West Mundijong Industrial Area

LOCAL WATER MANAGEMENT STRATEGY

DOCUMENT QUALITY CONTROL

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1 EXECUTIVE SUMMARY

The West Mundijong Industrial Area Local Water Management Strategy (LWMS) has been prepared to support the Structure Planning process for the subject land. The subject land is bounded by Mundijong Road (south), Tonkin Highway Road reserve (east), Bishop Road (north) and Kargotich Road (west). It is approximately 474 hectares in area. The land is approximately 1.5km west of the existing Mundijong town site (see Figure 1).

The subject land has a number of minor water courses that either traverse or begin on the site. This includes waterways that begin on the scarp to the east. All water leaving the site via the surface flows under Kargotich Road and into Oakland's drain, which flows southward. A small section of one of the waterways (Manjedal Brook) is considered a Conservation Category wetland. Around 80% of the remainder of the site is also considered Multiple Use wetland.

The majority of the site has been cleared and is composed of pastures. The remaining native vegetation on the site is degraded. It is usually composed of native overstorey species with none or limited native understorey.

Historically the land has been used for broad acre agricultural purposes, and currently is used for livestock grazing purposes. There are a number of dwellings on the subject land, especially in the rural residential section in the south east corner.

The future Tonkin Highway and rail line are located along the eastern boundary. This area may also include an intermodal area.

The LWMS has been prepared to satisfy the Better Urban Water Management guidelines that require a LWMS to support the current Structure Planning Process.

The objective of the LWMS is to demonstrate how a best management practices approach will achieve the principles, objectives and requirements of total water cycle management. The constraints of the site, proposed land use and surrounding environment have all been investigated to determine potential issues and outline potential strategies to manage, protect and conserve the total water cycle of the local environment and the greater catchment.

The strategies include:

- Integrate water sensitive urban designs (WSUD) into the development and surrounding landscape;
- Achieve water quality targets entering surrounding waterways and the groundwater resource
- Manage water quantity and flooding for the industrial development and hydrological regimes;
- Manage the groundwater resource with close to source treatment trains and to minimise the required fill;
- Investigate opportunities for stormwater, superficial groundwater and greywater harvesting and reuse;
- Investigate innovative schemes for Industrial wastewater management;
- Protect associated ecosystems dependent on water resources from the development; and
- Investigate practical methods to reduce potable water demand.

The effectiveness, efficiency and benefits provided by the best management practices will require a collaborative effort between local governments, developers and relevant regulatory authorities

PURPOSE OF LOCAL WATER MANAGEMENT STRATEGY

The LWMS will support the development of a Local Structure Plan (LSP) for West Mundijong Industrial Area. The LSP will be a strategic document which guides future industrial subdivisions across the subject land. This LWMS refines the works undertaken as part of the DWMS which assisted with the rezoning of the land to Industry.

It is proposed that the development will predominantly support general and light industry. Any heavy industry sites will be limited and need to satisfy planning, site and environmental conditions for their consideration. The lot size will initially be limited to 2ha. This is to reflect the lack of sewer available. Future subdivision may be undertaken to smaller lots, provided the wastewater management is in keeping with the increased density. This LWMS deals primarily with the 2ha option of subdivision, however it does provide direction on the future subdivision to smaller lots.

SUPPORTING DOCUMENTATION

The LWMS was compiled using information contained within the detailed assessments and reports undertaken for the subject land. These reports listed below have been included on the enclosed CD accompanying the DWMS.

- TME. 2012. West Mundijong Industrial Area Fill Analysis.
- TME. 2012. West Mundijong Industrial Area Feasibility Study.
- PGV Environmental. 2012. West Mundijong Industrial Area Environmental Assessment.
- TME. 2012. Drainage modelling - HECRAS and DRAINS
- Oversby Consulting. 2020. West Mundijong Industrial Area Wetland Management Report
- Urbaqua. 2020. West Mundijong Industrial Modelling Report

Typical flat plain and roadside swale within the subject land

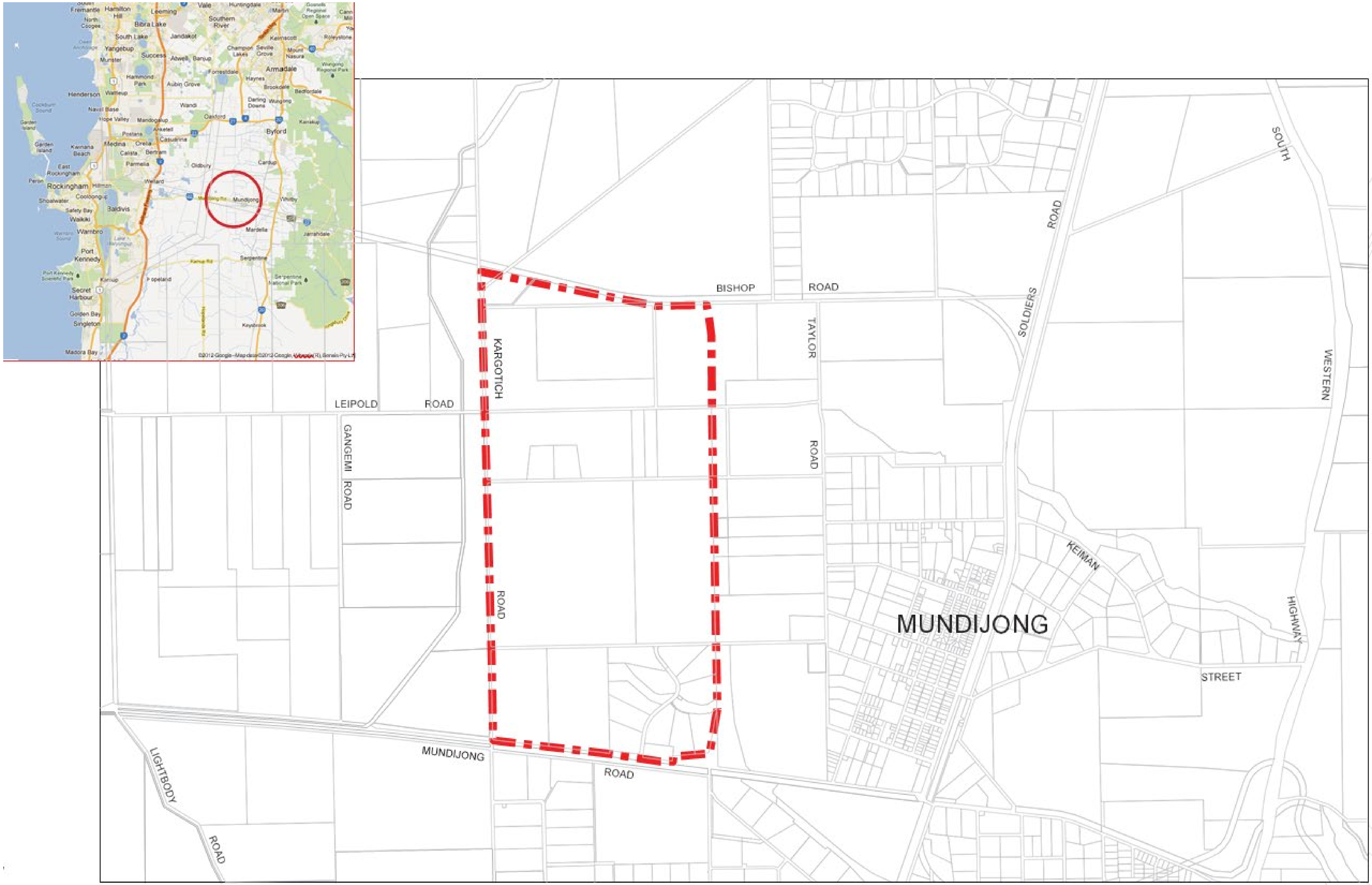


Figure 1 Location Plan

2 KEY ELEMENTS

Water management strategies for the subject land are based on best practice water sensitive designs that suit the site's constraints. They also provide recognition of the importance of water as a resource across the entire development and surrounding environment.

The recommended strategies provide an integrated approach through the synthesis of industrial planning and designs to manage, protect and conserve the total water cycle. The plans and designs for the development are appropriate for the subject land's development constraints and unique surrounding environment and providing a sustainable industrial estate.

A summary of the key best water management practice elements that are recommended for implementation within the development to achieve best management practices are outlined below, and visually represented in Figure 2.

WATER QUALITY AND ENVIRONMENTAL PROTECTION

- Establishment of appropriate management practices for foreshore reserves and wetlands along Manjedal Brook.
- Utilisation of water sensitive designs, including bioretention gardens, basins, swales, and flow spreader devices to capture, detain, treat and convey all development runoff.
- Investigation of building design guidelines that encourage structural separation of potentially polluted runoff in work areas from the stormwater runoff pathways.
- Providing lot owners with information relating to the establishment and maintenance of water wise and nutrient wise gardens in their required landscape areas on each development.
- Encourage non-structural best management practices.
- The pre development monitoring of groundwater and surface water quality to establish benchmarks and identify any potential issues.
- The monitoring of storm water outflow rates and quality post-development.

STORMWATER MANAGEMENT AND FLOOD PROTECTION

- Utilisation of best practice to treat, store, convey, control and discharge stormwater runoff;
- Lot storage and treatment of all runoff up to the 10%AEP on each lot.
- Treatment of the 1EY event in road reserves
- Post development monitoring of water quality.
- No development to be within the 1%AEP floodways of the subject land waterways.
- All finished floor levels on lots to be designed to maintain a minimum separation clearance of 500mm to the 1%AEP flood levels of the Manjedal Brook, Oaklands Drain and all flood storage areas.
- All building floor levels on lots to be designed to maintain a minimum separation clearance of 300mm to the internal 1%AEP flood levels.
- Protection of buildings and infrastructure with conveyance and storage of flood waters via the open and piped drainage network and road reserves.
- Discharge of 10% AEP flow rates from the site is not to exceed pre development flow rates.
- Discharge of 1% AEP flood flow rates from the site is not to exceed pre development flow rates.
- Storage of predevelopment flood volumes as well as the extra post development runoff, to control downstream flooding.

GROUNDWATER MANAGEMENT

- Ensure development has no negative impact on the groundwater resource, or ecosystems dependent on the resource.
- Filling building and infrastructure sites where necessary so that there is an appropriate clearance to the controlled groundwater level (CGL).
- The installation of a sub-soil drainage pipe network and swale systems at the proposed CGL to control groundwater from rising above this level.
- Treatment of controlled groundwater and the stormwater runoff infiltration via planted swales and basins.
- The monitoring of the groundwater quality and levels across the subject land post development to identify any future detrimental impacts on the groundwater resource.
- There is potential to harvest excess superficial groundwater for use on site.

WATER CONSERVATION AND SERVICING

- Development to be connected to a reticulated water supply.
- Encourage water efficient fixtures and fittings for all buildings constructed.
- Encourage lot owners to install a suitable rainwater tank. The tank size will be dependent on the roof area and water usage patterns of the business.
- Encourage greywater reuse schemes for landscape irrigation and business related purposes.
- Public areas Multiple Use Corridors and street landscaping will have a strong focus on using locally suitable native water wise species and use of soil amendments to reduce irrigation requirements.
- 2ha lots are to be developed initially to allow for onsite effluent disposal (for dry industry).

OTHER ASPECTS

- Future investigations and liaison are to take place with the Department of Indigenous Affairs (DIA) prior to construction, for sites of significance.

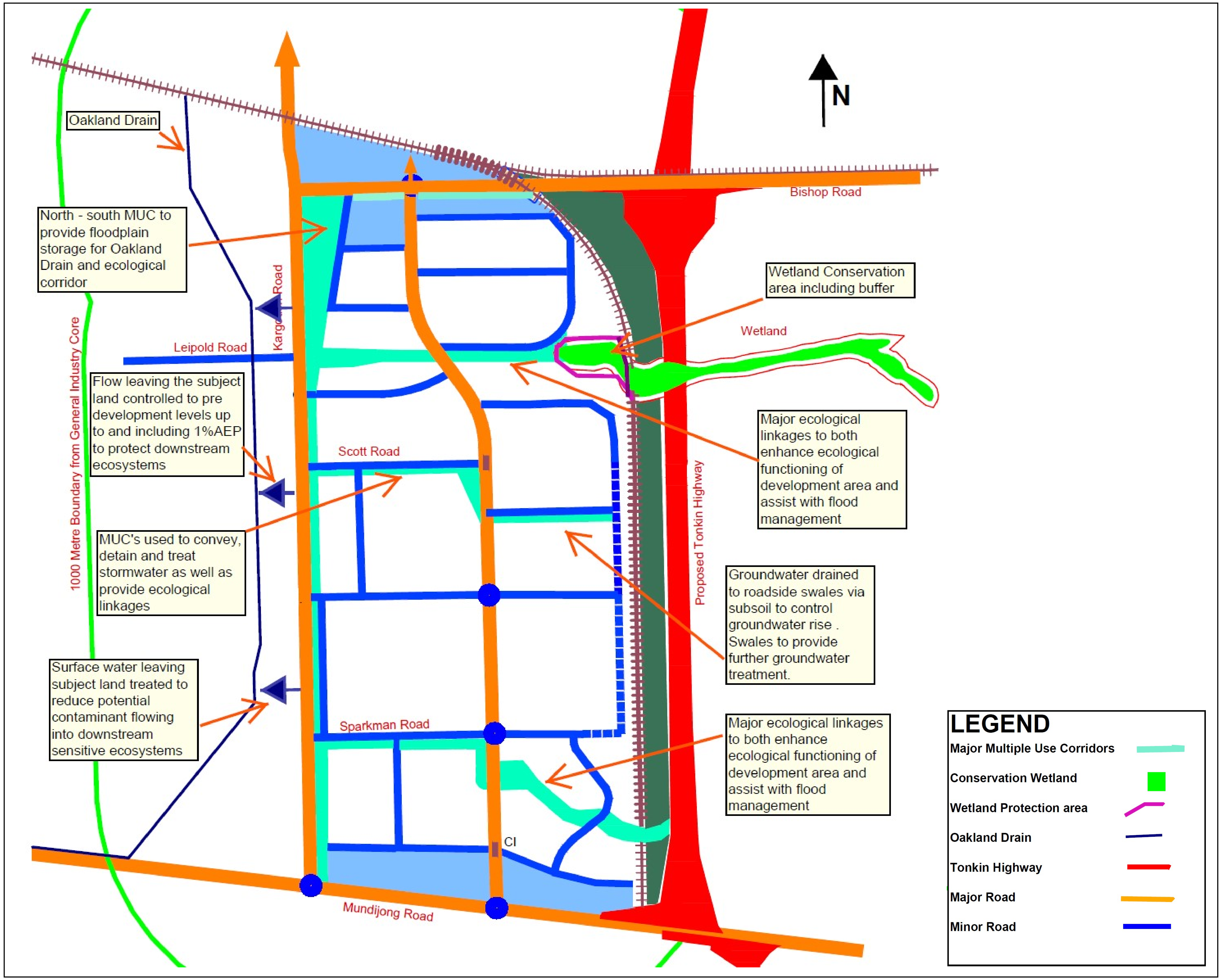


Figure 2 Key Elements Plan

3 LANDFORM & SOILS

The subject land is located on the Swan Coastal Plain and the landforms are typical of this area. The land is composed of three (3) main landforms, which are shown in Figure 4 Page 9 and described below.

