borehole or Well	61404155	MURRAY RIVER CATCHMENT 614	86	2033-2-NE-0161	Livestock	10000101		01-01-1000 - Unknown	= 5.18 m from Ground level			Static water level 2.130 m from Ground level on 01-01-1000	TDSolids (in situ) 196.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N

20023344	Ground	Borehole or Well	61404156	MURRAY RIVER CATCHMENT 614	87	2033-2-NE-0162	Livestock	10000101		01-01-1000 - Unknown	= 3.66 m from Ground level			Static water level 1.830 m from Ground level on 01-01-1000	TDSolids (in situ) 196.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023371	Ground	Borehole or Well	61404183	MURRAY RIVER CATCHMENT 614	106	2033-2-NE-0189	Garden Irrigation	10000101		01-01-1000 - Unknown	= 7.92 m from Ground level		Borehole water supply 4.546 m3/day on 01-01-1000	Static water level 1.830 m from Ground level on 01-01-1000	TDSolids (in situ) 343.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023353	Ground	Borehole or Well	61404165	MURRAY RIVER CATCHMENT 614	89	2033-2-NE-0171				30-06-1973 - Known year	= 13.72 m from Ground level			Static water level 6.100 m from Ground level on 30-06-1973		30-06-1973 to 30-06-1973		N
20023706	Ground	Borehole or Well	61404482	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0524	Irrigation	26/10/1997		26-10-1997 - Known day	= 22 m from Ground level	Top of top inlet =16m, Bottom of bottom inlet =22m, from Ground level					Operating	N
15719	Supply	Pipe tapping point	6534070	MUNDIJONG	405 03-02			1/01/1970							Cond uncomp (lab) 25800.004 uS/m on 23-07-1998	07-07-1987 to 23-07-1998	Operating	N
20084092	Ground	Borehole or Well	61405919	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0549	Irrigation/Livestock			26-03-2000 - Known day	= 22.2 m from Ground level	Top of top inlet =10.2m, Bottom of bottom inlet =22.2m, from Ground level		Static water level 2.650 m from Ground level on 26-03-2000	TDSolids (in situ) 440.000 mg/L on 26-03-2000	26-03-2000 to 26-03-2000		N
20023363	Ground	Borehole or Well	61404175	MURRAY RIVER CATCHMENT 614	98	2033-2-NE-0181				01-01-1000 - Unknown	= 4.27 m from Ground level			Static water level 1.980 m from Ground level on 01-01-1000	TDSolids (in situ) 167.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023364	Ground	Borehole or Well	61404176	MURRAY RIVER CATCHMENT 614	99	2033-2-NE-0182				01-01-1000 - Unknown	= 7.62 m from Ground level			Static water level 2.440 m from Ground level on 01-01-1000	TDSolids (in situ) 364.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023306	Ground	Borehole or Well	61404118	MURRAY RIVER CATCHMENT 614	24	2033-2-NE-0124	Livestock	30/06/1950		30-06-1950 - Known year	= 6.1 m from Ground level			Static water level 2.130 m from Ground level on 30-06-1950	TDSolids (in situ) 1700.000 mg/L on 30-06-1950	30-06-1950 to 30-06-1950	Operating	N
20038107	Ground	Unknown	61406876	MURRAY RIVER CATCHMENT 614	BORE	2133-3-NW-0003												N
20023362	Ground	Borehole or Well	61404174	MURRAY RIVER CATCHMENT 614	97	2033-2-NE-0180				30-06-1950 - Known year			Borehole water supply 18.184 m3/day on 30-06-1950	Static water level 4.570 m from Ground level on 30-06-1950	TDSolids (in situ) 111.000 mg/L on 30-06-1950	30-06-1950 to 30-06-1950		N
20023338	Ground	Borehole or Well	61404150	MURRAY RIVER CATCHMENT 614	81	2033-2-NE-0156				30-06-1950 - Known year	= 6.71 m from Ground level			Static water level 2.740 m from Ground level on 30-06-1950	TDSolids (in situ) 510.000 mg/L on 30-06-1950	30-06-1950 to 30-06-1950		N
20023339	Ground	Borehole or Well	61404151	MURRAY RIVER CATCHMENT 614	82	2033-2-NE-0157				30-06-1950 - Known year	= 2.74 m from Ground level			Static water level 1.220 m from Ground level on 30-06-1950	TDSolids (in situ) 355.000 mg/L on 30-06-1950	30-06-1950 to 30-06-1950		N
20038106	Ground	Borehole or Well	61405677	MURRAY RIVER CATCHMENT 614	WHITBY FALLS NO. 2	2133-3-NW-0002				30-06-1962 - Known year	= 210.31 m from Ground level	Top of top inlet =67.06m, Bottom of bottom inlet =207.26m, from Ground level	Borehole water supply 43.642 m3/day on 30-06-1962	Static water level 28.350 m from Ground level on 30-06-1962	TDSolids (in situ) 2542.000 mg/L on 30-06-1962	30-06-1962 to 30-06-1962		N
20023342	Ground	Borehole or Well	61404154	MURRAY RIVER CATCHMENT 614	85	2033-2-NE-0160	Livestock	10000101		01-01-1000 - Unknown	= 3.96 m from Ground level			Static water level 1.520 m from Ground level on 01-01-1000	TDSolids (in situ) 326.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023595	Ground	Borehole or Well	61404377	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0413	Domestic/Household			16-05-1988 - Known day	= 30 m from Ground level	Top of top inlet =18m, Bottom of bottom inlet =30m, from Ground level						N
20023335	Ground	Borehole or Well	61404147	MURRAY RIVER CATCHMENT 614	78	2033-2-NE-0153	Garden Irrigation			30-06-1972 - Known year	= 32 m from Ground level		Borehole water supply 196.391 m3/day on 30-06-1972	Static water level 3.050 m from Ground level on 30-06-1972		30-06-1972 to 30-06-1972		N
20023340	Ground	Borehole or Well	61404152	MURRAY RIVER CATCHMENT 614	83	2033-2-NE-0158	Irrigation/Livestock	10000101		01-01-1000 - Unknown	= 3.35 m from Ground level			Static water level 1.220 m from Ground level on 01-01-1000	TDSolids (in situ) 580.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023341	Ground	Borehole or Well	61404153	MURRAY RIVER CATCHMENT 614	84	2033-2-NE-0159	Livestock	10000101		01-01-1000 - Unknown	= 5.49 m from Ground level			Static water level .610 m from Ground level on 01-01-1000	TDSolids (in situ) 421.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023367	Ground	Borehole or Well	61404179	MURRAY RIVER CATCHMENT 614	102	2033-2-NE-0185	Garden Irrigation	10000101		01-01-1000 - Unknown	= 4.27 m from Ground level			Static water level 2.130 m from Ground level on 01-01-1000	TDSolids (in situ) 240.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023334	Ground	Borehole or Well	61404146	MURRAY RIVER CATCHMENT 614	77	2033-2-NE-0152	Garden Irrigation/Livestock	30/06/1914		30-06-1914 - Known year	= 7.62 m from Ground level			Static water level 3.660 m from Ground level on 30-06-1914	TDSolids (in situ) 193.000 mg/L on 30-06-1914	30-06-1914 to 30-06-1914	Operating	N
20023197	Ground	Unknown	61406543	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0015												N
20023368	Ground	Borehole or Well	61404180	MURRAY RIVER CATCHMENT 614	103	2033-2-NE-0186	Garden Irrigation	10000101		01-01-1000 - Unknown	= 5.79 m from Ground level		Borehole water supply 6.819 m3/day on 01-01-1000	Static water level 2.440 m from Ground level on 01-01-1000	TDSolids (in situ) 450.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023332	Ground	Borehole or Well	61404144	MURRAY RIVER CATCHMENT 614	75	2033-2-NE-0150	Garden Irrigation/Livestock	30/06/1935		30-06-1935 - Known year	= 8.23 m from Ground level			Static water level 3.050 m from Ground level on 30-06-1935	TDSolids (in situ) 110.000 mg/L on 30-06-1935	30-06-1935 to 30-06-1935	Operating	N
20023333	Ground	Borehole or Well	61404145	MURRAY RIVER CATCHMENT 614	76	2033-2-NE-0151	Garden Irrigation/Livestock	30/06/1935		30-06-1935 - Known year	= 6.71 m from Ground level			Static water level 4.570 m from Ground level on 30-06-1935	TDSolids (in situ) 340.000 mg/L on 30-06-1935	30-06-1935 to 30-06-1935	Operating	N
20023200	Ground	Borehole or Well	61404065	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0018				01-01-1000 - Unknown	= 9.14 m from Ground level		Borehole water supply 109.106 m3/day on 01-01-1000	Static water level 4.570 m from Ground level on 01-01-1000		01-01-1000 to 01-01-1000		N
20023198	Ground	Unknown	61406544	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0016												N