Figure 4 Page 9 displays contour information derived for the subject land from LiDAR (Light Detection and Ranging data) modelling.

1. **Wet Flats** – The majority of the site is a mildly sloping wet plain. This landform slopes downwards from east to west with a fall from 25-26mAHD to 16mAHD. The slopes vary between 0.2 and 1% with the slope generally flattening towards the west. These flats are generally sands over loams and clays. The low slopes and predominately sandy surface of this landform produces a low runoff rate until the land becomes waterlogged. These areas are classified as wetlands.

2. **Sand Rises/Ridges** – Low Bassendean sand ridges are located sporadically across the subject land. These are low relief dunes with deep bleached grey sands. The sand ridges rise between 2m and 6m above the surrounding plain with the peaks being up to 27mAHD. The slopes vary from 1 to 5% on the sides of the ridges. The sandy nature of this landform produces a low runoff rate, with most water infiltrating into the soil profile.

3. Waterways - There are also a number of minor waterways that traverse or begin on the subject land. Many of these have been modified through drainage works. The largest of these waterways is known as Manjedal Brook. The waterways/drains tend to be incised within the wet flats landform. It is likely that historically these waterways were considerably more braided and less defined.

Shallow Drainage line to allow for drainage of the flat plains within the subject land

4 GEOTECHNICAL

GEOLOGY

The superficial formations over the land consist predominately of Pinjarra System alluvial soils overlaid with aeolian Bassendean System sands.

The Pinjarra soils are likely to have a high Phosphorus Retention Index (PRI) while the Bassendean sands are likely to have a low PRI. There is a need for a geotechnical investigation of the site to be undertaken as part of later planning for the area.

CONTAMINATED SITES

An analysis of the Department of Environment and Conservation's (DEC) Contaminated Sites database was undertaken on 9th July 2012, and no known sites were found on the subject land or in the near vicinity.

ACID SULPHATE SOILS (ASS)

The DEC ASS mapping for the Swan Coastal Plan has modelled the whole subject land as moderate to low disturbance risk of ASS.

To protect on site and downstream water resources, ASS investigations should be undertaken across the subject land to determine the potential and actual ASS risks as part of future investigatory works.

Detailed ASS investigations and management plans (where appropriate) will also be required on land modelled as 'Moderate to Low' in accordance with DEC's 2009 Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes guidelines if any of the following works are proposed:

- Soil or sediment disturbance of equal to or greater than 100m3 with excavation from below the natural water table.
- Lowering of the water table, whether temporary or permanent (e.g. for groundwater abstraction, dewatering, installation of new drainage, modification to existing drainage).
- Excavation to or greater than 3m below the natural ground surface level.

The ASS investigations should happen as a condition of subdivision, unless there is evidence of high risk ASS. If this is the case then it may be appropriate to undertake investigation at an earlier stage, should the proposed development strategies be subject to high risk activities being undertaken.

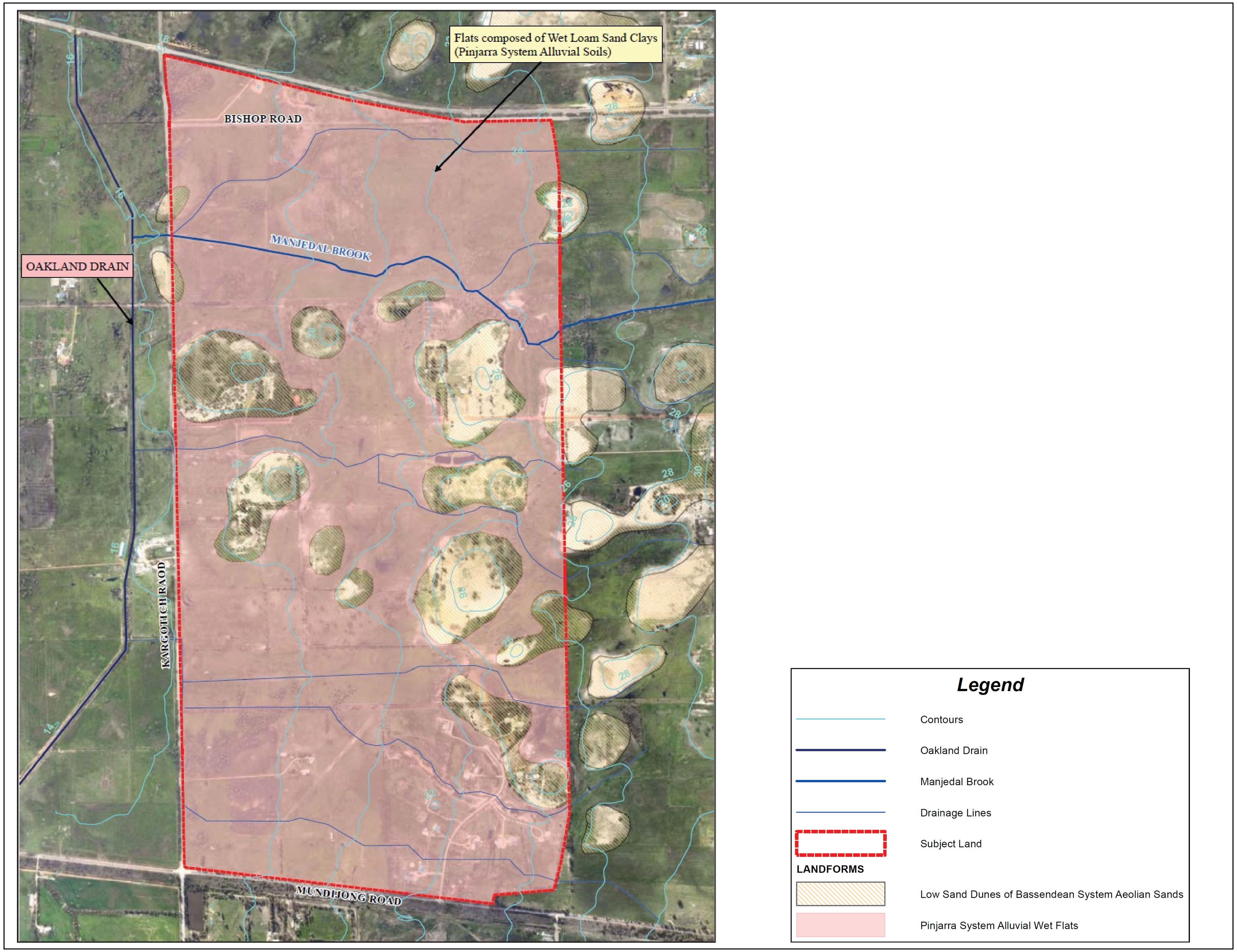


Figure 3 Landform, Soil and Geotechnical Plan

5 ENVIRONMENT

PGV Environmental undertook an environmental assessment of the subject land. Oversby Consulting also undertook an assessment of the Manjedal Brook Wetland system. The following is a summary of this information and site visits by Oversby Consulting.

WETLANDS AND WATERWAYS

According to the Department of Biodiversity, Conservation and Attractions's (DBCA) Geomorphic Wetlands Swan Coastal Plain dataset (as shown in Figure 5), the Paluasplain Multiple Use Wetland (Number 15785) covers the majority of the site. The Multiple use wetlands areas are predominately devoid of native vegetation, although there are small areas of isolated *Melaleuca rhaphiophylla*, *Eucalyptus rudis* and *Casuarina obesa* trees. The main vegetation is composed of pasture species. These areas have limited ecological functioning and therefore provided few habitats for fauna

There is also a small area of Paluasplain Conservation Category (CC) Wetland associated with Manjedal Brook that traverses the northern portion of the site This has the reference Number 14945. The overstorey vegetation is largely intact and forms part of a corridor of vegetation along the brook and constructed drain. The understorey is predominately composed of pasture species and environmental weeds as well as isolated rushes. For much of the portion in which the brook is within the CC wetland, it exists as a shallow single channel. There are some minor side channels which would receive flows during flood events. This area provides some basic habitat value for fauna and acts as a limited corridor for fauna movement. A Wetland Management Report has been prepared for this wetland area (see Appendix B).

The other waterways and drains tend to be very degraded in nature, with limited ecological functioning, although there is still likely to be a limited range of fauna that use these waterways. The main flora along the waterways are introduced grasses and pasture weeds. They are likely to be classified as 'D' grade waterways using the Penn and Scott method.

To the south of the site, there is some higher quality wetland type vegetation associated with the reserve along Mundijong Road. This area is regarded as a Paluasplain Conservation Category Wetland (Number 14817).

OTHER AREAS

Some of the sand mounds have parkland cleared native vegetation, with some areas of denser, although degraded native vegetation. The vegetation tends to be dominated by marri trees. This will provide some habitat for wetland and waterway dependent fauna that are also able to use these other vegetation types. There are scattered native trees across some of the paddocks, predominately, C. obesa and M. rhaphiophylla.

There has also been some windbreak and Landcare planting along fence lines and drains. These will also provide some limited habitat to generalist species.

VEGETATION AND FLORA

The subject land is within the Southwest Botanical Province within the Swan Coastal Plain Bioregion and is dominated by vegetation of the Pinjarra Plain and Bassendean System. Most of the native vegetation however has been cleared.

The different areas of vegetation include:

1. Completely cleared farmland containing pasture grasses, which is the predominant vegetation type over the entire site;
2. *Casuarina obesa* Woodland over pasture grasses which is dominant in the south western corner of the site
3. *Melaleuca rhaphiophylla* (Paperbark) Woodland over pasture grasses which is associated with the Conservation Category Wetland and has some *Eucalyptus rudis* (Flooded Gum);
4. *Corymbia calophylla* Woodland over pasture grasses which is mainly in the area around Scott Rd;and
5. *Kingia australis* and *Melaleuca rhaphiophylla* over pasture grasses, which occurs in the north of the site near Bishop Road.

The degraded nature of the site means it is highly unlikely that any Threatened or Priority Flora exist on the site. The priority flora found to the south of Mundijong Road will not be impacted by the development of the subject land.

FAUNA

The degraded nature of the site's vegetation means that there is likely to be limited opportunity for endangered fauna species that rely on wetlands and waterways to use the site. Generalist species, and those suited to agricultural landscapes may be able to make use of the degraded wetland and waterway habitats occurring on site. The waterways also provide some limited ecological linkage function for fauna moving across the site.

6 HERITAGE AND CULTURAL SITES

There is one Registered Aboriginal Site present on the northern portion of the eastern boundary. It is a scatter site located on a sand rise and doesn't impact on the existing water ways and wetland areas. (see Figure 4). There is also another non registered Heritage Place that crosses the eastern boundary towards the south, which is also an artefacts scatter site. This is also located out of the drainage lines that exist on the subject land.

The aboriginal heritage issues are therefore unlikely to affect the water management of the site.

Investigations should be undertaken at future planning stages to ensure that Aboriginal and heritage consent is granted for proposed designs and practices.

All contractors working on any future development of the site will be made aware of their responsibilities under the Aboriginal Heritage Act 1972 with regard to finding potential archaeological sites. In the event that a potential site is discovered, all work in the area will cease and the DIA will be contacted.

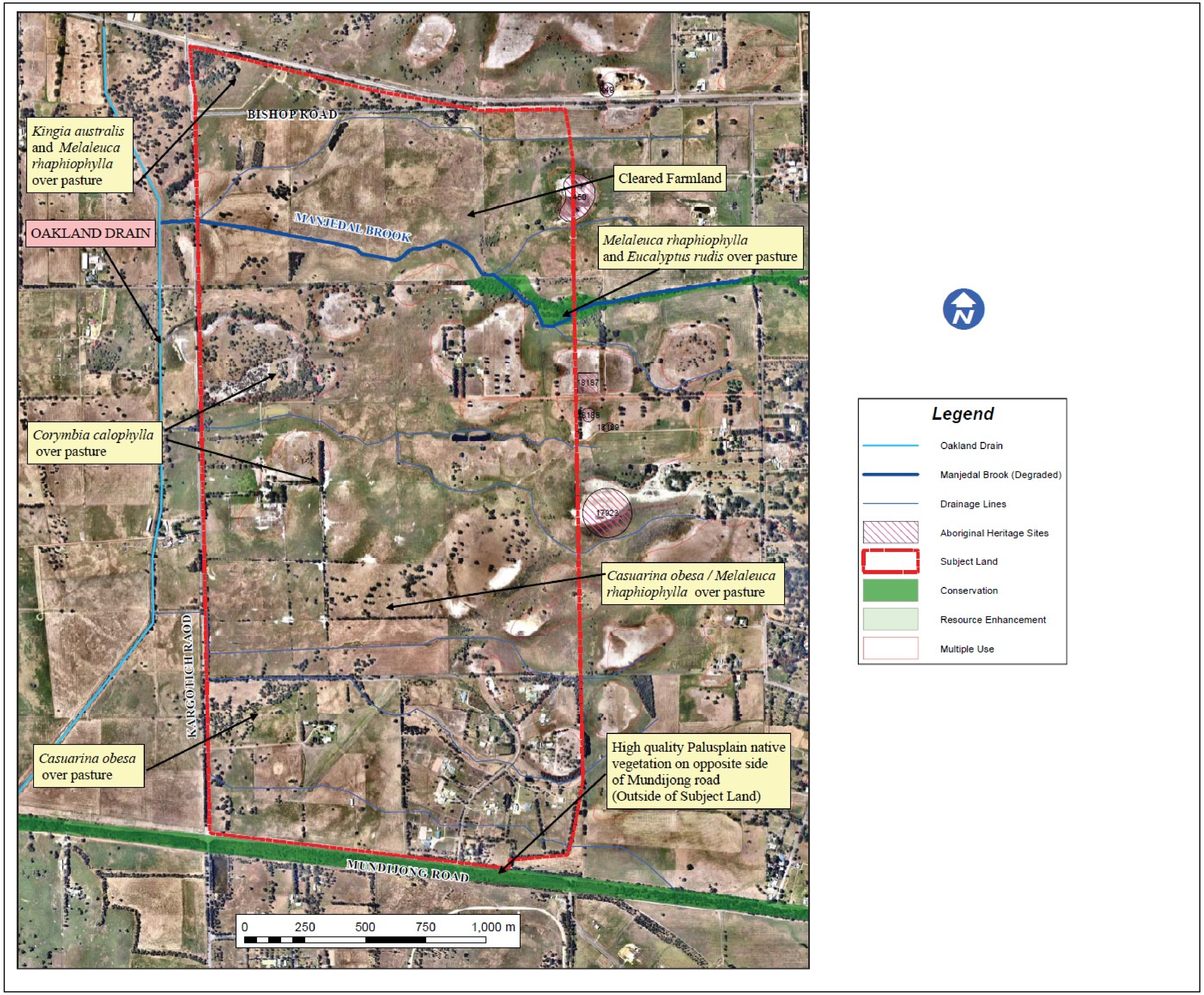


Figure 4 Environmental and Heritage Plan

7 GROUNDWATER HYDROLOGY

GROUNDWATER INVESTIGATIONS

The Department of Water and Environmental Regulation (DWER) has undertaken broad scale analysis of the regions groundwater levels as part of Perth Regional Aquifer Modelling Systems (PRAMS) model development. Hydrology and groundwater modelling, with a focus on the Lower Serpentine Regional Model (2008) has also been undertaken.

As part of the DWMS, this information was analysed by TME, in conjunction with LIDAR. From this information, indicative groundwater levels for the site were developed.

Maximum, minimum and average maximum groundwater contours were determined as well as the depth to groundwater. From this analysis, the groundwater can be seen to be moving generally in a westerly direction.

Maximum levels ranged from 26mAHD on the eastern boundary down to 16mAND on the western boundary. Minimum levels fell from 23mAHD to 14.5mAHD and Average levels fell from 24mAHD to 15mAHD. Seasonal variation between the minimum and maximum level was usually between 2 and 3m.

The depth to groundwater varied across the site. Approximately a quarter of the site had water at the surface, with another quarter showing water within 0.5m of the surface. Under some of the sand dunes, the ground water was at least 3m below the surface. A map of groundwater depth can be seen in Figure 5.

This DWMS data was compared to recently collected groundwater levels as part of the Tonkin Highway expansion. A total of 6 bores, from 5 locations were analysed. All of these occur approximately 50-100m to the east of the subject land boundary of the subject land. These stretched from the north to the south of the eastern side. Their location can be seen in Figure 5.

The levels collected over the 2020 winter and spring period were compared to the PRAMS model and depth modelling undertaken as part of the DWMS. The analysis also considered the closest bore to the subject land with longterm data is 61410151, located next in the north west of the subject land (Bishop Road and Kargotich Road intersection). The levels for 2020 are close to average with a reading of 16.9mAHD (noting that this is above the AAMGL within the PRAMS model of approximately 15.7mAHD). It is however close to the modelled maximum level of 16.8mAHD. The maximum recorded for this bore is 17.18mAHD. This would suggest that in this localised corner, groundwater can rise above the general regional groundwater contours. Over much of the subject land groundwater rises until it is intercepted by the drainage network or the low areas of the surface then runs off. This limits further rise.

Given this, although rainfall was below average over winter and early spring, the fact that groundwater was observed to rise to the surface within the subject land, that the 2020 Main Roads data is likely to be close to the average for this location.

The levels in the Tonkin High bores also generally matched relatively closely with the modelled levels determined for the subject land. Due to groundwater rising to the surface over much of the site then running off, provides a controlling level in the current situation. Based on this analysis, the levels modelled in the DWMS are considered suitable for this LWMS.

A full summary of the analysis can be seen in Appendix C

GROUNDWATER QUALITY

Groundwater quality has not been analysed in detail for the subject land. Due to the current land use and soil types present, it is likely that the nutrient levels of the groundwater will be elevated. This has the potential to impact on wetlands and river systems both on and downstream of the subject land.

It is also likely that the pH of the groundwater will be under 7 and have elevated levels of iron and aluminium. The salinity is likely to be in the fresh to brackish range. Groundwater exhibiting the above characteristics is common throughout the eastern portion of the Swan Coastal Plain.

AQUIFER AND ALLOCATION INFORMATION

The subject land is within the Byford 3 sub area.

DWER provided advice in January 2021 regarding groundwater availability for the subject land. The Yarragadee, was noted as having no allocation. The Perth-Cattamarra Coal Measures and the Perth Leederville have no allocation available. The Perth-Superficial Swan had some allocation, noting that the yield rate may be low in some locations, especially towards the east, due to the presence clay sediments.

This means there is limited easily available groundwater resources that may be used within the development. It is likely that any industry that may want to make use of groundwater would need to enter into a trading process with current licence holders within the relevant groundwater sub area.

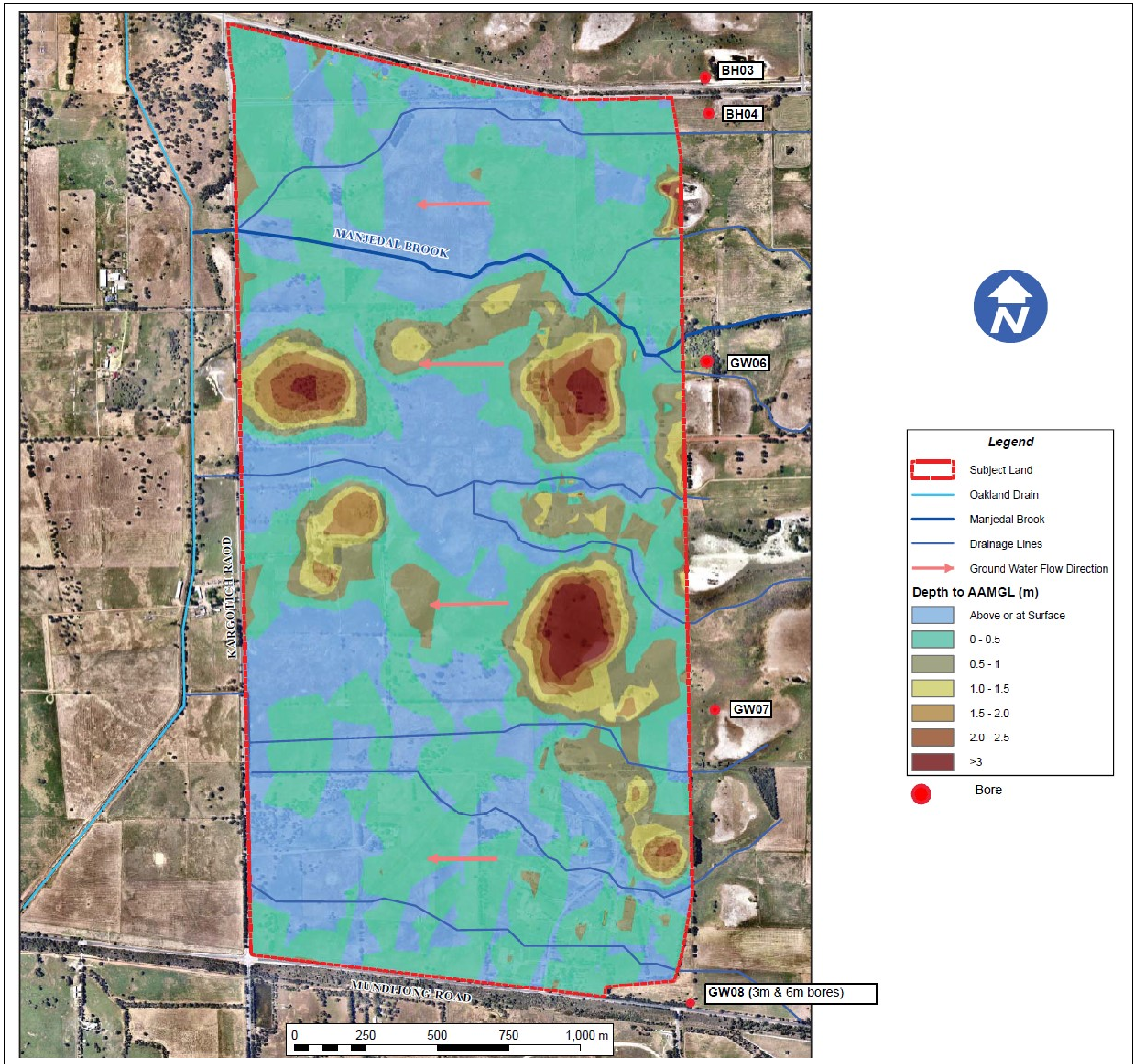


Figure 5 Predevelopment depth to groundwater Plan

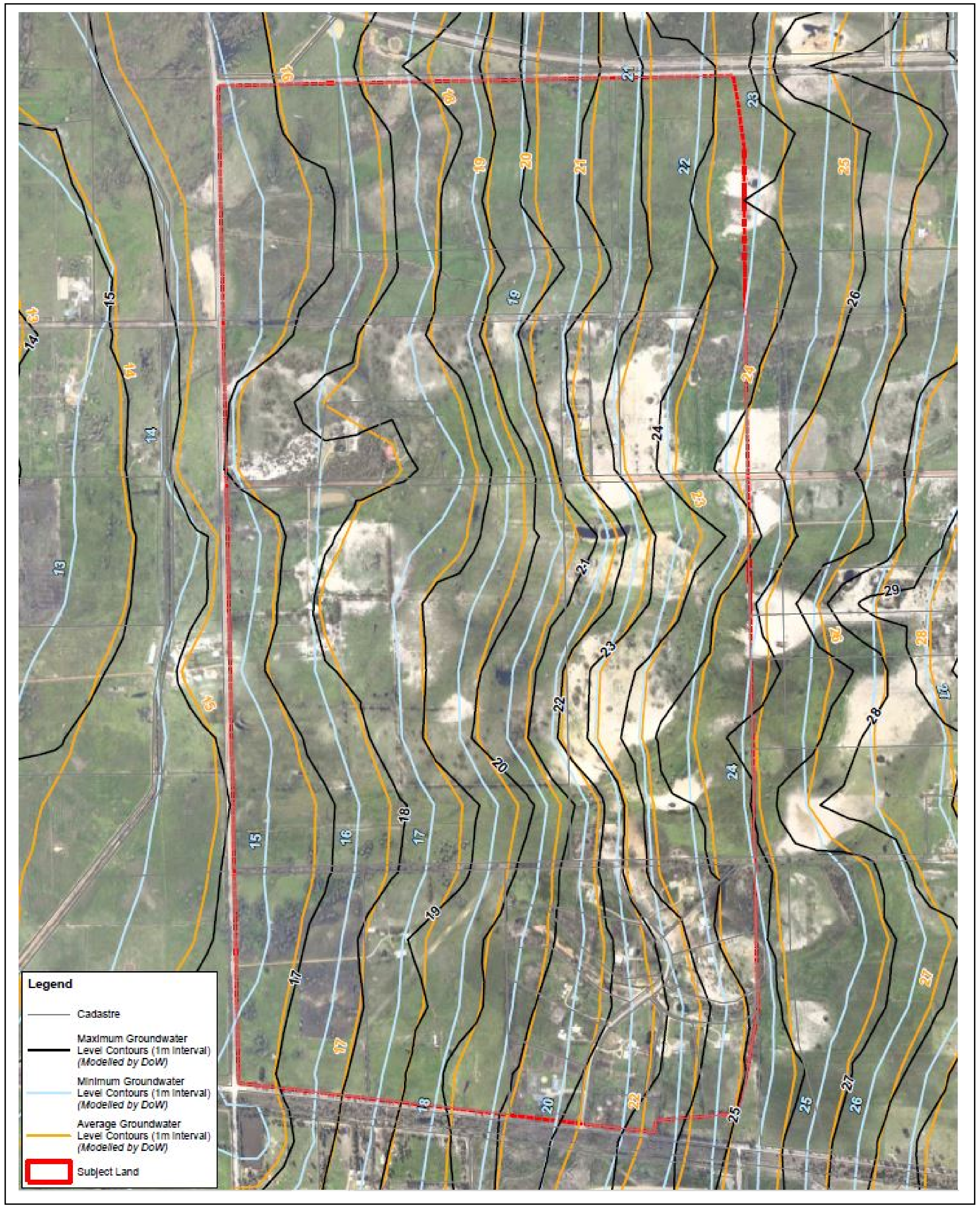


Figure 6 Predevelopment groundwater countour plan

8 SURFACE WATER & DRAINAGE PRE-DEVELOPMENT

PREDEVELOPMENT SURFACE WATER.

The major drainage lines within the subject land is Manjedal Brook and its tributaries. These cover the northern portion of the subject land and generally run from east to west. This area is within Catchment 1. There are another 5 small drainage lines which transport external inflows during high flow events, which traverse Catchments 2 and 3.

Water generated on the site, and water that enters the site from upstream all flow across Kargotich Road and into Oakland drain. This major Water Corporation drain runs southward, parallel to the subject land. Water from this drain is ultimately discharged into the Serpentine River and Peel Harvey Inlet. These drainage lines and discharge points can be seen in Figure 6.

PRE-DEVELOPMENT DRAINAGE MODELLING ASSESSMENT

An assessment of the pre-development runoff from the subject land and upstream flows was modelled as part of the DWMS. This was to determine flows from the 1 in 10 year and 1 in 100 year events. This modelling incorporated original broad scale modelling by the Department of Water, with more detailed modelling within the subject land by TME.

Flood mapping information for the subject land was obtained from the DWER modelling and used as the base case. Refinement of this specifically to the subject land as undertaken using DRAINS modelling software.

Hydrologic Engineering Centres River Analysis System (HEC-RAS) was used for modelling flood and ArcGIS for flood inundation mapping. Cross sections of drainage lines were extracted from LiDAR and inflows from Department of Water modelling were used. Based on three major outlets, three major catchments were identified. The model identified where the water is stored during the large flood events.

The model shows that the existing capacity of the culverts under Kargotich Road are not adequate to cater for even the 10% AEP pre-development flow. This results in flooding of the subject land and overtopping of the road.

A refinement of the drainage was undertaken as part of the LWMS process using XP-Storm, as recommended by the Shire of Serpentine Jarrahdale. This allowed for the more detailed modelling necessary. The models were compared so that the results obtained as part of the detailed XP-Storm modelling was in keeping with the initial parameters set out in the DWMS DRAINS modelling. Flows were also converted from Annual Recurrence Interval (ARI) flow to Annual Exceedance Probability (AEP) flows). A summary can be seen in Table 1 with a full comparison in the Modelling Report (Appendix A).

Pre development inflows and outflows from the subject land, as well as the 3 major catchments are shown in Figure 6 and 7.

A flood inundation map for 1% AEP equivalent for the modelling exercise is presented in Figure 7. This flood inundation is heavily influenced by the external upstream flows as well as back flooding from Oakland Drain. The design of the Oaklands MD western levee bank results in flooding along Kargotich Road, the effects of which can be seen in the photos shown in Figure 3-4 of the Birrega Oaklands Flood Management and Drainage Study.

The loss parameters used the XP-Storm modelling for the predevelopment scenario are shown in Table 2. These reflect the current rural land use with areas of surface inundation.