23025412	Surface	Sampling point	6140893	MURRAY RIVER BASIN	MAN010			26/09/2002							Cond uncomp (in situ) 36000.000 uS/m on 26-09-2002	26-09-2002 to 26-09-2002	Operating	N
20023329	Ground	Borehole or Well	61404141	MURRAY RIVER CATCHMENT 614	72	2033-2-NE-0147	Garden Irrigation	30/06/1971		30-06-1971 - Known year	= 9.14 m from Ground level			Static water level .000 m from Ground level on 30-06-1971	TDSolids (in situ) 271.000 mg/L on 30-06-1971	30-06-1971 to 30-06-1971	Operating	N
20023614	Ground	Borehole or Well	61404396	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0432	Domestic/Household			11-06-1989 - Known day	= 39 m from Ground level	Top of top inlet =27m, Bottom of bottom inlet =39m, from Ground level		Static water level 1.800 m from Ground level on 11-06-1989		11-06-1989 to 11-06-1989		N
20023305	Ground	Borehole or Well	61404117	MURRAY RIVER CATCHMENT 614	22	2033-2-NE-0123				01-01-1000 - Unknown	= 7.32 m from Ground level			Static water level 1.830 m from Ground level on 01-01-1000	TDSolids (in situ) 240.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023331	Ground	Borehole or Well	61404143	MURRAY RIVER CATCHMENT 614	74	2033-2-NE-0149	Garden Irrigation/Livestock	10000101		01-01-1000 - Unknown	= 3.96 m from Ground level			Static water level 2.740 m from Ground level on 01-01-1000	TDSolids (in situ) 480.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
12923	Surface	Sampling point	6141039	MANJEDAL BROOK	ML 3			21/01/1970	26/09/1977						Cond calc 25 deg C 36500.000 uS/m on 26-09-1977	21-01-1970 to 26-09-1977	Not operating	N
20023199	Ground	Unknown	61406545	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0017												N
20023613	Ground	Borehole or Well	61404395	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0431	Horticulture			28-01-1990 - Known day	= 34.5 m from Ground level	Top of top inlet =6m, Bottom of bottom inlet =34.5m, from Ground level		Static water level 7.400 m from Ground level on 28-01-1990	TDSolids (in situ) 240.000 mg/L on 28-01-1990	28-01-1990 to 28-01-1990		N
20023689	Ground	Borehole or Well	61404465	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0507		28/01/1998		28-01-1998 - Known day	= 42 m from Ground level	Top of top inlet =30m, Bottom of bottom inlet =42m, from Ground level	Borehole water supply 272.765 m3/day on 28-01-1998	Static water level 5.000 m from Ground level on 28-01-1998		28-01-1998 to 28-01-1998	Operating	N
20023591	Ground	Borehole or Well	61404373	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0409	Domestic/Household			01-02-1989 - Known day	= 27.5 m from Ground level	Top of top inlet =6m, Bottom of bottom inlet =27.5m, from Ground level		Static water level 5.000 m from Ground level on 01-02-1989		01-02-1989 to 01-02-1989		N
20023525	Ground	Borehole or Well	61404319	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0343				15-02-1987 - Known day	= 17 m from Ground level	Top of top inlet =6m, Bottom of bottom inlet =17m, from Ground level		Static water level 3.500 m from Ground level on 15-02-1987	TDSolids (in situ) 27.000 mg/L on 15-02-1987	15-02-1987 to 15-02-1987		N
20023657	Ground	Borehole or Well	61404436	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0475	Domestic/Household			02-04-1991 - Known day	= 50 m from Ground level	Top of top inlet =32m, Bottom of bottom inlet =50m, from Ground level		Static water level 4.300 m from Ground level on 02-04-1991		02-04-1991 to 02-04-1991		N
20023330	Ground	Borehole or Well	61404142	MURRAY RIVER CATCHMENT 614	73	2033-2-NE-0148		10000101		01-01-1000 - Unknown	= 5.79 m from Ground level			Static water level 3.050 m from Ground level on 01-01-1000	TDSolids (in situ) 700.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
23025413	Surface	Sampling point	6140894	MURRAY RIVER BASIN	MAN020			26/09/2002							Cond uncomp (in situ) 36500.000 uS/m on 26-09-2002	26-09-2002 to 26-09-2002	Operating	N
20023328	Ground	Borehole or Well	61404140	MURRAY RIVER CATCHMENT 614	71	2033-2-NE-0146	Garden Irrigation/Livestock			01-01-1000 - Unknown	= 9.45 m from Ground level			Static water level 5.180 m from Ground level on 01-01-1000		01-01-1000 to 01-01-1000		N
23016693	Surface	Sampling point	6140540	SERPENTINE CATCHMENT	SERPENTINE RIVER			1/08/2000									Operating	N
20023656	Ground	Borehole or Well	61404435	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0474	Irrigation			16-11-1994 - Known day	= 28.96 m from Ground level	Top of top inlet =16.76m, Bottom of bottom inlet =28.96m, from Ground level						N
20023693	Ground	Borehole or Well	61404469	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0511	Domestic/Household	22/05/1998		22-05-1998 - Known day	= 30 m from Ground level	Top of top inlet =24m, Bottom of bottom inlet =30m, from Ground level	Borehole water supply 36.000 m3/day on 22-05-1998	Static water level 5.400 m from Ground level on 22-05-1998	TDSolids (in situ) 300.000 mg/L on 22-05-1998	22-05-1998 to 22-05-1998	Operating	N
20023703	Ground	Borehole or Well	61404479	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0521	Domestic/Household	26/06/1998		26-06-1998 - Known day	= 55 m from Ground level	Top of top inlet =43m, Bottom of bottom inlet =55m, from Ground level					Operating	N
23016700	Surface	Sampling point	6140547	SERPENTINE CATCHMENT	SERPENTINE RIVER			1/08/2000									Operating	N
20023324	Ground	Borehole or Well	61404136	MURRAY RIVER CATCHMENT 614	67	2033-2-NE-0142	Garden Irrigation	10000101		01-01-1000 - Unknown	= 5.18 m from Ground level			Static water level 2.440 m from Ground level on 01-01-1000	TDSolids (in situ) 347.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023323	Ground	Borehole or Well	61404135	MURRAY RIVER CATCHMENT 614	66	2033-2-NE-0141	Garden Irrigation			30-06-1955 - Known year	= 4.57 m from Ground level			Static water level 2.130 m from Ground level on 30-06-1955	TDSolids (in situ) 540.000 mg/L on 30-06-1955	30-06-1955 to 30-06-1955		N
20038148	Ground	Borehole or Well	61405698	MURRAY RIVER CATCHMENT 614	BORE	2133-3-NW-0044				30-06-1977 - Known year	= 67.06 m from Ground level				TDSolids (in situ) 4290.000 mg/L on 30-06-1977	30-06-1977 to 30-06-1977		N
23003159	Surface	Sampling point	6142797	SERPENTINE CATCHMENT	SR18090			30/08/2000							Cond uncomp (lab) 35000.000 uS/m on 22-09-2003	31-08-2000 to 13-09-2004	Operating	N
20023319	Ground	Borehole or Well	61404131	MURRAY RIVER CATCHMENT 614	63	2033-2-NE-0137	Livestock	10000101		01-01-1000 - Unknown	= 9.14 m from Ground level			Static water level 3.960 m from Ground level on 01-01-1000	TDSolids (in situ) 630.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023322	Ground	Borehole or Well	61404134	MURRAY RIVER CATCHMENT 614	65	2033-2-NE-0140	Industry	10000101		01-01-1000 - Unknown	= 5.18 m from Ground level		Borehole water supply 4.546 m3/day on 01-01-1000	Static water level 3.350 m from Ground level on 01-01-1000	TDSolids (in situ) 780.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023320	Ground	Borehole or Well	61404132	MURRAY RIVER CATCHMENT 614	64	2033-2-NE-0138	Livestock			01-01-1000 - Unknown	= 5.79 m from Ground level			Static water level 2.740 m from Ground level on 01-01-1000	TDSolids (in situ) 1680.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
23003432	Surface	Sampling point	6140005	SERPENTINE CATCHMENT	SR18058			30/08/2000							Cond uncomp (lab) 28200.000 uS/m on 22-09-2003	31-08-2000 to 13-09-2004	Operating	N
20023639	Ground	Borehole or Well	61404419	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0457	Domestic/Household/Livestock			18-05-1994 - Known day	= 39.9 m from Ground level	Top of top inlet =33m, Bottom of bottom inlet =39m, from Ground level	Borehole water supply 294.586 m3/day on 18-05-1994	Static water level 4.100 m from Ground level on 18-05-1994		18-05-1994 to 18-05-1994		N