Table 1 Comparison of DRAINS vs XP-Storm modelled outflows

Catchment	Drains Post-dev 1% AEP Outflow	XP-Storm Post-dev 1% AEP Outflow
1	36.15 m3/s	39.15 m3/s
2	8.02 m3/s	7.30 m3/s
3	16.06 m3/s	16.51 m3/s

Table 2 Loss Parameters used in XP-Storm Modelling

Land use	Initial Loss (mm)	Proportional Loss (%)
Road	3	0.1
General industry	15	0.1
Light industry	10	0.1
Rural area	7	0.3
POS	8	0.3
Wetland	0	0.0
Commercial	10	0.1

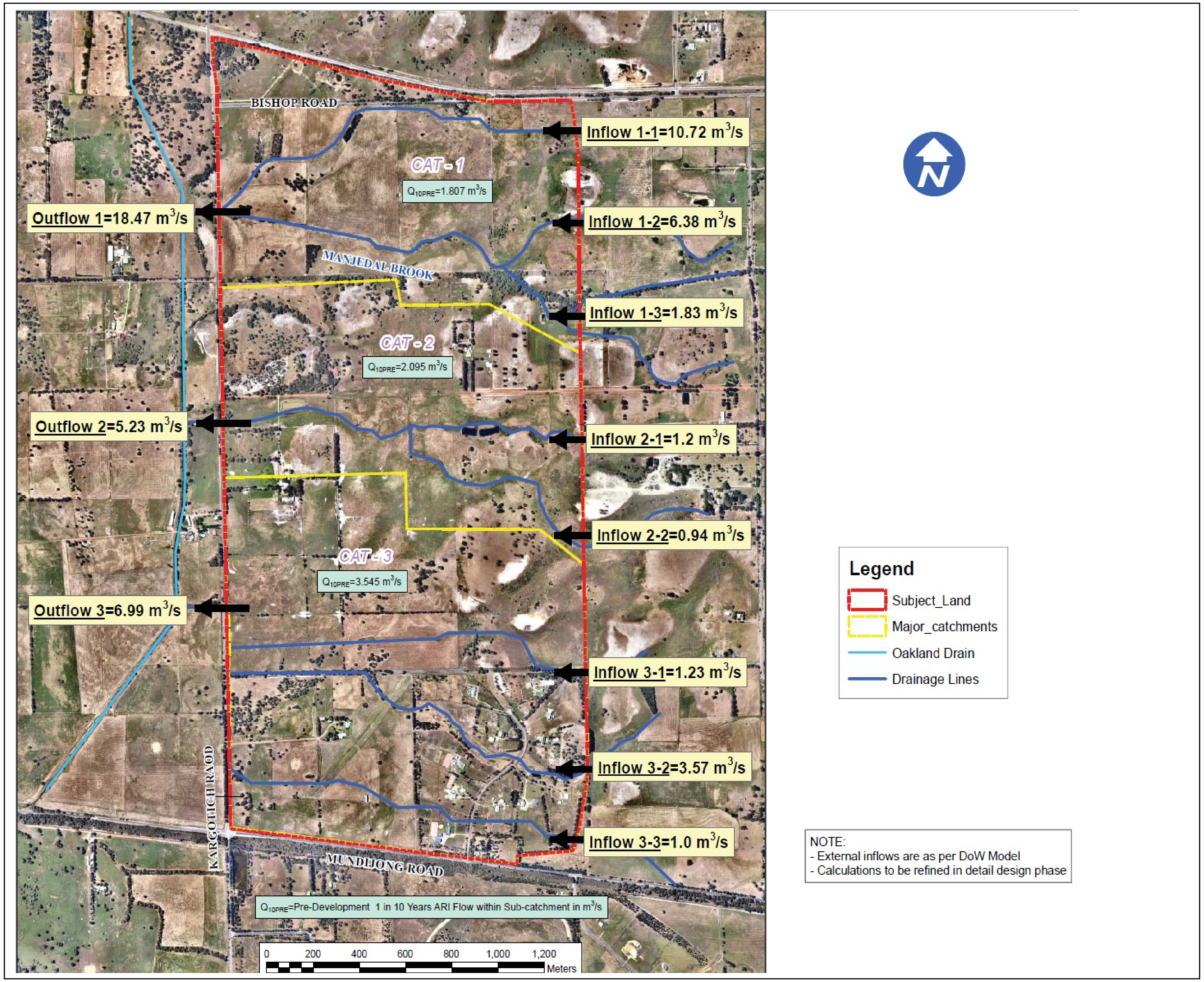


Figure 7 10% AEP Pre Development Scenario (based on historical DoW ARI modelling)

SURFACE WATER QUALITY

No pre-development monitoring has been undertaken to date. There is some limited water quality data available for Manjedal Brook, which was collected in October 2007 as part of the Mundijong – Whitby District Structure Plan Environmental Study (2009). The results are typical for waterways on the eastern edge of the Swan Coastal Plain, although nutrient levels were lower than most waterways. This may be due to the larger flows of Spring diluting the results.

The results can be seen in Table 3.

As the subject land is within the Peel Harvey Water Quality Improvement Plan (WQIP) area, the site will need to consider the recommendations outlined within the WQIP. The Estuary and associated waterways are showing signs of stress according to the (WQIP). The Estuary is internationally, nationally and regionally significant for natural fauna and flora, recreation, aesthetics and hydrologic systems. The system has a history of water quality problems, which are derived from its large and diverse catchment and land uses.

Table 3 Manjedal Brook Surface Water Quality Results

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

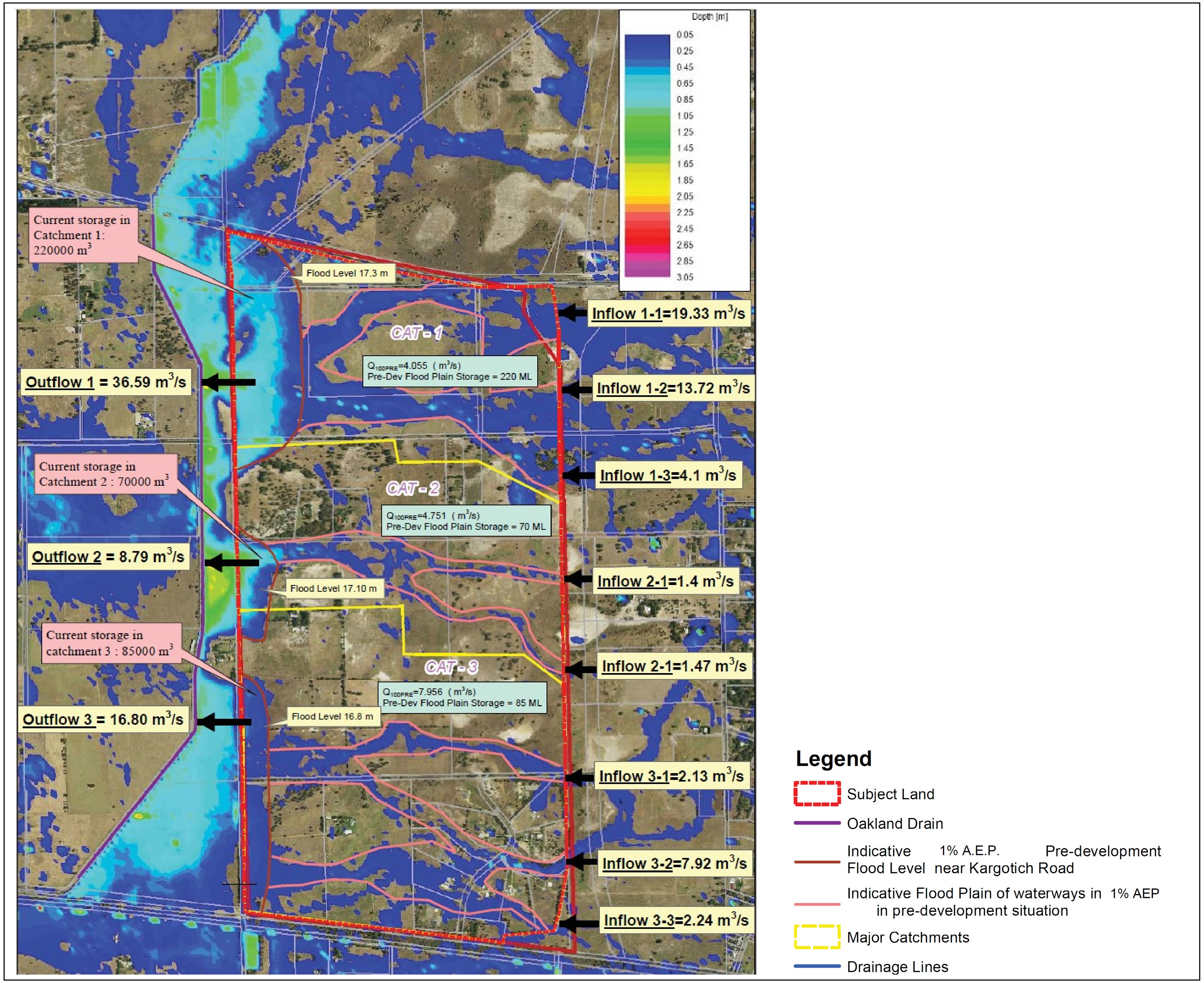


Figure 8 1% AEP Predevelopment Scenario, based on DWER historical modelling

9 DRAINAGE MANAGEMENT STRATEGY

DRAINAGE SUMMARY

The objectives of the stormwater drainage management for the development area and relevant upstream and down stream flows, are to:

- mimic as close as possible the pre-development flows leaving the subject land
- maintain floodplain storage volumes
- treating the necessary volumes before the water is discharged to receiving water bodies or groundwater.

The subject land is divided into three major post development sub-catchments based on three major outlets. These are further divided into twenty one sub catchments based on outlets from proposed development areas. These can be seen in Figure 10 and 11.

The following three sections discuss and provide further details on how water is to be treated, conveyed, stored and discharged in three different flow scenarios.

A – 1EY event

B – The 10% AEP

C – The 1% AEP

These sections outline the guidelines the development may follow to ensure that best management practices of stormwater management and flood protection are achieved. They also provide critical inverts for each of the major swale networks to assist with the future detailed design of individual areas (see Figures 12-14). All swales are set at approximately the modelled AAMGL.

Detailed drainage designs, models and drawings will be required at the subdivisional stages, to accompany the Urban Water Management Plan (UWMP) for each relevant area. These are to generally follow the strategies outlined in this LWMS.

LOT DRAINAGE

The development relies on significant management of drainage within the large industrial lots proposed 1.5-2ha+. Each lot needs to detain and infiltrate its 10% AEP on site, while also maintaining separation to groundwater. The lots will also need to have a subsoil discharge (2 proposed) to the major swale network , or to the roadside pipe network, where swales are not present. The exact mechanism for on lot storage and groundwater management is to be determined for each subdivision at the UWMP stage as well as individual Lot design approvals. An indicative option is shown in Figure 10 that outlines how each lot can manage its own water. The shallow perimeter swale provides storage and infiltration areas that are above the groundwater. The subsoil line underneath assists with draining this localised area as well as overall control of groundwater across the development area. Further internal subsoil lines may also be installed, depending on the landuse and size of the lot, with these connected to the perimeter subsoil network. Double subsoil outlets are proposed to assist within minimising the total length that a subsoil network would need to run, and therefore minimise the total amount of fill required. This controlling of groundwater means that there will be minimal standing water within lots, assisting with minimising mosquito breeding. All on lot basins are to maintain a minimum 300mm clearance between the base of the structure and the controlled groundwater level.

Outfall of stormwater drainage and groundwater is to be via dedicated lot connection pits within the road reserve. Pits are to be set at both corners of each lot, to assist with minimising the length of drainage. The exception to this will be where it is not possible to drain to the front of the lot. In these cases, drainage easements will need to be constructed at the rear of the lot and flow through to a swale/pipe network on an alternative road. Lot connection pits will still be required at the discharge point to the drainage easement.

Drainage easements are to be designed and constructed to allow for ease of long term management by the Shire.

The Shire of Mundijong is to approved future developments based on this requirement for stormwater and groundwater management. Guidelines that mandate necessary design standards are also to be detailed in a Local Area Plan.

MODELLING SUMMARY

The following is a summary of the post development modelling, including assumption used to inform the modelling process.

- Management of the 15 mm rainfall event within lots will occur on-lot through the use of shallow landscaped basins, soakwells or rainwater tanks;
- Road runoff from the 15 mm rainfall event within road reserves will be managed in roadside bio-retention gardens and swales;
- Detention of up to the 10% AEP 6 hour event (56.6 mm) within 2 ha lots using basins;
- Conveyance of the 10% and 1% AEP events through roadside swales and a living stream incorporated into landscaped Multiple Use Corridors (MUCs);
- MUCs sized to ensure that the 1% AEP event is contained within the MUC and adjacent road reserve / public open space;
- Flood storage within the MUCs up to the 1% AEP event to reduce on-lot storage requirements;
- Restrict outflow from the site to pre-development rates to prevent an increase in flooding risk downstream; and,
- Ensure that the flood levels of buildings across the site are at least 500 mm above the adjacent water levels within the MUCs, swales and existing waterways.

The hydrology in the model was established with the land uses in the Local Structure Plan provided in Figure 2, losses in Table 2 and the 2016 IFD data, with an ensemble approach (AR&R, 2019). Inflows from the DWER modelling were also incorporated into the XP-Storm model.

The model was run for the 10% and 1% AEP events, with durations of 3, 6, 9, 12, 18 and 24 hours.

On-lot storage will be provided for up to the 10% AEP 6 hour (design) event, with disposal through infiltration into a subsoil network (discharging to adjacent MUCs and swales). To replicate this in the model, a single basin for each sub-catchment was sized, rather than for each 1.5 - 2ha lot. Outflow from the theoretical basins were restricted to a 300 mm pipe (to account for contribution from subsoil discharge) and the storage capacity was refined in the model to on-lot storage requirements. Larger events, including the 1% AEP discharge to the adjacent swales and MUC via overflow from these basins.