20023325	Ground	Borehole or Well	61404137	MURRAY RIVER CATCHMENT 614	68	2033-2-NE-0143	Domestic/Household/Irrigation	30/06/1956		30-06-1956 - Known year	= 7.01 m from Ground level			Static water level 2.740 m from Ground level on 30-06-1956	TDSolids (in situ) 320.000 mg/L on 30-06-1956	30-06-1956 to 30-06-1956	Operating	N
20023653	Ground	Borehole or Well	61404433	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0471	Domestic/Household			10-07-1990 - Known day	= 21 m from Ground level	Top of top inlet =9m, Bottom of bottom inlet =21m, from Ground level		Static water level 3.200 m from Ground level on 10-07-1990		10-07-1990 to 10-07-1990		N
23025414	Surface	Sampling point	6140895	MURRAY RIVER BASIN	MAN030			26/09/2002							Cond uncomp (in situ) 37000.000 uS/m on 26-09-2002	26-09-2002 to 26-09-2002	Operating	N
20023541	Ground	Borehole or Well	61404333	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0359	Domestic/Household/Livestock			06-12-1986 - Known day	= 19.8 m from Ground level	Top of top inlet =12m, Bottom of bottom inlet =19.8m, from Ground level	Borehole water supply 87.000 m3/day on 06-12-1986	Static water level 2.500 m from Ground level on 06-12-1986	TDSolids (in situ) 200.000 mg/L on 06-12-1986	06-12-1986 to 06-12-1986		N
20023327	Ground	Borehole or Well	61404139	MURRAY RIVER CATCHMENT 614	70	2033-2-NE-0145	Garden Irrigation/Livestock	10000101		01-01-1000 - Unknown	= 7.77 m from Ground level			Static water level 3.200 m from Ground level on 01-01-1000	TDSolids (in situ) 510.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023505	Ground	Borehole or Well	61404301	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0323				30-06-1976 - Known year	= 7.62 m from Ground level		Borehole water supply 54.553 m3/day on 30-06-1976			30-06-1976 to 30-06-1976		N
23016680	Surface	Sampling point	6140527	SERPENTINE CATCHMENT	SERPENTINE RIVER			1/08/2000									Operating	N
20083788	Ground	Borehole or Well	61405868	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0539	Domestic/Household			23-01-1999 - Known day	= 41 m from Ground level	Top of top inlet =29m, Bottom of bottom inlet =41m, from Ground level	Supply (tested) 218.212 m3/day on 23-01-1999	Static water level 7.800 m from Ground level on 23-01-1999		23-01-1999 to 23-01-1999		N
20023309	Ground	Borehole or Well	61404121	MURRAY RIVER CATCHMENT 614	46	2033-2-NE-0127				01-01-1000 - Unknown	= 7.62 m from Ground level			Static water level 2.130 m from Ground level on 02-01-1000	TDSolids (in situ) 173.000 mg/L on 01-01-1000	01-01-1000 to 02-01-1000		N
20023310	Ground	Borehole or Well	61404122	MURRAY RIVER CATCHMENT 614	47	2033-2-NE-0128				01-01-1000 - Unknown	= 2.44 m from Ground level			Static water level .910 m from Ground level on 01-01-1000	TDSolids (in situ) 491.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023311	Ground	Borehole or Well	61404123	MURRAY RIVER CATCHMENT 614	48	2033-2-NE-0129				01-01-1000 - Unknown	= 5.64 m from Ground level			Static water level 1.680 m from Ground level on 01-01-1000	TDSolids (in situ) 566.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
12572750	Ground	Borehole or Well	61414016	SOUTH EAST CORRIDOR	SES30		Observation	29/03/1996	30/03/1996	29-03-1996 - Unknown	= 5.2 m from Ground level	Top of top inlet =0m, Bottom of bottom inlet =5.2m, from Ground level					Not operating	N
12572858	Ground	Borehole or Well	61414035	SOUTH EAST CORRIDOR	SES49		Observation	29/03/1996	24/06/1999	29-03-1996 - Unknown	= 5.2 m from Ground level	Top of top inlet =0m, Bottom of bottom inlet =5.2m, from Ground level		Static water level 1.360 m from Top of casing on 29-09-1998		02-10-1996 to 29-09-1998	Not operating	N
20023304	Ground	Borehole or Well	61404116	MURRAY RIVER CATCHMENT 614	20	2033-2-NE-0122				01-01-1000 - Unknown	= 3.05 m from Ground level			Static water level .610 m from Ground level on 01-01-1000	TDSolids (in situ) 556.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023318	Ground	Borehole or Well	61404130	MURRAY RIVER CATCHMENT 614	60	2033-2-NE-0136				01-01-1000 - Unknown	= 30.48 m from Ground level			Static water level 27.740 m from Ground level on 01-01-1000		01-01-1000 to 01-01-1000		N
20023321	Ground	Borehole or Well	61404133	MURRAY RIVER CATCHMENT 614	62	2033-2-NE-0139				01-01-1000 - Unknown	= 3.96 m from Ground level			Static water level .610 m from Ground level on 01-01-1000	TDSolids (in situ) 528.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20084195	Ground	Borehole or Well	61405963	MURRAY RIVER CATCHMENT 614	BORE	2033-2-NE-0555	Irrigation			05-05-2000 - Known day	= 18 m from Ground level	Top of top inlet =12m, Bottom of bottom inlet =18m, from Ground level	Supply (recommended) 2.619 m3/day on 05-05-2000	Static water level 4.000 m from Ground level on 05-05-2000		05-05-2000 to 05-05-2000		N
23025415	Surface	Sampling point	6140896	MURRAY RIVER BASIN	MAN040			26/09/2002							Cond uncomp (in situ) 40500.000 uS/m on 26-09-2002	26-09-2002 to 26-09-2002	Operating	N
20038117	Ground	Borehole or Well	61405684	MURRAY RIVER CATCHMENT 614	33	2133-3-NW-0013	Domestic/Household/Livestock	10000101		01-01-1000 - Unknown							Operating	N
23003146	Surface	Sampling point	6142784	SERPENTINE CATCHMENT	SR18048			30/08/2000							Cond uncomp (lab) 29400.000 uS/m on 22-09-2003	31-08-2000 to 13-09-2004	Operating	N
23016675	Surface	Sampling point	6140522	SERPENTINE CATCHMENT	SERPENTINE RIVER			1/08/2000									Operating	N
20023521	Ground	Borehole or Well	61404315	MURRAY RIVER CATCHMENT 614	COOPER	2033-2-NE-0339				30-06-1985 - Known year	= 9.14 m from Ground level			Static water level .910 m from Ground level on 30-06-1985	TDSolids (in situ) 600.000 mg/L on 30-06-1985	30-06-1985 to 30-06-1985		N
20023345	Ground	Borehole or Well	61404157	MURRAY RIVER CATCHMENT 614	51	2033-2-NE-0163	Livestock	10000101		01-01-1000 - Unknown	= 5.49 m from Ground level		Borehole water supply 36.368 m3/day on 01-01-1000	Static water level 2.440 m from Ground level on 01-01-1000	TDSolids (in situ) 1120.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
23003135	Surface	Sampling point	6142773	SERPENTINE CATCHMENT	SR18024			30/08/2000							Cond uncomp (lab) 31200.000 uS/m on 22-09-2003	31-08-2000 to 13-09-2004	Operating	N
12572756	Ground	Borehole or Well	61414017	SOUTH EAST CORRIDOR	SES31		Observation	29/03/1996	30/03/1996	29-03-1996 - Unknown	= 5.2 m from Ground level	Top of top inlet =0m, Bottom of bottom inlet =5.2m, from Ground level					Not operating	N
20038118	Ground	Borehole or Well	61405685	MURRAY RIVER CATCHMENT 614	34	2133-3-NW-0014	Livestock	10000101		01-01-1000 - Unknown							Operating	N
20038147	Ground	Borehole or Well	61405697	MURRAY RIVER CATCHMENT 614	BORE	2133-3-NW-0043	Domestic/Household/Livestock			30-06-1976 - Known year	= 24.38 m from Ground level		Borehole water supply 109.106 m3/day on 30-06-1976	Static water level 13.000 m from Ground level on 01-03-1979	TDSolids (in situ) 510.000 mg/L on 01-03-1979	30-06-1976 to 01-03-1979		N
20023312	Ground	Borehole or Well	61404124	MURRAY RIVER CATCHMENT 614	49	2033-2-NE-0130	Domestic/Household/Livestock	10000101		01-01-1000 - Unknown	= 5.49 m from Ground level		Borehole water supply 36.368 m3/day on 01-01-1000	Static water level 4.270 m from Ground level on 01-01-1000	TDSolids (in situ) 690.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
23016662	Surface	Sampling point	6140509	SERPENTINE CATCHMENT	SERPENTINE RIVER			1/08/2000									Operating	N
23003133	Surface	Sampling point	6142771	SERPENTINE CATCHMENT	SR18020			30/08/2000							Cond uncomp (lab) 82300.000 uS/m on 22-09-2003	31-08-2000 to 13-09-2004	Operating	N
20023190	Ground	Unknown	61406538	MURRAY RIVER CATCHMENT 614	MUNDIJONG NO. 8 ATWELL	2033-2-NE-0008				01-01-1000 - Unknown	= 39.62 m from Ground level		Borehole water supply .000 m3/day on 01-01-1000			01-01-1000 to 01-01-1000		N
20038112	Ground	Borehole or Well	61405680	MURRAY RIVER CATCHMENT 614	WELL	2133-3-NW-0008	Livestock			01-01-1000 - Unknown	= 14 m from Ground level			Static water level 9.500 m from Ground level on 01-03-1979	TDSolids (in situ) 410.000 mg/L on 01-03-1979	01-03-1979 to 01-03-1979		N
20038111	Ground	Unknown	61406878	MURRAY RIVER CATCHMENT 614	BORE	2133-3-NW-0007				01-01-1000 - Unknown	= 30.48 m from Ground level							N
23018480	Surface	Sampling point	6140674	CRAIGS DRAIN	SOLDIERS ROAD			1/06/2004								23-06-2004 to 23-06-2004	Operating	N
23016679	Surface	Sampling point	6140526	SERPENTINE CATCHMENT	SERPENTINE RIVER			1/08/2000									Operating	N
23003150	Surface	Sampling point	6142788	SERPENTINE CATCHMENT	SR18057			30/08/2000							Cond uncomp (lab) 19800.000 uS/m on 22-09-2003	31-08-2000 to 13-09-2004	Operating	N
20038108	Ground	Borehole or Well	61405678	MURRAY RIVER CATCHMENT 614	HOUSE BORE	2133-3-NW-0004	Garden Irrigation/Livestock			30-06-1969 - Known year	= 36.58 m from Ground level		Borehole water supply 21.821 m3/day on 30-06-1969	Static water level 19.000 m from Ground level on 30-06-1969	TDSolids (in situ) 700.000 mg/L on 30-06-1969	30-06-1969 to 30-06-1969		N
20023317	Ground	Borehole or Well	61404129	MURRAY RIVER CATCHMENT 614	59	2033-2-NE-0135	Livestock	10000101		01-01-1000 - Unknown	= 4.88 m from Ground level			Static water level 1.520 m from Ground level on 01-01-1000	TDSolids (in situ) 973.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20038110	Ground	Unknown	61406877	MURRAY RIVER CATCHMENT 614	BORE	2133-3-NW-0006				01-01-1000 - Unknown	= 18.29 m from Ground level							N
20023314	Ground	Borehole or Well	61404126	MURRAY RIVER CATCHMENT 614	56	2033-2-NE-0132	Livestock	10000101		01-01-1000 - Unknown	= 16.76 m from Ground level		Borehole water supply 32.732 m3/day on 01-01-1000	Static water level 3.050 m from Ground level on 01-01-1000	TDSolids (in situ) 460.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000	Operating	N
20023313	Ground	Borehole or Well	61404125	MURRAY RIVER CATCHMENT 614	55	2033-2-NE-0131	Livestock	30/06/1965		30-06-1965 - Known year	= 117.04 m from Ground level		Borehole water supply 2.182 m3/day on 30-06-1965	Static water level .000 m from Ground level on 30-06-1965	TDSolids (in situ) 445.000 mg/L on 30-06-1965	30-06-1965 to 30-06-1965	Operating	N
20023326	Ground	Borehole or Well	61404138	MURRAY RIVER CATCHMENT 614	69	2033-2-NE-0144				01-01-1000 - Unknown	= 9.14 m from Ground level			Static water level 4.570 m from Ground level on 01-01-1000	TDSolids (in situ) 170.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
20023290	Ground	Unknown	61406591	MURRAY RIVER CATCHMENT 614	I	2033-2-NE-0108	Livestock			01-01-1000 - Unknown								N
12572738	Ground	Borehole or Well	61414014	SOUTH EAST CORRIDOR	SES28		Observation	29/03/1996	24/06/1999	29-03-1996 - Unknown	= 5.2 m from Ground level	Top of top inlet =0m, Bottom of bottom inlet =5.2m, from Ground level		Static water level .790 m from Top of casing on 29-09-1998		02-10-1996 to 29-09-1998	Not operating	N
20023307	Ground	Borehole or Well	61404119	MURRAY RIVER CATCHMENT 614	29	2033-2-NE-0125				01-01-1000 - Unknown	= 14.02 m from Ground level			Static water level 2.130 m from Ground level on 01-01-1000	TDSolids (in situ) 384.000 mg/L on 01-01-1000	01-01-1000 to 01-01-1000		N
23016673	Surface	Sampling point	6140520	SERPENTINE CATCHMENT	SERPENTINE RIVER			1/08/2000									Operating	N
8893059	Ground	Borehole or Well	61421735	BUNNING BROS	DEEP BORE			1/01/1981	2/01/1981								Not operating	N
23003158	Surface	Sampling point	6142796	SERPENTINE CATCHMENT	SR18089			30/08/2000							Cond uncomp (lab) 61000.000 uS/m on 22-09-2003	31-08-2000 to 13-09-2004	Operating	N