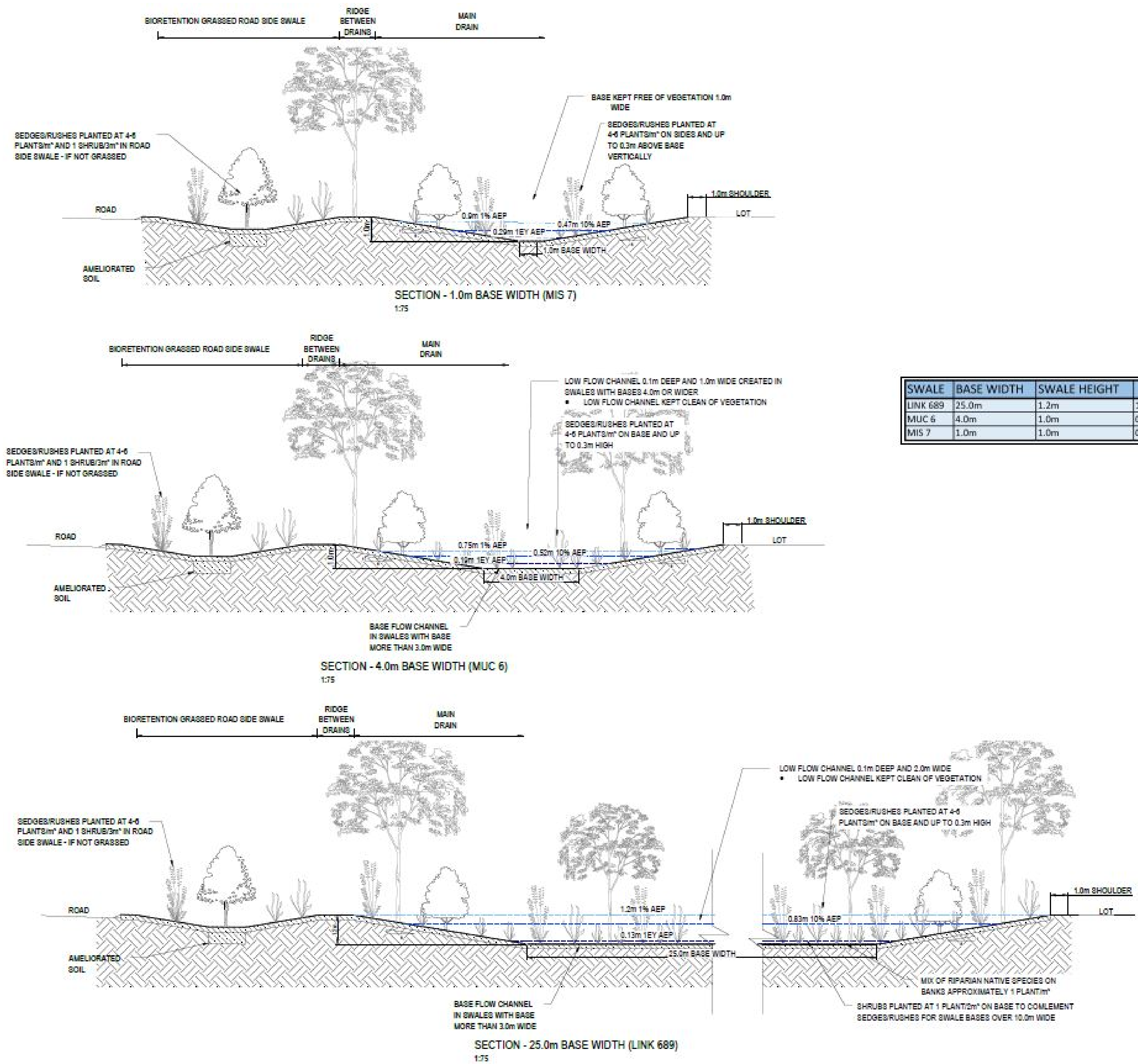
The Oakland floodplain storage is to be detained in the North-South Ecological corridor.

The modelled loss parameters assumed for each land use can be seen in Table 3

TEMPORARY DRAINAGE INFRASTRUCTURE

Due to the size and ownership nature of the development, it is noted that the ultimate swale network may not be possible for each area of development, at the time of development. Temporary options to join drainage of a particular development area to a future swale network may be required. Any temporary structure will need to be detailed up and approved by the Shire. Details will also need to be provided as to how the ultimate future drainage will be undertaken, as part of future development.

Related to this is the location of the future northern discharge point. With this discharge moving southward, there may be a need to temporarily take flows across to the current discharge location (eg though the culvert that takes water from the degraded Manjedal Brook). The ultimate location will also need to secure a drainage easement west of Kargotich Road through to Oakland Drain



SWALE	BASE WIDTH	SWALE HEIGHT	1%	10%	1EY
LINK 689	25.0m	1.2m	1.2m	0.83m	0.13m
MUC 6	4.0m	1.0m	0.75m	0.52m	0.19m
MIS 7	1.0m	1.0m	0.9m	0.47m	0.29m

Figure 9 Typical swale and roadside treatment for various swale sizes

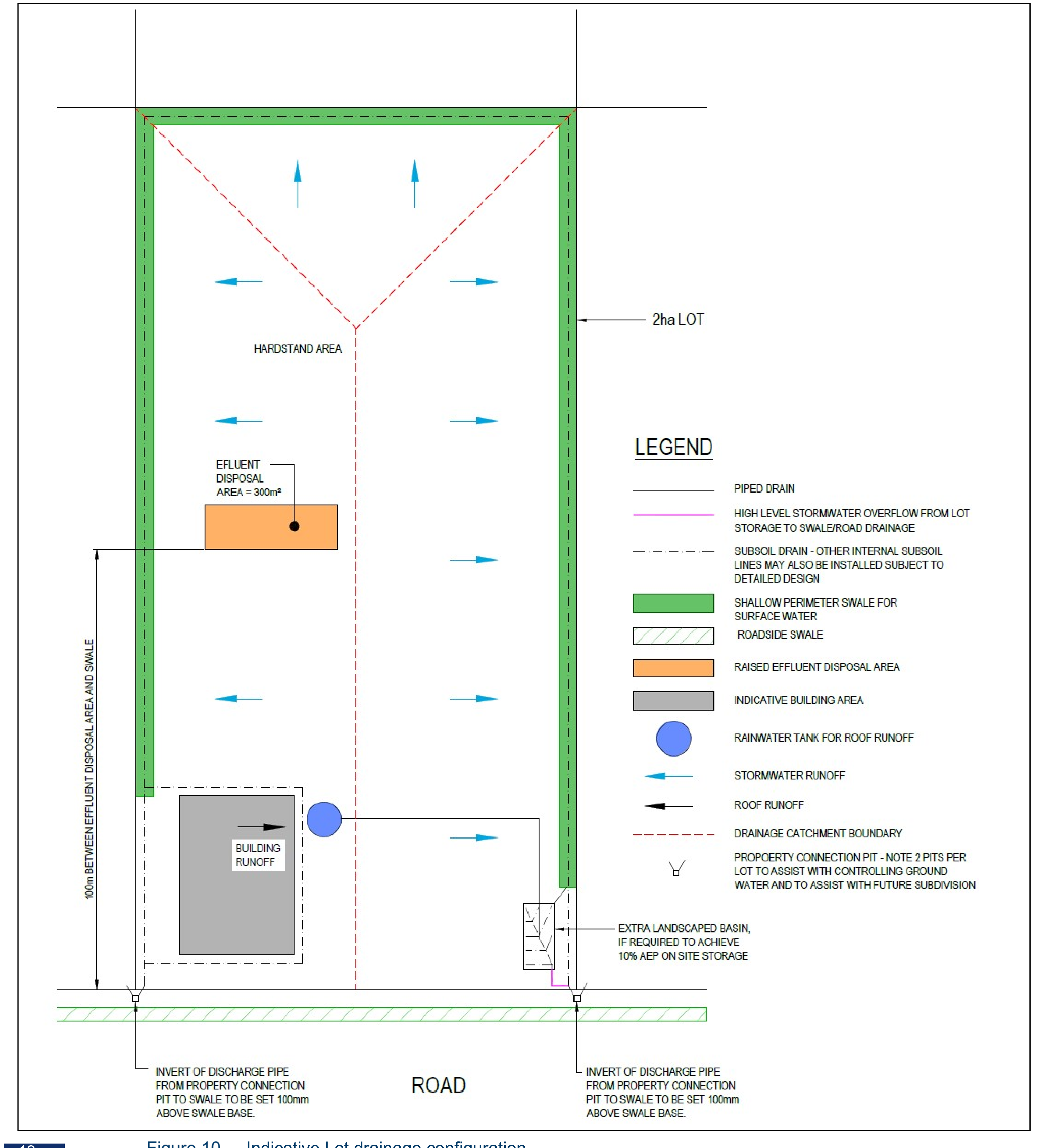


Figure 10 Indicative Lot drainage configuration

9.1 DRAINAGE MANAGEMENT STRATEGY – 1 EY

The drainage management system for the development will be designed to capture and provide treatment for the first 15mm of rainfall, which is being used as a surrogate for the likely event that will happen annually (1EY). The designs will also provide protection of the ecological functions for all receiving natural environments post development. The flow generated from this rain volume will be collected and treated, both on lots and within the road reserve.

Surface water on the land will take two main directions; infiltration to the groundwater and surface run off. Two separate treatment trains have been designed and specified to treat and manage the two different flow paths.

INFILTRATION TO GROUNDWATER

The majority of the water that falls on pervious surfaces in the development area will infiltrate through to the shallow groundwater because of the high hydraulic conductivity of the imported fill's free draining nature that will be laid across the majority of the developable area. This will include any overflow from installed rainwater tanks, on-site bioretention systems, swale bases and property soak wells. Any fill used will ensure that the fines content of the fill is restricted to less than 5% to promote drainage across the site.

Piped subsoil drains will be used to intercept and convey ground water flows to the drainage system and ensure levels across the site do not rise above the designated controlled groundwater level (CGL) for the site. These pipes will also ensure the required clearances to lots are maintained, allowing soakwells and basins to function as per their design parameters.

Each lot will be responsible for capturing, detaining and treating all lot runoff of the first 15mm on-site. The runoff could be detained and treated by a variety of methods and combinations, including shallow landscaped bioretention basins, rainwater tanks and soak wells. A typical lot drainage can be seen in Figure 10.

Rainwater tanks, with air gaps, will be encouraged for each lot and business throughout the development. The tanks will assist in reducing the peak runoff flows from the lots, providing some of their on-site storage requirements especially during summer storm events. Overflow from these will be directed to infiltration areas and soak wells. The base of the soak wells and infiltration areas will generally be installed 300mm above the CGL Water that enters the soak wells will infiltrate into the soil profile and ultimately into the groundwater. There is no direct link between the lots and the street drainage network.

SURFACE FLOW

Runoff within the development will occur off the road reserves during the 1EY.

This water will also be captured and detained and treated.

This will generally be provided in road side bioretention gardens and swales as shown in Figure 9. The bioretention gardens and swales will be protected from traffic. Bioretention gardens will be located so that they do not obstruct lot access and cross overs are to be provided over the swales (noting that appropriate culverts to manage the required flood flows are to be installed). The water entering the bioretention gardens will pass through an amended soil layer to reduce the quantity of sediments and nutrients entering the groundwater. The gardens will be constructed according to the latest FAWB Adoption Guidelines for Filter Media in Biofiltration Systems and the Stormwater Management Manual for WA design guidelines. They are to be designed to capture and absorb nutrients and other contaminants.

Indicative sizings of the overall bioretention needed for each catchment can be seen in Figure 11.

Bioretention gardens may require irrigation during the initial 2 to 3 years to assist with the establishment of plants. Irrigation and fertiliser applications should be met by storm water runoff after this period, although subsequent watering may still be required in drier years.

Table 4 Swale Dimension, to be used in conjunction with Figures 11-20.

Type	Depth	Base Width	Side Slopes
1	1.2 m	25.0 m	1:6
2	1.0 m	1.0 m	1:6
3	1.0 m	2.0 m	1:6
4	1.0 m	4.0 m	1:6
5	0.75 m	2.0 m	1:6
6	1.0 m	18.0 m	1:6
7	1.0 m	8.0 m	1:6
8	1.0 m	10.0 m	1:6
9	1.0 m	20.0 m	1:6

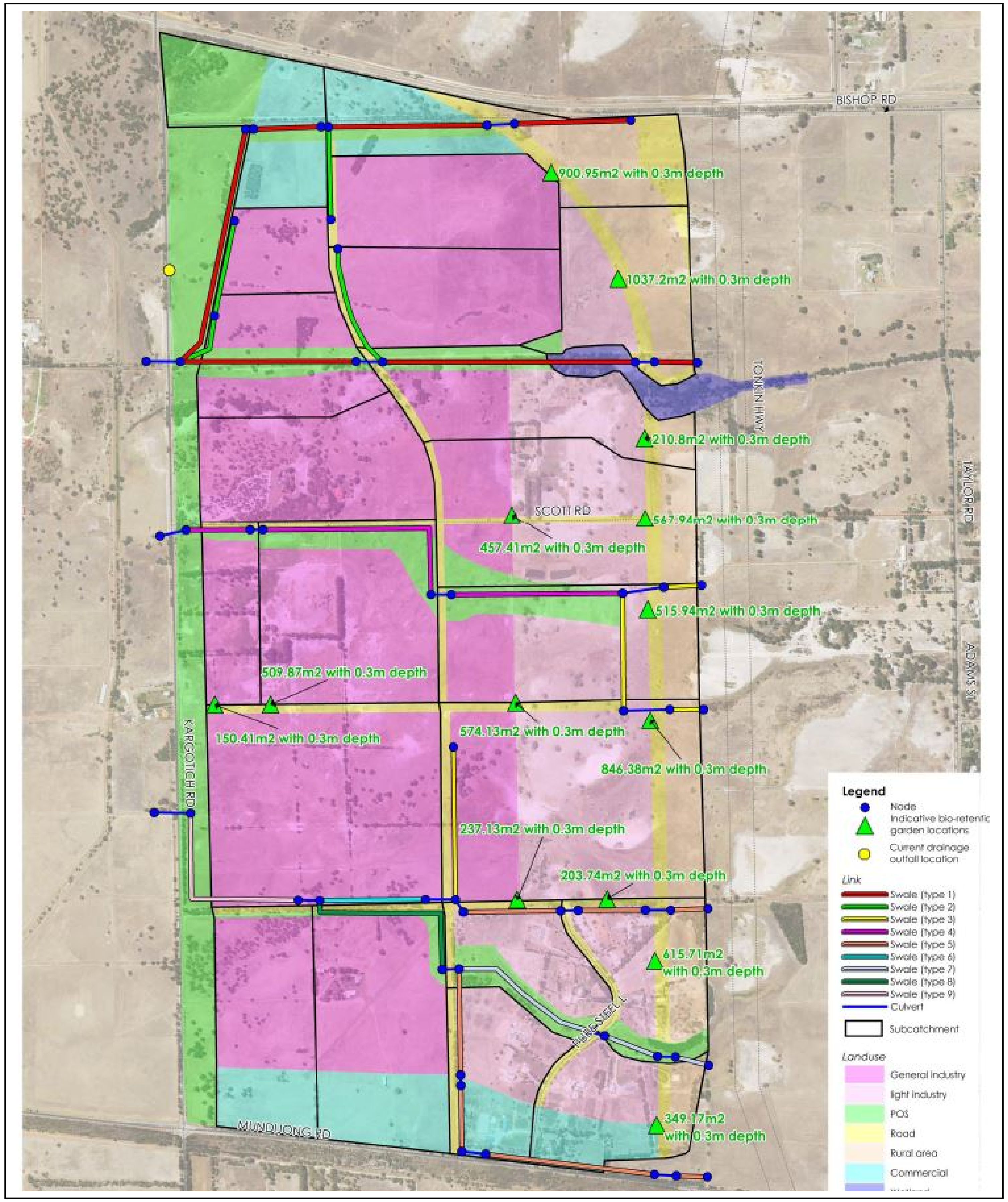


Figure 11 Modelled Treatment areas for each catchment

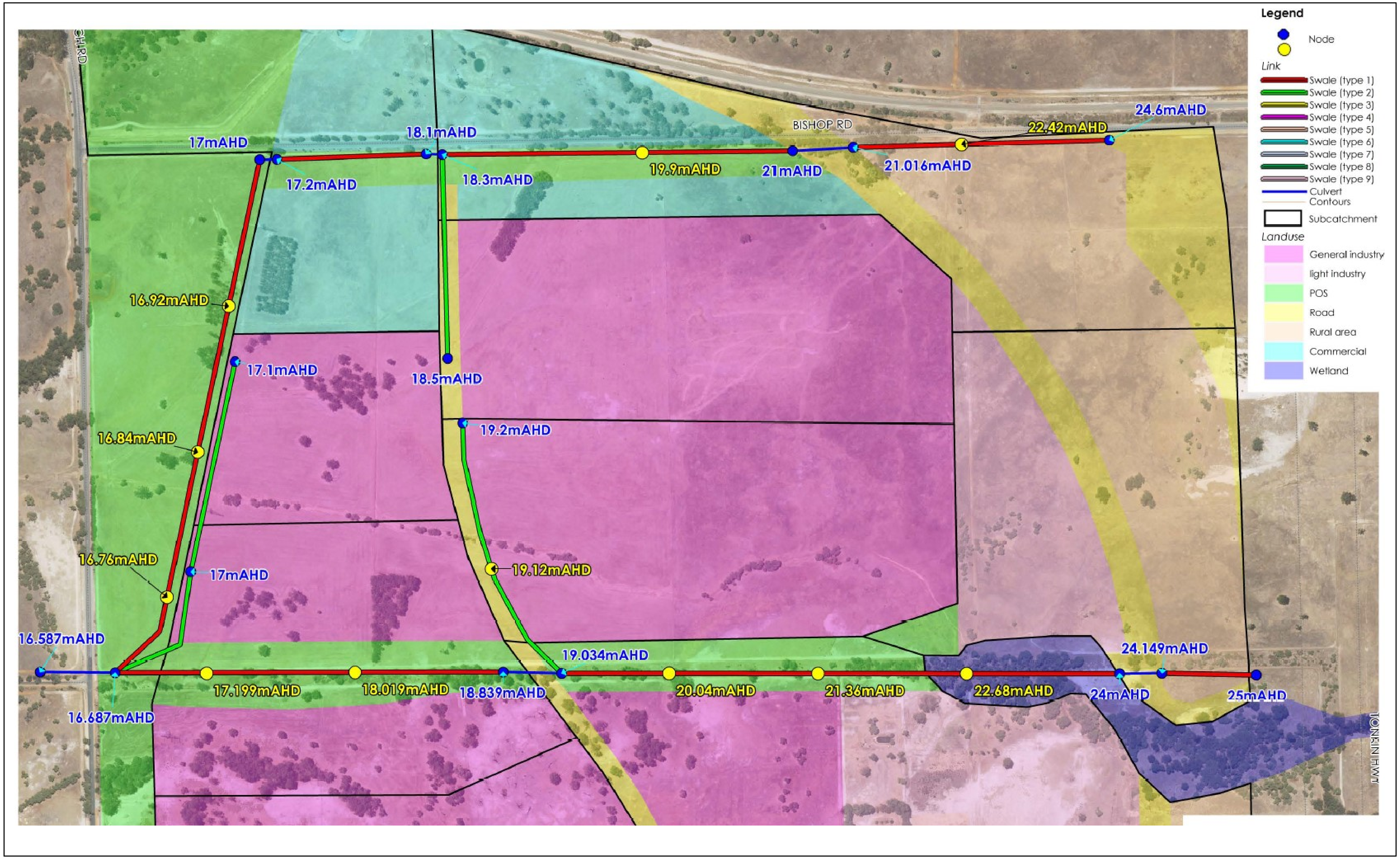


Figure 12 Critical swale inverts – northern portion

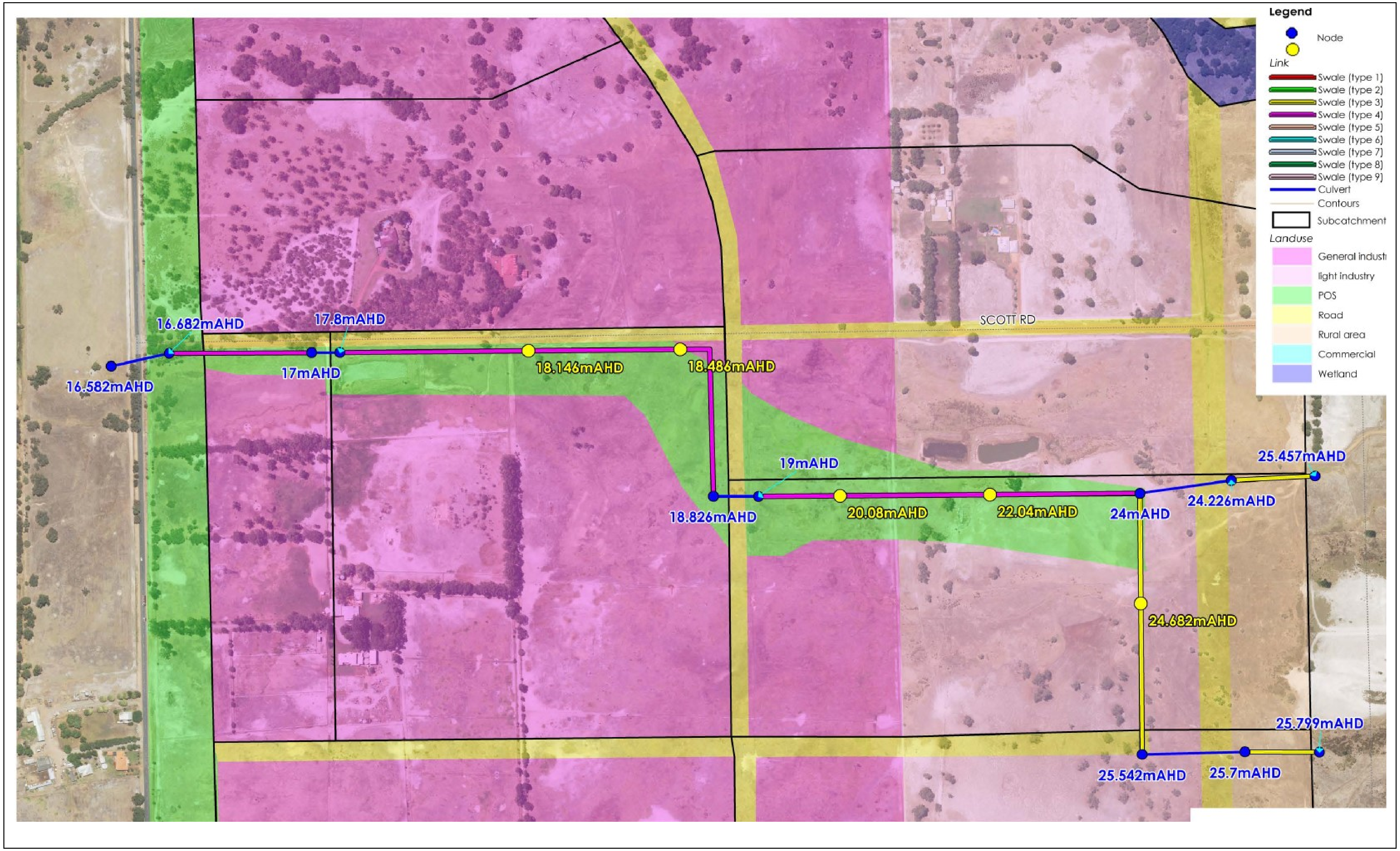


Figure 13 Critical swale inverts – central portion

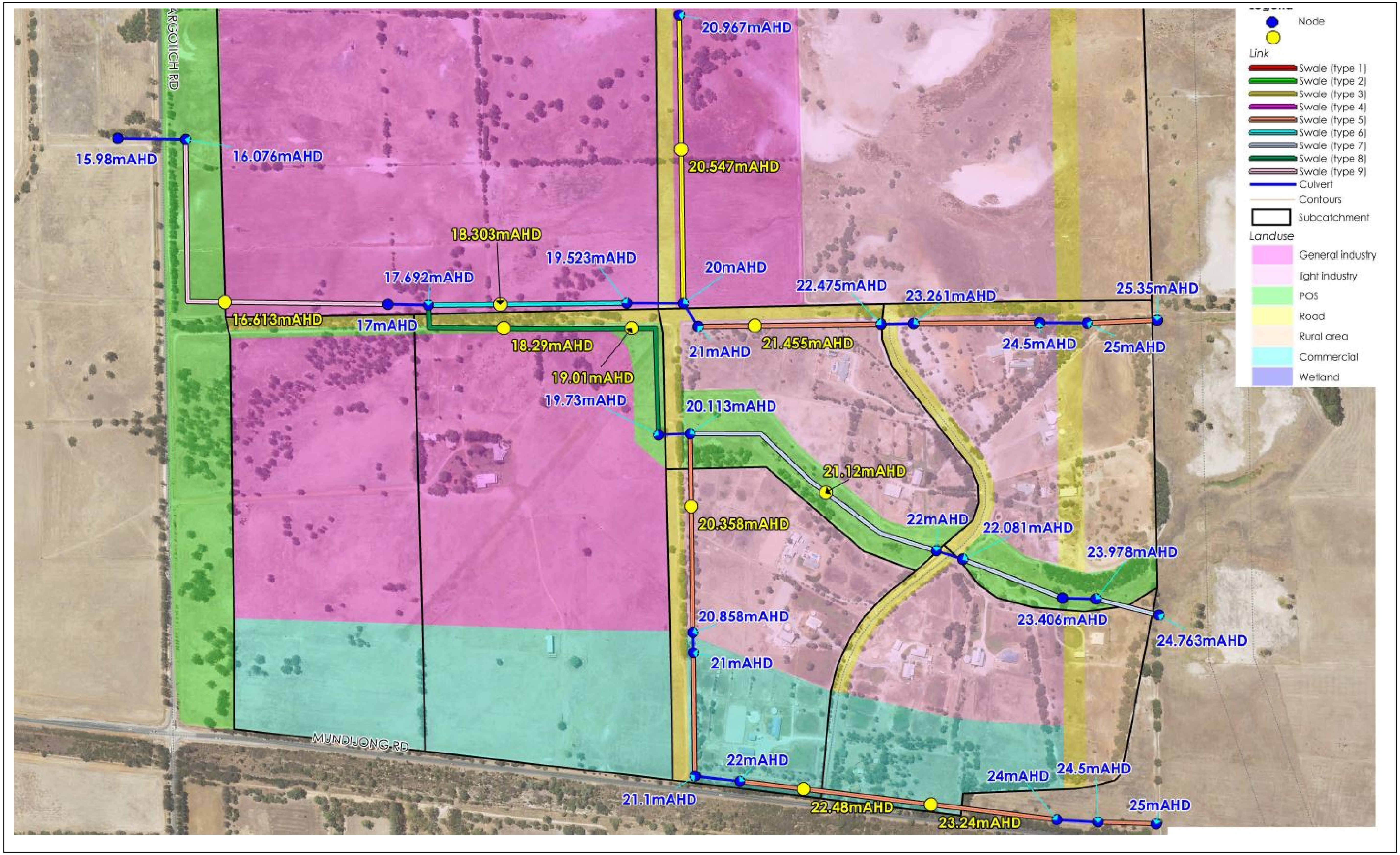


Figure 14 Critical Swale Inverts – southern portion

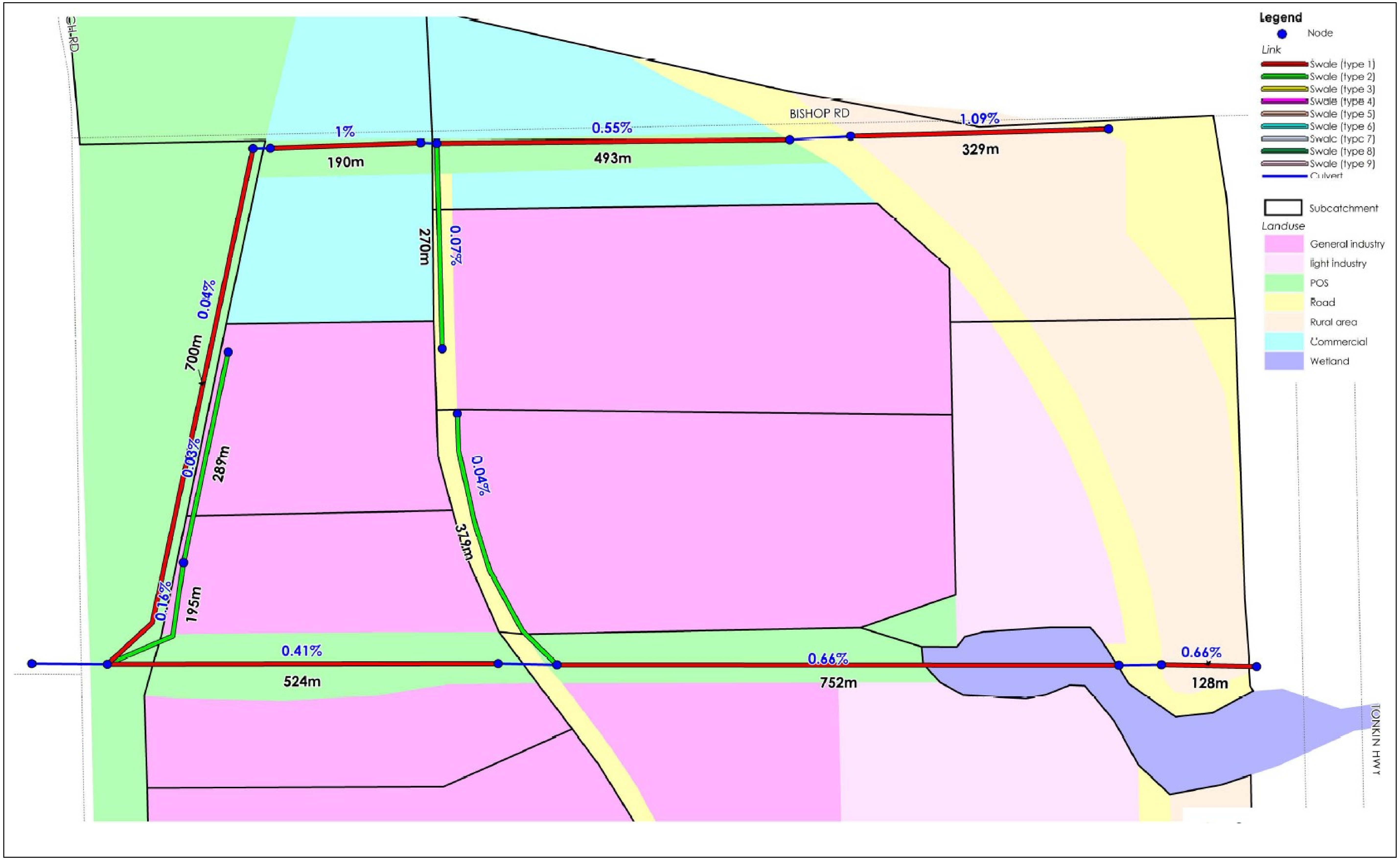


Figure 15 Swale longitudinal grades – northern portion

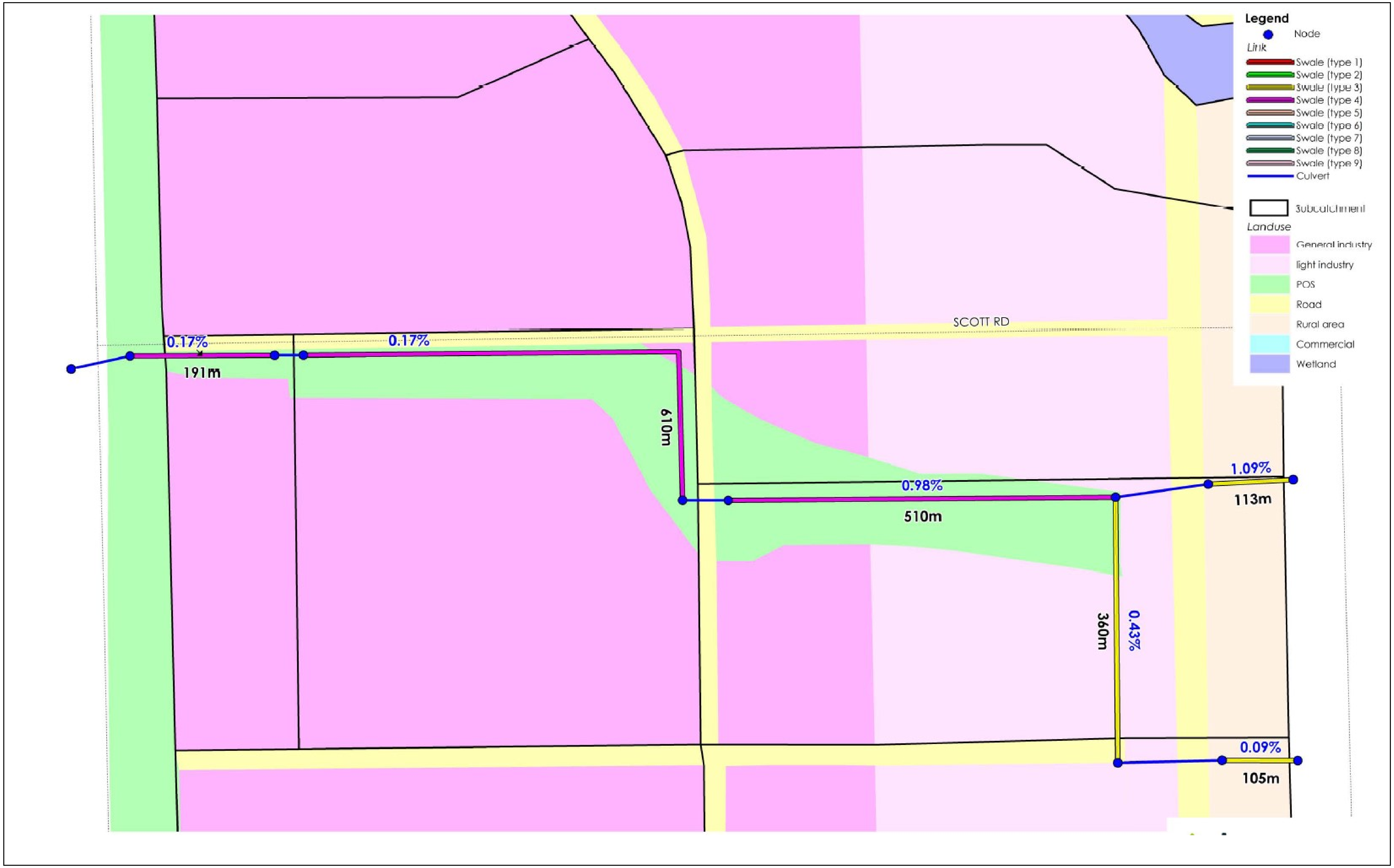


Figure 16 Swale longitudinal grades – central potion

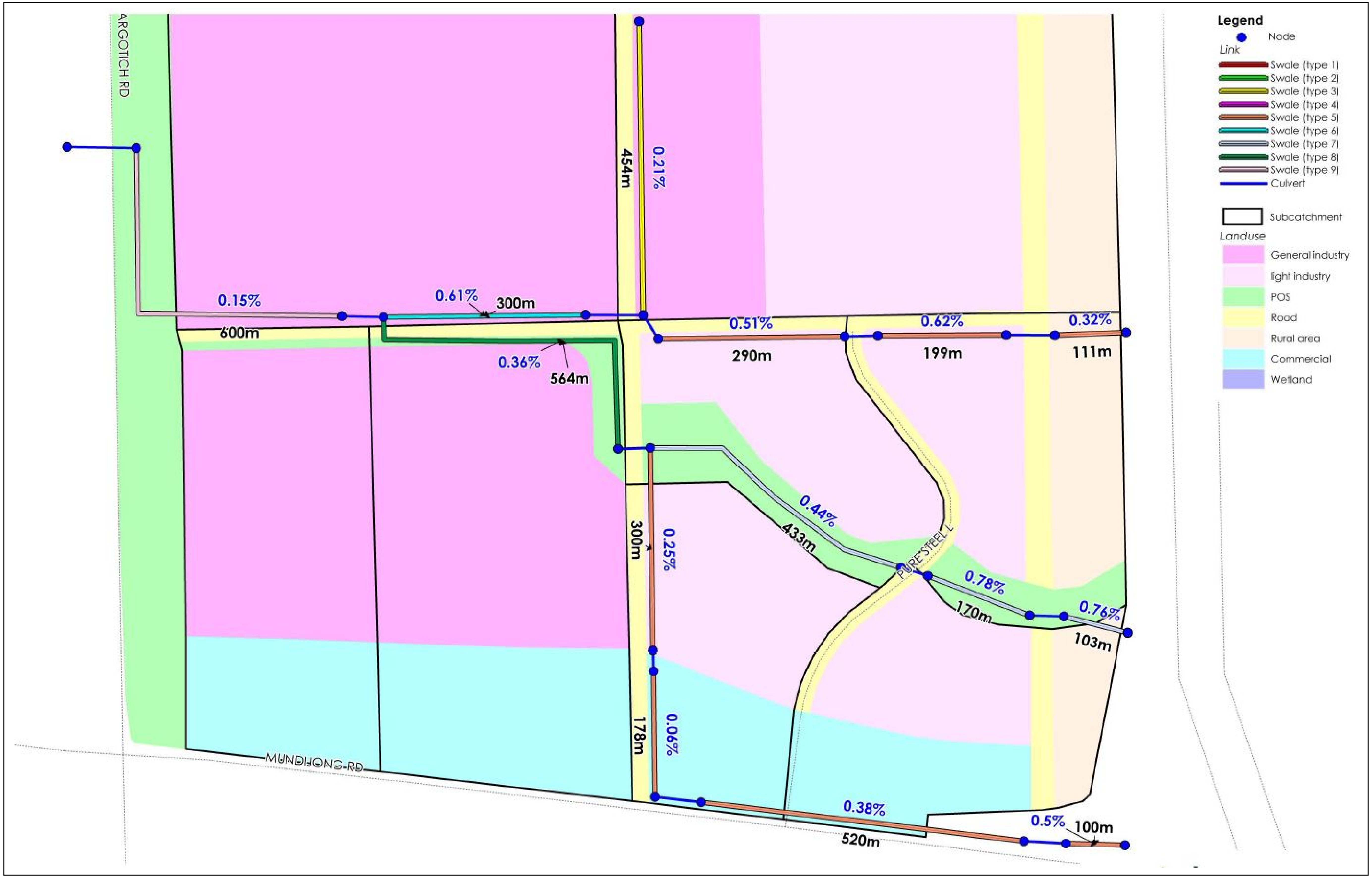


Figure 17 Swale longitudinal grades – southern portion

9.2 DRAINAGE MANAGEMENT STRATEGY – 10% AEP

The drainage management system for the subject land is to be designed to manage the 10% AEP utilising pipe, swale and detention basin systems with controlled outlets. The objective of the drainage systems in the 10%AEP is to release flows from the subject land at the predevelopment rate. This is to be achieved through storage and controlled outlet structures. The drainage system is to be designed to slow the rate of water flow, allow for partial infiltration of water on-site, and control discharged water out of the development at pre-development rates to the Oaklands Drain.

LOT MANAGEMENT