{Blank Page for Double Sided Printing}

Appendix E

Budget Estimate Calculations

Data and Calculation Sheets

{Blank Page for Double Sided Printing}

Variables		
Cost Relationship Year	2004	
Start Year	2010	
Life Cycle	50	years
Real Discount rate	5.5%	p.a.
Inflation Rate	2.0%	p.a.
Basin Depth	1.5	m
Bioretention Area	1.5%	of impervious catchment surface area
Catchment Treatment	50.0%	of total impervious catchment is treated by bioretention swales
Lot Yield	12	per Hectare
Rain Tank Uptake	50%	of lots have a rainwater tank
Average Tank Size	5	kL

TAC	Total Acquisition Cost
TAM	Total Annual Maintenance
RC	Renewal Cost
DC	Decommissioning Cost
Cost Relationship Source	MUSIC Manual v3

Basin	Volume	Depth	Area	2004 Unit Cost				2010 Unit Cost				Discounted Total Cost				
	m^3	m	m^2	TAC	TAM	RC	DC	TAC	TAM	RC	DC	TAC	TAM	RC	DC	TOTAL
B1	6,300	1.5	4,200	$ 496,118	$ 10,001	$ 6,946	$ 193,486	$ 558,709	$ 11,262	$ 7,822	$ 217,897	$ 558,709	$ 190,686	$ 132,437	$ 14,984	$ 896,816
M17	9,300	1.5	6,200	$ 674,666	$ 12,047	$ 10,120	$ 273,240	$ 759,783	$ 13,567	$ 11,397	$ 307,712	$ 759,783	$ 229,705	$ 192,964	$ 21,160	$ 1,203,613
M20B	7,100	1.5	4,733	$ 545,209	$ 10,589	$ 8,178	$ 220,810	$ 613,994	$ 11,925	$ 9,210	$ 248,668	$ 613,994	$ 201,900	$ 155,938	$ 17,100	$ 988,932
M27	18,300	1.5	12,200	$1,151,113	$ 16,649	$ 17,267	$ 466,201	$1,296,340	$ 18,750	$ 19,445	$ 525,018	$1,296,340	$ 317,458	$ 329,235	$ 36,104	$ 1,979,137
M30	22,000	1.5	14,667	$1,331,188	$ 18,181	$ 19,968	$ 539,131	$1,499,134	$ 20,475	$ 22,487	$ 607,149	$1,499,134	$ 346,667	$ 380,739	$ 41,752	$ 2,268,292
M34	10,300	1.5	6,867	$ 731,303	$ 12,650	$ 10,970	$ 296,178	$ 823,566	$ 14,245	$ 12,353	$ 333,544	$ 823,566	$ 241,197	$ 209,163	$ 22,937	$ 1,296,863
M40B	20,000	1.5	13,333	$1,234,719	$ 17,371	$ 18,521	$ 500,061	$1,390,494	$ 19,563	$ 20,857	$ 563,150	$1,390,494	$ 331,228	$ 353,148	$ 38,726	$ 2,113,596
M41B	10,500	1.5	7,000	$ 742,489	$ 12,766	$ 11,137	$ 300,708	$ 836,163	$ 14,377	$ 12,542	$ 338,646	$ 836,163	$ 243,424	$ 212,363	$ 23,288	$ 1,315,237
M42B	12,000	1.5	8,000	$ 825,017	$ 13,608	$ 12,375	$ 334,132	$ 929,103	$ 15,325	$ 13,937	$ 376,287	$ 929,103	$ 259,468	$ 235,967	$ 25,876	$ 1,450,414
M45	10,000	1.5	6,667	$ 714,439	$ 12,472	$ 10,717	$ 289,348	$ 804,574	$ 14,046	$ 12,069	$ 325,853	$ 804,574	$ 237,813	$ 204,340	$ 22,408	$ 1,269,135
M46B	5,000	1.5	3,333	$ 413,392	$ 8,955	$ 6,201	$ 167,424	$ 465,547	$ 10,084	$ 6,983	$ 188,546	$ 465,547	$ 170,743	$ 118,236	$ 12,966	$ 767,491
M49B	7,300	1.5	4,867	$ 557,296	$ 10,730	$ 8,359	$ 225,705	$ 627,606	$ 12,084	$ 9,414	$ 254,180	$ 627,606	$ 204,599	$ 159,395	$ 17,479	$ 1,009,079
M56B	75,000	1.5	50,000	$3,504,701	$ 32,675	$ 52,571	$1,419,404	$3,946,863	$ 36,798	$ 59,203	$1,598,479	$3,946,863	$ 623,038	$1,002,396	$ 109,922	$ 5,682,218
B57	55,100	1.5	36,733	$2,747,616	$ 28,197	$ 41,214	$1,112,785	$3,094,262	$ 31,755	$ 46,414	$1,253,176	$3,094,262	$ 537,657	$ 785,858	$ 86,177	$ 4,503,954
M58	10,000	1.5	6,667	$ 714,439	$ 12,472	$ 10,717	$ 289,348	$ 804,574	$ 14,046	$ 12,069	$ 325,853	$ 804,574	$ 237,813	$ 204,340	$ 22,408	$ 1,269,135
M58A	10,000	1.5	6,667	$ 714,439	$ 12,472	$ 10,717	$ 289,348	$ 804,574	$ 14,046	$ 12,069	$ 325,853	$ 804,574	$ 237,813	$ 204,340	$ 22,408	$ 1,269,135
M59B	8,700	1.5	5,800	$ 640,070	$ 11,669	$ 9,601	$ 259,228	$ 720,823	$ 13,141	$ 10,812	$ 291,933	$ 720,823	$ 222,498	$ 183,069	$ 20,075	$ 1,146,465
M60B	21,300	1.5	14,200	$1,297,643	$ 17,902	$ 19,465	$ 525,545	$1,461,357	$ 20,161	$ 21,920	$ 591,849	$1,461,357	$ 341,350	$ 371,145	$ 40,699	$ 2,214,551
M61B	26,000	1.5	17,333	$1,518,811	$ 19,692	$ 22,782	$ 615,118	$1,710,427	$ 22,177	$ 25,656	$ 692,723	$1,710,427	$ 375,485	$ 434,402	$ 47,636	$ 2,567,950
M62B	21,000	1.5	14,000	$1,283,195	$ 17,781	$ 19,248	$ 519,694	$1,445,087	$ 20,024	$ 21,676	$ 585,260	$1,445,087	$ 339,044	$ 367,013	$ 40,246	$ 2,191,389
												#########	$5,889,585	$6,236,488	$ 684,349	$ 37,403,402

Catchment	Total Area	Impervious	Bioretention Area													
	m^2	m^2	m^2	TAC	TAM	RC	DC	TAC	TAM	RC	DC	TAC	TAM	RC	DC	TOTAL
B1	291,899	128,465	963	$ 75,451	$ 1,011	$ 1,509	$ 29,426	$ 84,970	$ 1,139	$ 1,699	$ 33,138	$ 84,970	$ 19,285	$ 28,773	$ 2,279	$ 135,307
M16	172,051	68,906	517	$ 46,783	$ 768	$ 936	$ 18,245	$ 52,685	$ 865	$ 1,054	$ 20,547	$ 52,685	$ 14,653	$ 17,841	$ 1,413	$ 86,592
M17	257,044	107,311	805	$ 65,721	$ 934	$ 1,314	$ 25,631	$ 74,013	$ 1,052	$ 1,480	$ 28,865	$ 74,013	$ 17,814	$ 25,063	$ 1,985	$ 118,875
M20	180,856	75,960	570	$ 50,416	$ 802	$ 1,008	$ 19,662	$ 56,776	$ 903	$ 1,136	$ 22,143	$ 56,776	$ 15,296	$ 19,226	$ 1,523	$ 92,821
M20B	153,192	61,353	460	$ 42,796	$ 730	$ 856	$ 16,690	$ 48,195	$ 822	$ 964	$ 18,796	$ 48,195	$ 13,921	$ 16,320	$ 1,293	$ 79,729
M25	269,815	104,891	787	$ 64,581	$ 925	$ 1,292	$ 25,187	$ 72,729	$ 1,042	$ 1,455	$ 28,364	$ 72,729	$ 17,635	$ 24,628	$ 1,951	$ 116,943
M27	313,985	137,120	1,028	$ 79,322	$ 1,041	$ 1,586	$ 30,935	$ 89,329	$ 1,172	$ 1,787	$ 34,838	$ 89,329	$ 19,847	$ 30,250	$ 2,396	$ 141,822
M28	274,926	115,440	866	$ 69,509	$ 965	$ 1,390	$ 27,108	$ 78,278	$ 1,087	$ 1,566	$ 30,528	$ 78,278	$ 18,397	$ 26,507	$ 2,099	$ 125,281
M30	701,858	298,322	2,237	$ 144,019	$ 1,466	$ 2,880	$ 56,168	$ 162,189	$ 1,652	$ 3,244	$ 63,254	$ 162,189	$ 27,963	$ 54,922	$ 4,350	$ 249,424
M34	266,119	125,043	938	$ 73,904	$ 999	$ 1,478	$ 28,823	$ 83,228	$ 1,126	$ 1,665	$ 32,459	$ 83,228	$ 19,057	$ 28,183	$ 2,232	$ 132,700
M37	217,820	105,643	792	$ 64,936	$ 928	$ 1,299	$ 25,325	$ 73,129	$ 1,045	$ 1,463	$ 28,520	$ 73,129	$ 17,691	$ 24,764	$ 1,961	$ 117,545
M40	738,384	309,341	2,320	$ 148,084	$ 1,490	$ 2,962	$ 57,753	$ 166,766	$ 1,678	$ 3,335	$ 65,039	$ 166,766	$ 28,413	$ 56,472	$ 4,472	$ 256,124
M40B	386,388	154,748	1,161	$ 87,035	$ 1,098	$ 1,741	$ 33,944	$ 98,016	$ 1,236	$ 1,960	$ 38,226	$ 98,016	$ 20,935	$ 33,191	$ 2,629	$ 154,770
M41	64,128	26,934	202	$ 22,754	$ 508	$ 455	$ 8,874	$ 25,625	$ 572	$ 512	$ 9,994	$ 25,625	$ 9,683	$ 8,677	$ 687	$ 44,672
M41B	102,420	41,019	308	$ 31,422	$ 611	$ 628	$ 12,255	$ 35,387	$ 688	$ 708	$ 13,801	$ 35,387	$ 11,657	$ 11,983	$ 949	$ 59,975
M42	221,610	93,016	698	$ 58,893	$ 877	$ 1,178	$ 22,968	$ 66,324	$ 988	$ 1,326	$ 25,866	$ 66,324	$ 16,725	$ 22,459	$ 1,779	$ 107,287
M43	352,417	148,015	1,110	$ 84,114	$ 1,077	$ 1,682	$ 32,805	$ 94,726	$ 1,212	$ 1,895	$ 36,943	$ 94,726	$ 20,528	$ 32,077	$ 2,540	$ 149,872
M44	307,304	134,998	1,012	$ 78,378	$ 1,034	$ 1,568	$ 30,567	$ 88,267	$ 1,164	$ 1,765	$ 34,424	$ 88,267	$ 19,711	$ 29,890	$ 2,367	$ 140,235
M45	207,713	109,312	820	$ 66,660	$ 942	$ 1,333	$ 25,997	$ 75,070	$ 1,061	$ 1,501	$ 29,277	$ 75,070	$ 17,959	$ 25,421	$ 2,013	$ 120,463
M46	237,142	169,854	1,274	$ 93,483	$ 1,144	$ 1,870	$ 36,458	$ 105,277	$ 1,288	$ 2,106	$ 41,058	$ 105,277	$ 21,812	$ 35,650	$ 2,823	$ 165,562
M47	172,594	123,923	929	$ 73,395	$ 995	$ 1,468	$ 28,624	$ 82,655	$ 1,121	$ 1,653	$ 32,235	$ 82,655	$ 18,981	$ 27,990	$ 2,217	$ 131,842
M48	133,166	95,214	714	$ 59,958	$ 886	$ 1,199	$ 23,384	$ 67,523	$ 998	$ 1,350	$ 26,334	$ 67,523	$ 16,898	$ 22,865	$ 1,811	$ 109,098
M49	328,126	173,297	1,300	$ 94,933	$ 1,154	$ 1,899	$ 37,024	$ 106,910	$ 1,300	$ 2,138	$ 41,695	$ 106,910	$ 22,006	$ 36,203	$ 2,867	$ 167,987
M50	252,509	181,301	1,360	$ 98,280	$ 1,177	$ 1,966	$ 38,329	$ 110,679	$ 1,326	$ 2,214	$ 43,165	$ 110,679	$ 22,449	$ 37,479	$ 2,968	$ 173,576
M51	95,397	68,924	517	$ 46,792	$ 769	$ 936	$ 18,249	$ 52,696	$ 865	$ 1,054	$ 20,551	$ 52,696	$ 14,654	$ 17,844	$ 1,413	$ 86,608

M52	151,513	108,786	816	$ 66,414	$ 940	$ 1,328	$ 25,901	$ 74,793	$ 1,058	$ 1,496	$ 29,169	$ 74,793	$ 17,921	$ 25,327	$ 2,006	$ 120,047
M53	195,168	141,009	1,058	$ 81,042	$ 1,054	$ 1,621	$ 31,606	$ 91,267	$ 1,187	$ 1,825	$ 35,594	$ 91,267	$ 20,094	$ 30,906	$ 2,448	$ 144,714
M54	141,202	101,383	760	$ 62,917	$ 911	$ 1,258	$ 24,538	$ 70,855	$ 1,026	$ 1,417	$ 27,634	$ 70,855	$ 17,373	$ 23,994	$ 1,900	$ 114,122
M55	108,062	76,423	573	$ 50,652	$ 804	$ 1,013	$ 19,754	$ 57,042	$ 906	$ 1,141	$ 22,246	$ 57,042	$ 15,337	$ 19,316	$ 1,530	$ 93,225
M56	825,173	346,166	2,596	$ 161,431	$ 1,566	$ 3,229	$ 62,958	$ 181,798	$ 1,763	$ 3,636	$ 70,901	$ 181,798	$ 29,858	$ 61,562	$ 4,876	$ 278,094
M56B	2,140,660	857,334	6,430	$ 323,743	$ 2,336	$ 6,475	$ 126,260	$ 364,587	$ 2,631	$ 7,292	$ 142,189	$ 364,587	$ 44,541	$ 123,460	$ 9,778	$ 542,366
M57	400,143	167,865	1,259	$ 92,642	$ 1,138	$ 1,853	$ 36,130	$ 104,330	$ 1,282	$ 2,087	$ 40,689	$ 104,330	$ 21,699	$ 35,329	$ 2,798	$ 164,156
M57B	1,321,470	529,249	3,969	$ 223,593	$ 1,888	$ 4,472	$ 87,201	$ 251,802	$ 2,127	$ 5,036	$ 98,203	$ 251,802	$ 36,006	$ 85,268	$ 6,753	$ 379,829
M58	626,098	411,615	3,087	$ 184,371	$ 1,690	$ 3,687	$ 71,905	$ 207,632	$ 1,903	$ 4,153	$ 80,976	$ 207,632	$ 32,228	$ 70,310	$ 5,568	$ 315,739
M59	874,697	367,373	2,755	$ 168,967	$ 1,608	$ 3,379	$ 65,897	$ 190,284	$ 1,810	$ 3,806	$ 74,211	$ 190,284	$ 30,652	$ 64,436	$ 5,103	$ 290,474
M59A	209,266	106,520	799	$ 65,349	$ 931	$ 1,307	$ 25,486	$ 73,594	$ 1,049	$ 1,472	$ 28,702	$ 73,594	$ 17,756	$ 24,921	$ 1,974	$ 118,245
M59B	224,732	90,005	675	$ 57,425	$ 865	$ 1,149	$ 22,396	$ 64,670	$ 974	$ 1,293	$ 25,221	$ 64,670	$ 16,484	$ 21,899	$ 1,734	$ 104,788
M60	785,724	564,149	4,231	$ 234,822	$ 1,942	$ 4,696	$ 91,581	$ 264,448	$ 2,187	$ 5,289	$ 103,135	$ 264,448	$ 37,034	$ 89,550	$ 7,092	$ 398,124
M60B	225,784	161,436	1,211	$ 89,907	$ 1,119	$ 1,798	$ 35,064	$ 101,250	$ 1,260	$ 2,025	$ 39,487	$ 101,250	$ 21,329	$ 34,286	$ 2,715	$ 159,580
M61	1,192,530	513,917	3,854	$ 218,606	$ 1,864	$ 4,372	$ 85,256	$ 246,186	$ 2,099	$ 4,924	$ 96,012	$ 246,186	$ 35,542	$ 83,366	$ 6,602	$ 371,697
M62	908,425	446,288	3,347	$ 196,175	$ 1,752	$ 3,924	$ 76,508	$ 220,925	$ 1,973	$ 4,419	$ 86,161	$ 220,925	$ 33,398	$ 74,812	$ 5,925	$ 335,060
Catchment	Total Area Ha	No. Tanks										$4,616,902	$ 891,225	$1,563,423	$ 123,820	$ 7,195,370
B1	29	175		$ 535,278	$ 90	$ -	$ 200	$ 602,810	$ 101	$ -	$ 225	$ 602,810	$ 1,716	$ -	$ 15	$ 604,542
M16	17	103		$ 315,050	$ 90	$ -	$ 200	$ 354,797	$ 101	$ -	$ 225	$ 354,797	$ 1,716	$ -	$ 15	$ 356,529
M17	26	154		$ 471,045	$ 90	$ -	$ 200	$ 530,473	$ 101	$ -	$ 225	$ 530,473	$ 1,716	$ -	$ 15	$ 532,205
M20	18	109		$ 333,402	$ 90	$ -	$ 200	$ 375,465	$ 101	$ -	$ 225	$ 375,465	$ 1,716	$ -	$ 15	$ 377,196
M20B	15	92		$ 281,404	$ 90	$ -	$ 200	$ 316,906	$ 101	$ -	$ 225	$ 316,906	$ 1,716	$ -	$ 15	$ 318,638
M25	27	162		$ 495,515	$ 90	$ -	$ 200	$ 558,030	$ 101	$ -	$ 225	$ 558,030	$ 1,716	$ -	$ 15	$ 559,762
M27	31	188		$ 575,042	$ 90	$ -	$ 200	$ 647,591	$ 101	$ -	$ 225	$ 647,591	$ 1,716	$ -	$ 15	$ 649,322
M28	27	165		$ 504,691	$ 90	$ -	$ 200	$ 568,364	$ 101	$ -	$ 225	$ 568,364	$ 1,716	$ -	$ 15	$ 570,096
M30	70	421		$1,287,727	$ 90	$ -	$ 200	$1,450,190	$ 101	$ -	$ 225	$1,450,190	$ 1,716	$ -	$ 15	$ 1,451,921
M34	27	160		$ 489,397	$ 90	$ -	$ 200	$ 551,141	$ 101	$ -	$ 225	$ 551,141	$ 1,716	$ -	$ 15	$ 552,873
M37	22	131		$ 400,694	$ 90	$ -	$ 200	$ 451,247	$ 101	$ -	$ 225	$ 451,247	$ 1,716	$ -	$ 15	$ 452,978
M40	74	443		$1,355,019	$ 90	$ -	$ 200	$1,525,972	$ 101	$ -	$ 225	$1,525,972	$ 1,716	$ -	$ 15	$ 1,527,703
M40B	39	232		$ 709,626	$ 90	$ -	$ 200	$ 799,154	$ 101	$ -	$ 225	$ 799,154	$ 1,716	$ -	$ 15	$ 800,886
M41	6	38		$ 116,232	$ 90	$ -	$ 200	$ 130,896	$ 101	$ -	$ 225	$ 130,896	$ 1,716	$ -	$ 15	$ 132,628
M41B	10	61		$ 186,583	$ 90	$ -	$ 200	$ 210,123	$ 101	$ -	$ 225	$ 210,123	$ 1,716	$ -	$ 15	$ 211,854
M42	22	133		$ 406,812	$ 90	$ -	$ 200	$ 458,136	$ 101	$ -	$ 225	$ 458,136	$ 1,716	$ -	$ 15	$ 459,868
M43	35	211		$ 645,393	$ 90	$ -	$ 200	$ 726,817	$ 101	$ -	$ 225	$ 726,817	$ 1,716	$ -	$ 15	$ 728,549
M44	31	184		$ 562,807	$ 90	$ -	$ 200	$ 633,812	$ 101	$ -	$ 225	$ 633,812	$ 1,716	$ -	$ 15	$ 635,544
M45	21	125		$ 382,342	$ 90	$ -	$ 200	$ 430,579	$ 101	$ -	$ 225	$ 430,579	$ 1,716	$ -	$ 15	$ 432,310
M46	24	142		$ 434,340	$ 90	$ -	$ 200	$ 489,138	$ 101	$ -	$ 225	$ 489,138	$ 1,716	$ -	$ 15	$ 490,869
M47	17	104		$ 318,108	$ 90	$ -	$ 200	$ 358,242	$ 101	$ -	$ 225	$ 358,242	$ 1,716	$ -	$ 15	$ 359,973
M48	13	80		$ 244,699	$ 90	$ -	$ 200	$ 275,570	$ 101	$ -	$ 225	$ 275,570	$ 1,716	$ -	$ 15	$ 277,302
M49	33	197		$ 602,571	$ 90	$ -	$ 200	$ 678,592	$ 101	$ -	$ 225	$ 678,592	$ 1,716	$ -	$ 15	$ 680,324
M50	25	152		$ 464,928	$ 90	$ -	$ 200	$ 523,584	$ 101	$ -	$ 225	$ 523,584	$ 1,716	$ -	$ 15	$ 525,316
M51	10	57		$ 174,348	$ 90	$ -	$ 200	$ 196,344	$ 101	$ -	$ 225	$ 196,344	$ 1,716	$ -	$ 15	$ 198,076
M52	15	91		$ 278,345	$ 90	$ -	$ 200	$ 313,461	$ 101	$ -	$ 225	$ 313,461	$ 1,716	$ -	$ 15	$ 315,193
M53	20	117		$ 357,872	$ 90	$ -	$ 200	$ 403,022	$ 101	$ -	$ 225	$ 403,022	$ 1,716	$ -	$ 15	$ 404,753
M54	14	85		$ 259,992	$ 90	$ -	$ 200	$ 292,794	$ 101	$ -	$ 225	$ 292,794	$ 1,716	$ -	$ 15	$ 294,525
M55	11	65		$ 198,818	$ 90	$ -	$ 200	$ 223,901	$ 101	$ -	$ 225	$ 223,901	$ 1,716	$ -	$ 15	$ 225,633
M56	83	495		$1,514,073	$ 90	$ -	$ 200	$1,705,092	$ 101	$ -	$ 225	$1,705,092	$ 1,716	$ -	$ 15	$ 1,706,824
M56B	214	1284		$3,927,414	$ 90	$ -	$ 200	$4,422,906	$ 101	$ -	$ 225	$4,422,906	$ 1,716	$ -	$ 15	$ 4,424,638
M57	40	240		$ 734,096	$ 90	$ -	$ 200	$ 826,711	$ 101	$ -	$ 225	$ 826,711	$ 1,716	$ -	$ 15	$ 828,443
M57B	132	793		$2,425,576	$ 90	$ -	$ 200	$2,731,593	$ 101	$ -	$ 225	$2,731,593	$ 1,716	$ -	$ 15	$ 2,733,324
M58	63	376		$1,150,084	$ 90	$ -	$ 200	$1,295,181	$ 101	$ -	$ 225	$1,295,181	$ 1,716	$ -	$ 15	$ 1,296,913
M59	87	525		$1,605,835	$ 90	$ -	$ 200	$1,808,431	$ 101	$ -	$ 225	$1,808,431	$ 1,716	$ -	$ 15	$ 1,810,163
M59A	21	126		$ 385,400	$ 90	$ -	$ 200	$ 434,024	$ 101	$ -	$ 225	$ 434,024	$ 1,716	$ -	$ 15	$ 435,755
M59B	22	135		$ 412,929	$ 90	$ -	$ 200	$ 465,025	$ 101	$ -	$ 225	$ 465,025	$ 1,716	$ -	$ 15	$ 466,757
M60	79	471		$1,440,664	$ 90	$ -	$ 200	$1,622,421	$ 101	$ -	$ 225	$1,622,421	$ 1,716	$ -	$ 15	$ 1,624,153
M60B	23	135		$ 412,929	$ 90	$ -	$ 200	$ 465,025	$ 101	$ -	$ 225	$ 465,025	$ 1,716	$ -	$ 15	$ 466,757
M61	119	716		$2,190,054	$ 90	$ -	$ 200	$2,466,356	$ 101	$ -	$ 225	$2,466,356	$ 1,716	$ -	$ 15	$ 2,468,088
M62	91	545		$1,667,010	$ 90	$ -	$ 200	$1,877,324	$ 101	$ -	$ 225	$1,877,324	$ 1,716	$ -	$ 15	$ 1,879,056
												#########	$ 70,360	$ -	$ 635	$ 35,268,236
															TOTAL	$ 79,867,009

Variables		
Cost Relationship Year	2008	
Start Year	2010	
Life Cycle	50	years
Growth Rate	7.0%	p.a.
Reserve factor	1.8	
Land Value	17.41655	per m^2
Source	http://www.homehound.com.au/lot+200+52+adamson+street+mardella+wa+6125/	