In the 10%AEP, the flows will be directed to the on lot storage devices, including those used in the 1EY scenario for treatment. This water is to be stored and infiltrated into the lots fill/insitu soils, where a portion of it may enter the subsoil network for discharge to the road swale network.

ROAD RESERVE MANAGEMENT

As existing drainage lines are not well defined, indicative major drainage lines/swales will be realigned post development. They are to predominately be located along road edges. The major systems will also be incorporated into MUC. Adequate sized swales to carry 10% AEP external inflows in addition with 10% AEP produced from the subject lands roads have been modelled for the currently proposed road layout. These swales vary in size, depending on their need to carry external flows and the size of the internal catchment feeding them. The location of the swales can be seen in Figure 19 and 20 and the swale sizes can be seen in Figure 18.

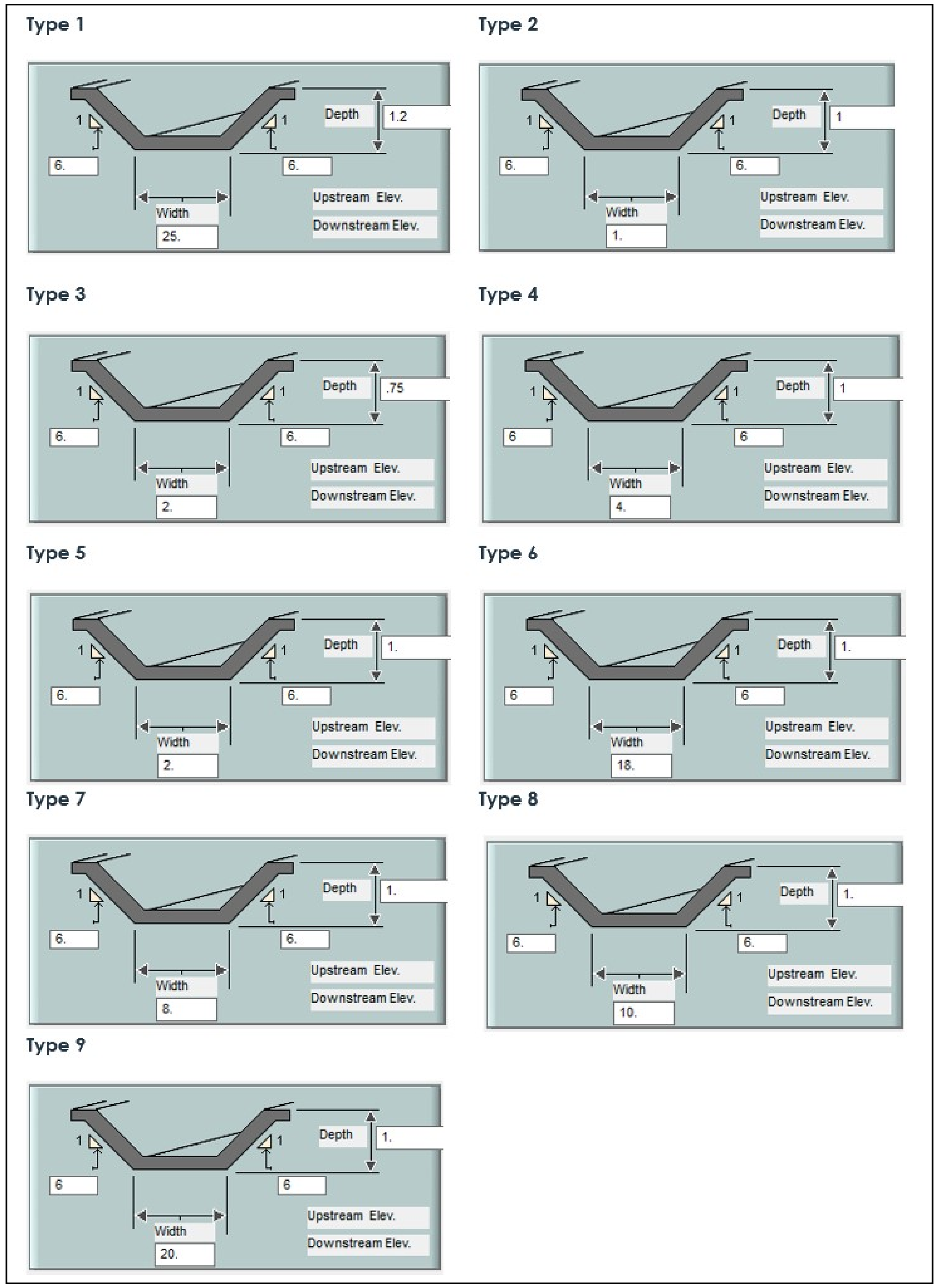
In addition to the lot storage to maintain pre-development flow rates, the modelling also shows the requirement of additional storage for external and internal inflows to maintain pre-development flow rates at the final outlets. Table 6 shows summary of storage requirement to maintain pre-development flow rates which will be refined in later stages of design. This includes the existing pre development storage on the subject land plus the extra generated as part of changing the land use from rural to industrial.