Basin	Area m^2	Reserve m^2	2008 Cost	2010 Cost
B1	4200	7560	$131,669	$150,748
M17	6200	11160	$194,369	$222,533
M20B	4733.333	8520	$148,389	$169,891
M27	12200	21960	$382,467	$437,887
M30	14666.67	26400	$459,797	$526,421
M34	6866.667	12360	$215,269	$246,461
M40B	13333.33	24000	$417,997	$478,565
M41B	7000	12600	$219,448	$251,247
M42B	8000	14400	$250,798	$287,139
M45	6666.667	12000	$208,999	$239,282
M46B	3333.333	6000	$104,499	$119,641
M49B	4866.667	8760	$152,569	$174,676
M56B	50000	90000	########	########
B57	36733.33	66120	########	########
M58	6666.667	12000	$208,999	$239,282
M58A	6666.667	12000	$208,999	$239,282
M59B	5800	10440	$181,829	$208,176
M60B	14200	25560	$445,167	$509,672
M61B	17333.33	31200	$543,396	$622,134
M62B	14000	25200	$438,897	$502,493
TOTAL				########

Catchment	Basin				Bioretention		Rainwater Tanks		Total
	Volume	Reserve	Cost	Land	Area	Cost	Count	Cost	Cost
	m^3	m^2	2010 $	2010 $	m^2	2010 $	m^2	2010 $	2010 $
B1	6,300	7,560	$ 896,816	$ 150,748	963	$ 135,307	175	$ 604,542	$ 1,787,413
M16	0	0	$ -	$ -	517	$ 86,592	103	$ 356,529	$ 443,120
M17	9,300	11,160	$ 1,203,613	$ 222,533	805	$ 118,875	154	$ 532,205	$ 2,077,225
M20	0	0	$ -	$ -	570	$ 92,821	109	$ 377,196	$ 470,017
M20B	7,100	8,520	$ 988,932	$ 169,891	460	$ 79,729	92	$ 318,638	$ 1,557,190
M25	0	0	$ -	$ -	787	$ 116,943	162	$ 559,762	$ 676,705
M27	18,300	21,960	$ 1,979,137	$ 437,887	1,028	$ 141,822	188	$ 649,322	$ 3,208,168
M28	0	0	$ -	$ -	866	$ 125,281	165	$ 570,096	$ 695,377
M30	22,000	26,400	$ 2,268,292	$ 526,421	2,237	$ 249,424	421	$ 1,451,921	$ 4,496,058
M34	10,300	12,360	$ 1,296,863	$ 246,461	938	$ 132,700	160	$ 552,873	$ 2,228,897
M37	0	0	$ -	$ -	792	$ 117,545	131	$ 452,978	$ 570,523
M40	0	0	$ -	$ -	2,320	$ 256,124	443	$ 1,527,703	$ 1,783,827
M40B	20,000	24,000	$ 2,113,596	$ 478,565	1,161	$ 154,770	232	$ 800,886	$ 3,547,817
M41	0	0	$ -	$ -	202	$ 44,672	38	$ 132,628	$ 177,300
M41B	10,500	12,600	$ 1,315,237	$ 251,247	308	$ 59,975	61	$ 211,854	$ 1,838,313
M42	0	0	$ -	$ -	698	$ 107,287	133	$ 459,868	$ 567,154
M43	0	0	$ -	$ -	1,110	$ 149,872	211	$ 728,549	$ 878,421
M44	0	0	$ -	$ -	1,012	$ 140,235	184	$ 635,544	$ 775,779
M45	10,000	12,000	$ 1,269,135	$ 239,282	820	$ 120,463	125	$ 432,310	$ 2,061,191
M46	0	0	$ -	$ -	1,274	$ 165,562	142	$ 490,869	$ 656,432
M47	0	0	$ -	$ -	929	$ 131,842	104	$ 359,973	$ 491,816
M48	0	0	$ -	$ -	714	$ 109,098	80	$ 277,302	$ 386,400
M49	0	0	$ -	$ -	1,300	$ 167,987	197	$ 680,324	$ 848,311
M50	0	0	$ -	$ -	1,360	$ 173,576	152	$ 525,316	$ 698,891
M51	0	0	$ -	$ -	517	$ 86,608	57	$ 198,076	$ 284,683
M52	0	0	$ -	$ -	816	$ 120,047	91	$ 315,193	$ 435,240
M53	0	0	$ -	$ -	1,058	$ 144,714	117	$ 404,753	$ 549,467
M54	0	0	$ -	$ -	760	$ 114,122	85	$ 294,525	$ 408,647
M55	0	0	$ -	$ -	573	$ 93,225	65	$ 225,633	$ 318,857
M56	0	0	$ -	$ -	2,596	$ 278,094	495	$ 1,706,824	$ 1,984,918
M56B	75,000	90,000	$ 5,682,218	$ 1,794,618	6,430	$ 542,366	1284	$ 4,424,638	$ 12,443,841
M57	0	0	$ -	$ -	1,259	$ 164,156	240	$ 828,443	$ 992,599
M57B	0	0	$ -	$ -	3,969	$ 379,829	793	$ 2,733,324	$ 3,113,153
M58	10,000	12,000	$ 1,269,135	$ 239,282	3,087	$ 315,739	376	$ 1,296,913	$ 3,121,069
M59	0	0	$ -	$ -	2,755	$ 290,474	525	$ 1,810,163	$ 2,100,637
M59A	0	0	$ -	$ -	799	$ 118,245	126	$ 435,755	$ 554,000
M59B	8,700	10,440	$ 1,146,465	$ 208,176	675	$ 104,788	135	$ 466,757	$ 1,926,186
M60	0	0	$ -	$ -	4,231	$ 398,124	471	$ 1,624,153	$ 2,022,277
M60B	21,300	25,560	$ 2,214,551	$ 509,672	1,211	$ 159,580	135	$ 466,757	$ 3,350,560
M61	0	0	$ -	$ -	3,854	$ 371,697	716	$ 2,468,088	$ 2,839,784
M62	0	0	$ -	$ -	3,347	$ 335,060	545	$ 1,879,056	$ 2,214,116
TOTAL			$ 23,643,990	$ 5,474,782		$ 7,195,370		$ 35,268,236	$ 71,582,379

Table 7-3. Summary of cost-related relationships for bioretention systems.

Element of Life Cycle Costing Model	Default Option for Estimation in MUSIC	Alternative(s)	Notes
Life cycle	50 years (Expert judgement)	25 years (From collected survey data, n = 6)	One could convincingly argue the life cycle is infinite for well-maintained and 're-set' bioretention systems, but we need to set the life cycle to a finite number to calculate a life cycle cost. Expected, upper and lower estimates based on expert judgement.
Total acquisition cost (TAC)	TAC ($2004) = 387.4 x $(A)^{0.7673}$ $R^2 = 0.59$; p = 0.04; n = 7 Where: A = surface area of treatment zone in m^2.	No alternative size / cost relationships in MUSIC. For literature values, see Taylor (2004) – Included in Appendix H.* (Note in particular some recently obtained unit rates for three types of bioretention systems from SE Qld that should be carefully considered.)	**Warning:** This algorithm derives from a combined data set involving bioretention systems *and* vegetated swales, as there was insufficient data to analyse bioretention systems on their own. Upper and lower estimates derived using a 68% (or 1 standard deviation) prediction interval for the regression. "Treatment zone" refers to the filter area of the system (not the storage area). Note however that the estimated TAC relates to the *whole* bioretention system, not just the filter area.
Typical annual maintenance (TAM) cost	TAM ($2004) = 48.87 x $(TAC)^{0.4410}$ $R^2 = 0.94$; p = 0.03; n = 4	TAM ($2004) = 4.610 x (A) + 2500 $R^2 = 0.65$; p = 0.19; n = 4 Where: A = surface area of treatment zone in m^2. For literature values, see Taylor (2005b).*	**Warning:** Default size / cost relationships for TAC, TAM, and RC derive from a combined data set involving bioretention systems *and* vegetated swales, as there was insufficient data to analyse bioretention systems on their own. Upper and lower estimates derived using a 68% (or 1 standard deviation) prediction interval for the regression. In approximate terms, TAM ≈ 4.4% of TAC (for the combined swale / bioretention system data set). Note the high (> 0.05) p value, associated with the *alternative* algorithm. This algorithm is derived from a data set *only* including bioretention systems. This p value indicates there is a ~19% chance that the regression relationship is a product of random variation (i.e. chance).
Annualised renewal / adaptation cost (RC)	RC ($2004) = 2.0% of TAC p.a. n = 3	No alternative size / cost relationships in MUSIC. For literature values, see Taylor (2005b).	Upper and lower estimates derived using a 84th and 16th percentile, respectively.
Renewal period	25 years n = 6	No alternative in MUSIC.	There is great uncertainty surrounding this period (and the associated RC), given the lack of experience in corrective maintenance associated with bioretention systems in Australia (e.g. replacing the infiltration media and landscaping).
Decommissioning cost (DC)	DC ($2004) = 39% of TAC n = 1	No alternative size / cost relationships in MUSIC.	**Warning:** Only one set of data was available.
General caveats / notes for this type of device	* There are several estimates of capital and maintenance costs reported in the literature for bioretention systems in Australia (see Taylor, 2005b or Appendix H for a summary). The typical annual maintenance cost is an average over the bioretention system's life cycle, so MUSIC's life cycle costing model does not simulate elevated maintenance costs in the first few years of the asset's life. It is likely that elevated maintenance costs typically occur in the first few years.		

Table 7-4. Summary of cost-related relationships for ponds and sediment basins.

Element of Life cycle Costing Model	Default Option for Estimation	Alternative(s)	Notes
Life cycle	50 years. (From collected survey data, n = 3)	No alternative in MUSIC.	One could convincingly argue the life cycle is infinite for well-maintained ponds / basins, but we need to set the LC to a finite number to calculate a life cycle cost. Upper and lower estimates derived using a 84th and 16th percentile, respectively.
Total acquisition cost (TAC)	TAC ($2004) = 685.1 x $(A)^{0.7893}$ $R^2 = 0.99$; $p < 0.01$; n = 4. Where: A = surface area of the basin / pond in m^2.	No alternative size / cost relationships in MUSIC. For literature values, see Taylor (2005b) – Included in Appendix H.*	Upper and lower estimates derived using a 68% (or 1 standard deviation) prediction interval for the regression. Note that a linear equation (TAC = 96.15 x (A) + 16,200) produced a slightly higher R^2 value, but due to the behaviour of the relationship when the treatment device size is small, the power relationship was preferred.
Typical annual maintenance (TAM) cost	TAM ($2004) = 185.4 x $(A)^{0.4780}$ $R^2 = 0.92$; $p = 0.04$; n = 4. Where: A = surface area of the basin / pond in m^2.	TAM ($2004) = 698.3 x $(V)^{0.7766}$ $R^2 = 0.72$; $p < 0.01$; n = 57. Where: V = average annual volume of removed material in m^3 (were "removed material" includes trapped gross pollutants, coarse sediment and TSS). For literature values, see Taylor (2005b).*	Upper and lower estimates derived using a 68% (or 1 standard deviation) prediction interval for the regression. **Warning:** The alternative cost / size relationship is based on an "open gross pollutant trap" data set, as these treatment devices are essentially a pond / basin with a trash rack. In addition, currently MUSIC estimates V using the *combined* estimated volume of gross pollutants, coarse sediment and TSS that are trapped in the basin / pond. To adjust this *manually* (i.e. to include only one or two of these three elements), use the procedure provided in the tip box within this section. Estimates from the North American and Australian literature (see Taylor, 2005b) suggest that ponds typically cost ~3% - 6% of the construction cost to maintain per year (equates to ~5.5% of the TAC, based on the CRCCH data set for sediment basins and ponds). Note however that the CRCCH data set for these types of device does not support the hypothesis that a strong correlation exists between TAM and TAC (albeit based on limited data).
Annualised renewal / adaptation cost (RC)	RC ($2004) = 1.4% of TAC p.a. n = 4	No alternative size / cost relationships in MUSIC. For literature values, see Taylor (2005b).	Upper and lower estimates derived using a 84th and 16th percentile, respectively.
Renewal period	1 year. (Default position due to lack of *high* quality data supporting an alternative period)	10 years.	There is *weak evidence* that major renewal / adaptation costs occur every 10 years on average (e.g. costs associated with access ramps, re-contouring), but this is likely to vary significantly on a site-by-site basis.
Decommissioning cost (DC)	DC ($2004) = 38% of TAC. n = 3.	No alternative size / cost relationships in MUSIC.	
General caveats / notes for this type of device	* There are several estimates of capital and maintenance costs reported in the literature for sediment ponds and basins (see Taylor, 2005b or Appendix H for a summary).		

Table 7-6. Summary of cost-related relationships for rainwater tanks.

Element of Life Cycle Costing Model	Default Option for Estimation in MUSIC	Alternative(s)	Notes
Life cycle	25 years.	No alternative in MUSIC.	Default value from Melbourne Water (2003) and relevant to metal, aboveground tanks. Estimates vary from 10 to 100 years depending on tank materials. It is recommended that users contact their tank suppliers to estimate the life cycle if they have a specific type of tank in mind. Upper and lower estimates have not been provided in MUSIC.
Total acquisition cost (TAC)	TAC/kL ($2004/kL) = 1,354 x $e^{[(-0.1589) \times (Vol)]}$ R^2 = 0.63; p = <0.01; n = 35. Where: Vol = volume of tank (kL or m^3); and e = 2.718.	No alternative size / cost relationships in MUSIC. For literature values, see Taylor (2005b) – Included in Appendix H or contact tank suppliers.* NB: Appendix H includes some approximate acquisition costs for plastic tanks (i.e. 0.5 to 48 kL in size)	**Warning:** The default relationship should <u>only</u> be applied to galvanized, colorbond, zincalume and aquaplate aboveground tanks, 1 to 10 kL in size. (NB: Underground tanks are generally more expensive to purchase and have longer life cycles.). TAC includes plumbing and installation costs (i.e. to connect tanks to toilets or hot water systems) but not GST. Note that an unexpected finding from the CRCCH dataset is that the predicted TAC costs rise as the tank size moves from 1 to 6 kL in size (as expected), but then slightly falls from 6 to 10 kL (unexpected). Upper and lower estimates derived using a 68% (or 1 standard deviation) prediction interval for the regression.
Typical annual maintenance (TAM) cost	TAM ($2004) = 90.	No alternative size / cost relationships in MUSIC. For literature values, see Taylor (2005b).*	Upper and lower estimates have not been provided in MUSIC due to limited data. This TAM estimate is based on: $75 for annual maintenance (from Kuczera and Coombes, 2001), scaled to $2004 using an annual inflation rate of 2%, plus $10 per year for operation and maintenance cost associated with pumps. Estimated using information from: Gardner (2004) and Grant and Hallmann (2003) on electricity use and cost that when combined, indicate pump running costs are typically $0.41 per kL; and Duncan (2004) who suggested a typical residential water usage rate for rainwater tanks would be approximately 20 kL per year. This TAM estimate assumes the tank is plumbed into a house (e.g. for toilet flushing) or the garden and includes a pump.
Annualised renewal / adaptation cost (RC)	RC ($2004) = $0	No alternative size / cost relationships in MUSIC.	Assumed to be minor and included in TAM.
Renewal period	N/A (as RC = $0)		
Decommissioning cost (DC)	DC ($2004) = $200	No alternative size / cost relationships in MUSIC.	Estimate obtained from a NSW plumber as no data was found in the literature. Given the low cost and effect of discounting in the life cycle analysis, the influence of any error associated with this estimate will be negligible.
General caveats / notes for this type of device	* Up to date acquisition cost estimates for rainwater tanks are easily obtained from the internet or directly from tank suppliers (for a list of suppliers see www.wsud.org/wsud.htm). This industry is rapidly evolving in Australia, so obtaining current estimates is recommended.		

{Blank Page for Double Sided Printing}

Appendix F

Recommended Plant Species

For Infiltration/ Detention Basins, Bioretention Swales, and Biofiltration Pockets within the Mundijong- Whitby Study Area

Mundijong Whitby UWMS- PLANT SELECTION LIST

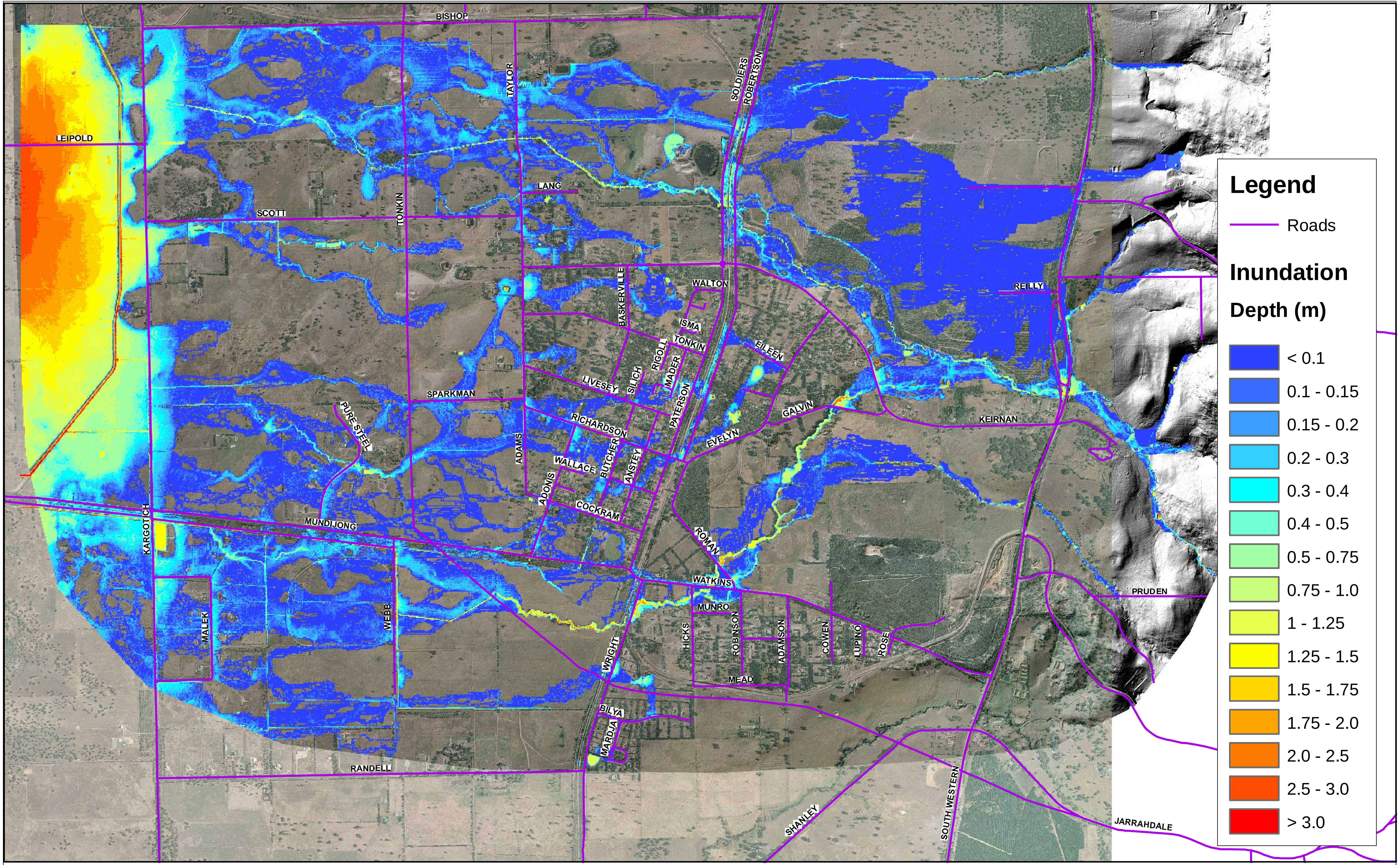
BOTANICAL NAME		COMMON NAME	HEIGHT	WIDTH	FOUND IN STUDY AREA	ORNAMENTAL	LOCATION	
Infiltration Basins								
Melaleuca	preissiana	Stout paperbark	6-10m	3-5m	Y		Tolerates waterlogged soils. Periodic inundation Salt Water Tolerant	Uplands
Melaleuca	rhaphiophylla	Freshwater paperbark	6m	3m	Y	Y	Wet depressions or clay flats	Levee/ Channel
Melaleuca	cuticularis	Saltwater paperbark	5m	6m		Y	tolerant to both waterlogging and in the salt air and water - Drought tolerant	
Melaleuca	lateritia	Robin redbreast bush	2.5m			Y	Fringing watercourses and in wet seasonally depressions	
Banksia	littoralis	Swamp banksia	12m				Swampy areas, does not tollerate inundation, prefers areas subject to only short winter water logging. -Deep sands and well drained soils, drought resistant	
Banksia	seminuda	River banksia	20m				Richer heavier soils along riverbanks and seasonally wet depressions	
Carex	appressa	Tall sedge	2m	0.5m			Brackish water, occur seasonally inundated or shallow permanent water	Levee
Carex	fascicularis	Tassel sedge	1.5m	1m			Fresh to brackish water. Seasonally waterlogged or partially inundated watercourses and lake margins	Levee
Carex	inversa	Knob sedge	0.1-0.15m	0.2m			seasonally wet or water logged soils and in fresh to semi saline conditions.	
Dianella	caerulea	King Alfred	0.3-0.5m			Y		
Dianela	revoluta	Little Rev	0.3-1.5m			Y	Variety of soils, laterite, granite, limestone	
Lomandra	histrix	Tropic Belle				Y		
Lomandra	longifolia	Lomandra				Y		
Juncus	caespiticius	Grassy rush	.09-.6m				Peaty Saline sand, winter depressions	
Juncus	holoschoenus	Jointleaf rush	.3-1m				Sand, swamps, creeks.	
Juncus	kraussii	Sea rush	0.8-1.5m				Saline to brackish habitats fringing watercourses and lakes, also on sea shores	Channel- Levee
Juncus	pallidus	Pale rush	2m				Common in seasonally damp areas. Max water depth 0.05m	(Levee)
Juncus	pauciflorus	Loose flower rush	1m				Permanently damp or seasonally wet soil fringing fresh watercourses	Levee
Juncus	subsecundus	Finger rush	1m		Y		Moist seasonally wet soils	Levee
Goodenia	pulchella	subsp. Coastal Plain	0.5m				Seasonally wet sites, undulating dunes	
Eucalyptus	occidentalis	Flat-topped-yate	20m	5m			Wet depressions or clay flats	Uplands
Eucalyptus	rudis	Flooded gum	25m	4m	Y		prolonged periods of flooding usually found in waterlogged areas,	
Casuarina	cunninghamiana	Casuarina	5-9m	5m		Y	Loam over granite, Eucalyptus woodlands along creek edge	
Ficinia	nodosa	Knotted club rush	1m			Y	Sands coastal dunes, winter wet depressions and fringing rivers and lke margins - Highly tolerant to salt spray and waterlogging-	
Lepidosperma	gladiatum	Coastal sword-sedge	1.5m				Perennial, found in seasonally moist or wet sands as well as dry dunes, full sun- part shade - Tolerates direct salt winds and alkaline soils.	
Bioretention Swales and Pockets								
Carex	appressa	Tall sedge	2m	0.5m			Brackish water, occur seasonally inundated or shallow permanent water	
Carex	appressa	Tassel sedge	1.5m	1m			Fresh to brackish water. Seasonally waterlogged or partially inundated watercourses and lake margins	
Carex	inversa	Knob sedge	0.1-0.15m	0.2m			seasonally wet or water logged soils and in fresh to semi saline conditions.	
Juncus	caespiticius	Grassy rush	.09-.6m				Peaty Saline sand, winter depressions	Channel- Levee
Juncus	holoschoenus	Jointleaf rush	.3-1m				Sand, swamps, creeks.	(Levee)
Juncus	kraussii	Sea rush	0.8-1.5m				Saline to brackish habitats fringing watercourses and lakes, also on sea shores	Levee
Juncus	pallidus	Pale rush	2m				Common in seasonally damp areas. Max water depth 0.05m	Levee
Juncus	pauciflorus	Loose flower rush	1m				Permanently damp or seasonally wet soil fringing fresh watercourses	
Juncus	subsecundus	Finger rush	1m		Y		Moist seasonally wet soils	
Ficinia	nodosa	Knotted club rush	1m			Y	Sands coastal dunes, winter wet depressions and fringing rivers and lke margins - Highly tolerant to salt spray and waterlogging-	
Dianella	caerulea	King Alfred	0.3-0.5m			Y		levee/ uplands
Dianela	revoluta	Little Rev	0.3-1.5m			Y	Variety of soils, laterite, granite, limestone	
Lomandra	histrix	Tropic Belle				Y		
Lomandra	longifolia	Lomandra				Y		
Lepidosperma	gladiatum	Coastal sword-sedge	1.5m				Perennial, found in seasonally moist or wet sands as well as dry dunes, full sun- part shade - Tolerates direct salt winds and alkaline soils.	

Appendix G

Floodplain Mapping

Mundijong Floodplain Management Study (SKM 2007)

{Blank Page for Double Sided Printing}



MUNDIJONG FLOOD STUDY

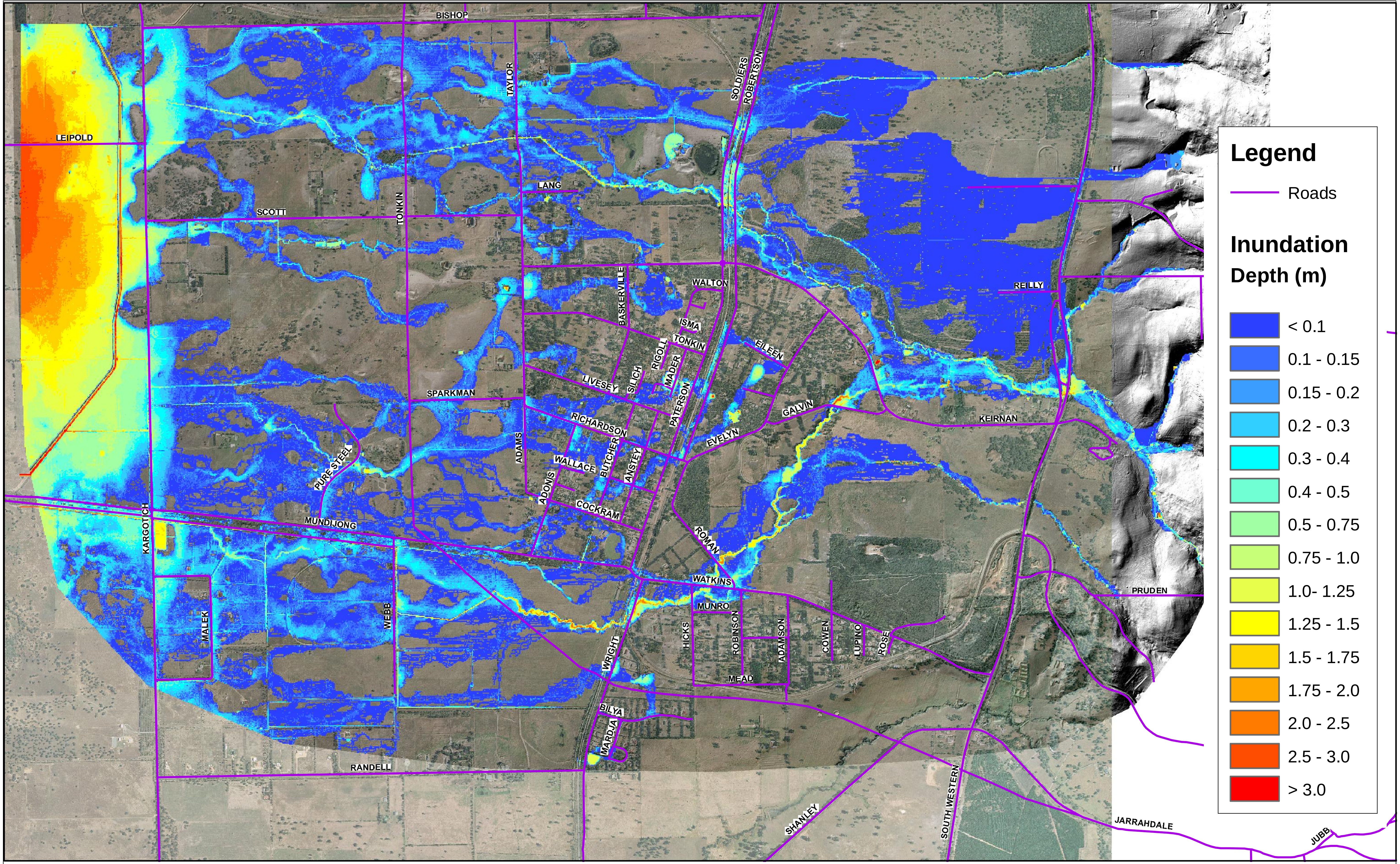
Figure D-3 10 Year ARI Existing Case Inundation Mapping

0 0.5 1 2
Kilometres

I:\QENV\Projects\QE09396\Spatial\Arc_MXD\Mundijong\Report_Figures\June 07\Mundijong_MIKE21_Existing_Q010_MGA50.mxd

Author: Sarah Gosling
Date: 09/11/07
Job No: QE09396.200

SINCLAIR KNIGHT MERZ



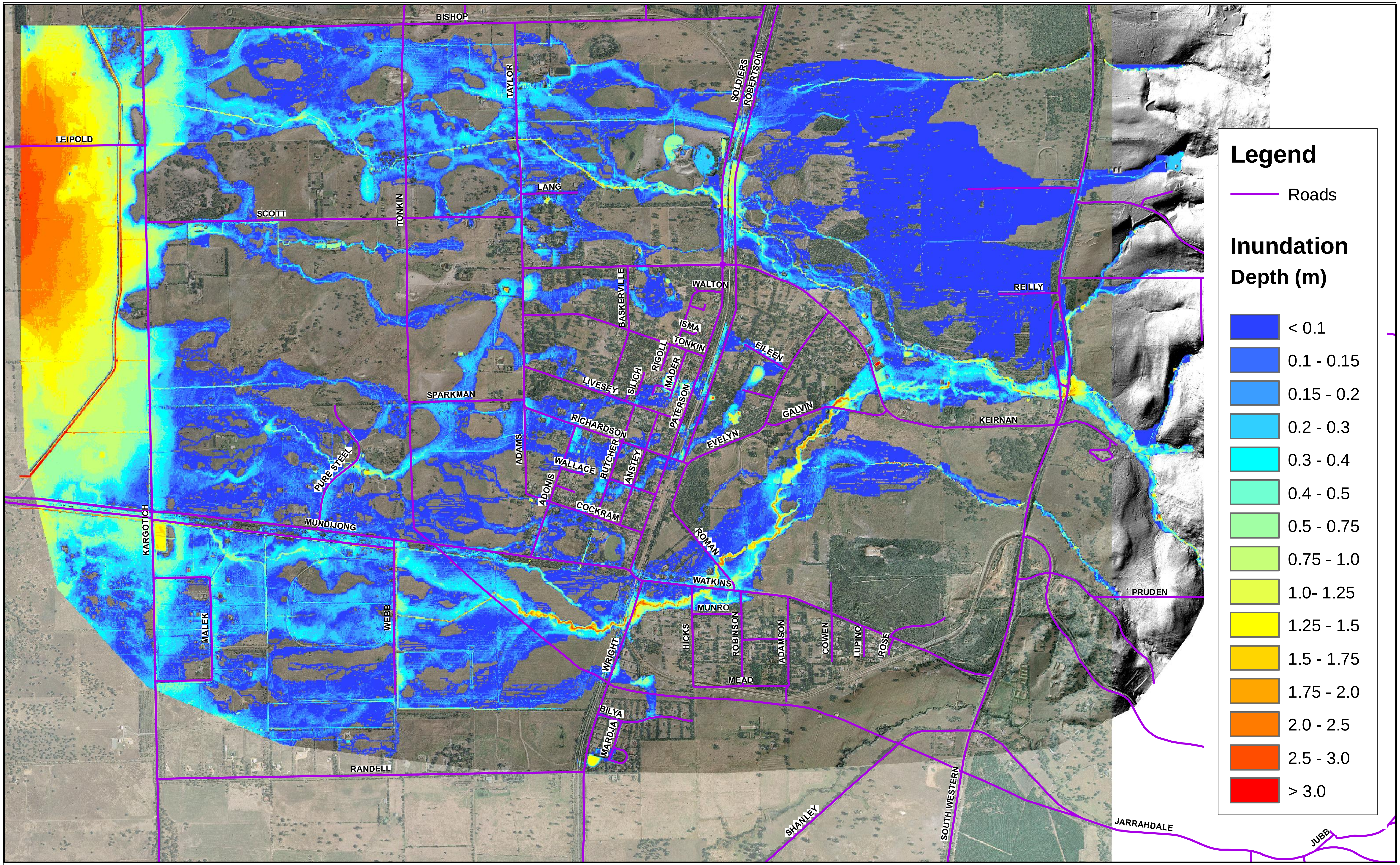
MUNDIJONG FLOOD STUDY

Figure D-2 25 Year ARI Existing Case Inundation Mapping

Author: Sarah Gosling
Date: 09/11/07
Job No: QE09396.200

SINCLAIR KNIGHT MERZ

I:\QENV\Projects\QE09396\Spatial\Arc_MXD\Mundijong\Report_Figures\June 07\Mundijong_MIKE21_Existing_Q25_MGA50.mxd



MUNDIJONG FLOOD STUDY

Figure D-1 100 Year ARI Existing Case Inundation Mapping

Author: Sarah Gosling
Date: 09/11/07
Job No: QE09396.200

SINCLAIR KNIGHT MERZ

I:\QENV\Projects\QE09396\Spatial\Arc_MXD\Mundijong\Report_Figures\June 07\Mundijong_MIKE21_Existing_Q100_MGA50.mxd

{Blank Page for Double Sided Printing}

GHD

GHD House, 239 Adelaide Tce. Perth, WA 6004
P.O. Box 3106, Perth WA 6832
T: 61 8 6222 8222 F: 61 8 6222 8555 E: permail@ghd.com.au

© GHD 2010

This document is and shall remain the property of GHD. The document may only be used for the purpose for which it was commissioned and in accordance with the Terms of Engagement for the commission. Unauthorised use of this document in any form whatsoever is prohibited.

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	N Deeks	H Brookes	On File	H Brookes	On File	2/7/09
0	N Deeks	H Brookes	On File	H Brookes	On File	8/9/09
1	N Deeks	H Brookes	On File	H Brookes	On File	19/11/09
2	N Deeks	H Brookes	On File	H Brookes	On File	10/03/10