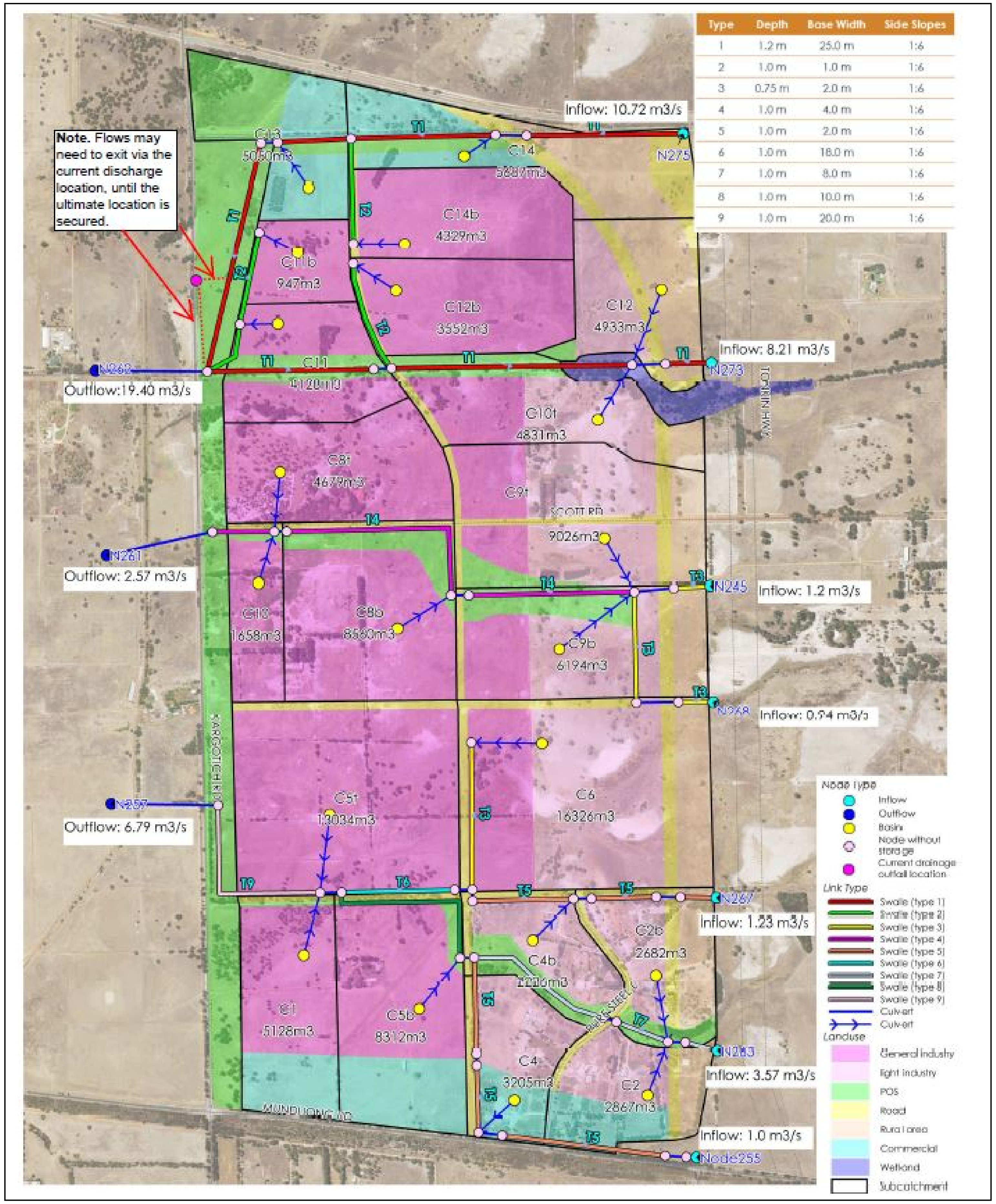
A comparison of the pre and post development modelled flow rates for the 10%AEP can be seen in Table 5.

Stormwater that infiltrates to the groundwater during short term 10% AEP events is likely to only have minimal effect on the flood peak. However, during longer duration storms, especially during peak groundwater level periods, expressions through seepage into the perforated sub-soil pipe system may occur. If expressions do occur, they may extend the period of time that water will continue to move through the sub-soil pipe network. To be conservative, this groundwater seepage effect has been modelled as a 300mm pipe discharge from each subcatchment.

It is not an objective of managing 10%AEP to treat runoff for quality, but the bio retention units and swale vegetation would allow for trapping and settling of suspended sediments, especially after the flood peak has passed. This is due to the slowing of water near the surfaces of the swales from the in-stream and bank vegetation, and the residence time.

Figure 18 Typical cross section of swale types





Type	Depth	Base Width	Side Slopes
1	1.2 m	25.0 m	1:6
2	1.0 m	1.0 m	1:6
3	0.75 m	2.0 m	1:6
4	1.0 m	4.0 m	1:6
5	1.0 m	2.0 m	1:6
6	1.0 m	18.0 m	1:6
7	1.0 m	8.0 m	1:6
8	1.0 m	10.0 m	1:6
9	1.0 m	20.0 m	1:6

Figure 19 10% AEP Post Development Stormwater Management

9.3 DRAINAGE MANAGEMENT STRATEGY – 1% AEP

The development is to be designed to safely convey the 1%AEP flood so that impacts on infrastructure, and the environment are minimised while also managing people's safety. All road and lots levels are to be designed to maintain a minimum 300mm separation clearance between finished floor levels and the internal 1% AEP flood levels, excluding the major swale network.

For the swale network that incorporate flows from upstream, a minimum 500mm separation clearance will also be required to finished floor levels. This 500mm of separation is also to apply to the flood waters generated by back flooding of the Oakland Drain. Furthermore, all lots are to be a minimum of 500mm above the top of the western levee bank of the Oaklands Main Drain, with the level to be determined as the section of levee bank that adjoins the corresponding area of development.

The 1% AEP's runoff is to predominantly be conveyed via the road reserves and drainage pipes to the swale network and MUC. Here water will fill the swale structure as well as flood out across the surrounding MUC, with potentially some flooding of the adjoining road. Some roads would be expected to partially flood however they should remain serviceable for emergency vehicles.

This network also holds the flood waters so that they are released at predevelopment rates for each of the 3 main catchments. Each swale is controlled by an orifice sized to hold back the flood waters generated. The required storage for each sub catchment to achieve this can be seen in Table 5. A comparison of the pre and post development flows, is shown in Table 5. These storages are all to be achieved prior to the North south green corridor along the western boundary. This is because this green corridor has been set aside to accommodate floodplain storage from Oakland Drain.

This swale network and the MUC/Roads along with the major ecological corridor on the western boundary will assist with holding the required flood plain storage volumes, to minimise downstream flood impacts.

As part of the DWMS modelling, peak runoffs were modelled using DRAINS software, with the rational method, for the critical time of concentration including 1 in 100 years' external inflows. This modelling was then refined in the LWMS using ARR 2016 data and XP Storm modelling software. The drainage investigation modelled that utilisation of the 1 in 1 year 1 hour lot storage in addition with 10% AEP storage on lots within sub catchments will require additional storage to maintain the 1% AEP outflow rates. These storage requirements within the swale networks of each subcatchment are shown in Table 6.

Detail analysis of existing capacity of outlets at Kargotich Road, including any potential upgrades is to be carried out in the detail design phase. The trigger will be related to the individual culvert that is affected by development in the corresponding upstream catchment that feed the culvert. This is to include designing a suitable connection from the culvert to the Oakland Drain, at the time of moving any culverts under Kargotich Road. The presence of the North South MUC for flood storage provides significant area in which the swale system can be redirected to best line up with landforms and land uses to the west of Kargotich Road. The culverts under Kargotich road should not act as the actual control point for flows from the development of upstream. All flows are to be controlled prior to entering the North south MUC. These diameter of the culverts under Kargotich Rd are also not to be changed.

The northern catchment C13 is to be subject to detailed design to determine the actual final area of development. Should sufficient flood plain storage be achieved south of Bishop Road then the full area may be able to be developed. This is to be determined as part of the relevant UWMP, noting that without detailed analysis the default will be that the current power line easement will the limit of development.

Floodplain storage for Oakland Drain

Along the western side of the development, a large area has been set aside to provide floodplain storage, predominately for the back flooding of the Oakland Drain. The original area of floodplain storage has been rationalised to this corridor, with the edge of the storage area being set as the western edge of the current powerline easement. As such the exact width of the storage area varies. Generally the area is between 60-70m wide from Mundijong road through to Leipold Road. From here the area expands eastward through to Bishop Road, with the depth increasing to approximately 140m wide. Subject to future detailed design and flood modelling, there may be options to utilise some of the most northern area for development.

Landuses that are compatible with flooding may be utilised in this floodplain storage area. The current proposed use is for the land to be set aside for ecological enhancement uses and potentially be used as offsets for other areas. And landuse must not lift the current level of the ground or have structures which take away flood storage.

Table 5 Modelled outflows from major catchments

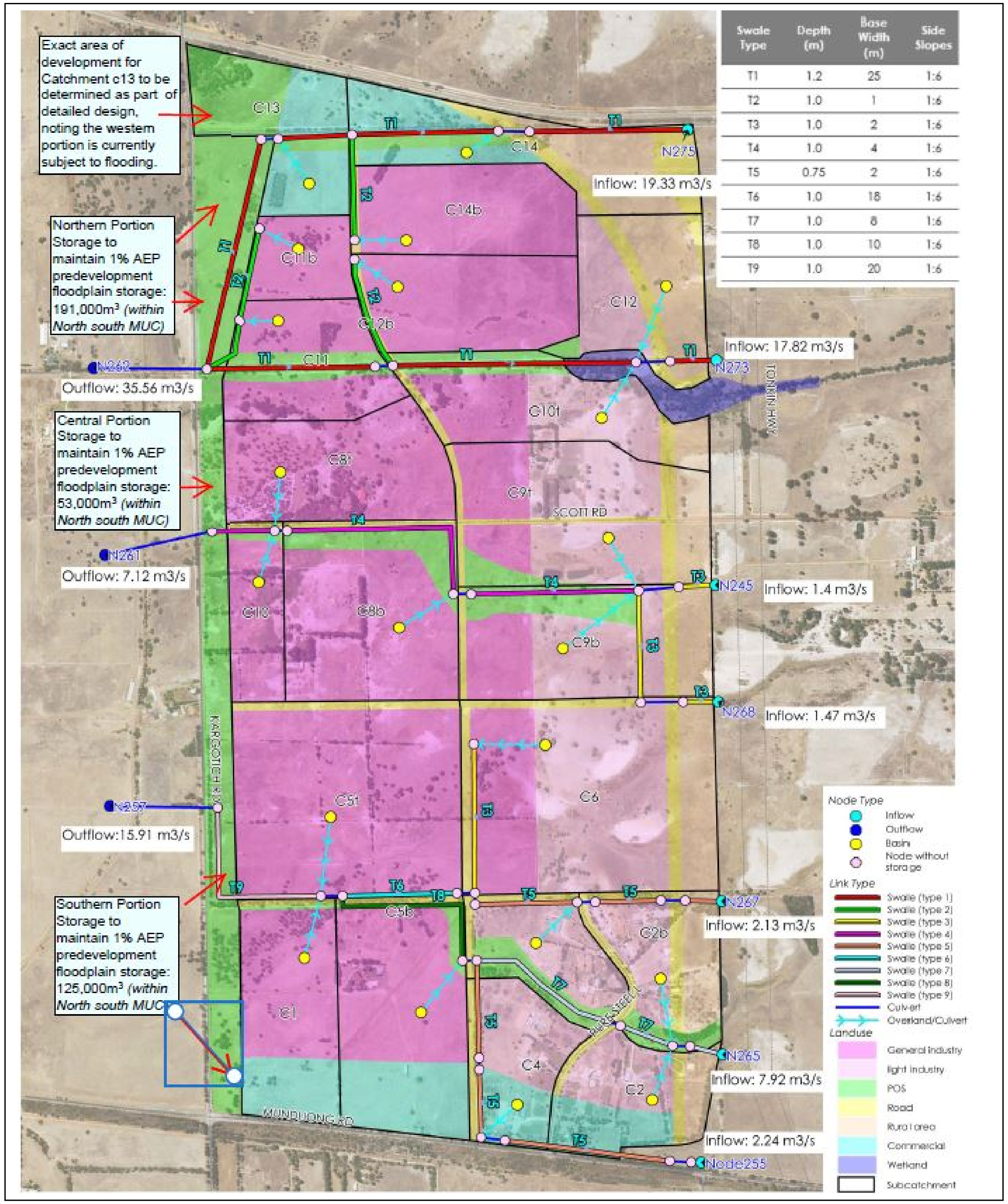
Catchment	Pre-development 10% AEP Outflow	Post-development 10% AEP Outflow	Pre-development 1% AEP Outflow	Post-development 1% AEP Outflow
1	18.47 m^3/s	19.40 m^3/s	36.59 m^3/s	35.56 m^3/s
2	5.23 m^3/s	2.57 m^3/s	8.79 m^3/s	7.12 m^3/s
3	6.99 m^3/s	6.79 m^3/s	16.80 m^3/s	15.91 m^3/s

Table 6 Sub Catchment storage requirements

Sub- Catchment	Sub-Catchment Size (ha)	Storage Volume (m^3)
1	20.06	5,127 m^3
2	15.54	2,866 m^3
2b	16.52	2,682 m^3
4	13.87	3,205 m^3
4b	13.64	2,226 m^3
5b	28.44	8,312 m^3
5t	41.75	13,034 m^3
6	46.31	16,014 m^3
8b	29.30	8,560 m^3
8t	22.16	4,679 m^3
9b	26.81	6,194 m^3
9t	32.78	9,026 m^3
10	9.18	1,658 m^3
10t	21.17	4,831 m^3
11	17.07	4,128 m^3
11b	8.01	947 m^3
12	18.46	4,933 m^3
12b	19.26	3,552 m^3
13	17.06	5,050 m^3
14	23.37	5,687 m^3
14b	18.79	4,329 m^3
TOTAL		**117,352 m^3**

Table 7 Floodplain Storage requirements for Oakland Drain and overall Catchment

Major Catchment	Floodplain Storage within North-South MUC (m^3)
1	191,000
2	59,000
3	125,000



Swale Type	Depth (m)	Base Width (m)	Side Slopes
T1	1.2	25	1:6
T2	1.0	1	1:6
T3	1.0	2	1:6
T4	1.0	4	1:6
T5	0.75	2	1:6
T6	1.0	18	1:6
T7	1.0	8	1:6
T8	1.0	10	1:6
T9	1.0	20	1:6

Figure 20 1%AEP Stormwater and Flood Management Plan

10 WATER QUALITY MANAGEMENT

The development will utilise a range of best management practices to manage water quality across the site. The major practice will be the implementation of best practice water sensitive designs to manage stormwater up to 1EY. Most of the other management practices will involve minimising the quantity of nutrients added to the surface and groundwater within the development. The development designs should concentrate on managing practices on lots for effluent disposal and stormwater runoff.

CONSTRUCTION CONTROLS

A key aspect of managing water quality for the development will be implementing suitable management strategies during the construction of the subdivision. At the subdivision stage of development there will be a requirement to prepare and implement erosion and sediment control plans. Management options should also focus on minimising potential pollutants during the construction phase. The management options may include:

- assessment of erosion risks;
- stabilisation of stock piles;
- minimise the exposure times for disturbed areas;
- sediment curtains, fences, and filters at inlets and other control points;
- cut off drains;
- temporary sediment basins;
- stone mattresses; and
- hydro-mulching and interim plantings.

ON-SITE LOT TREATMENT

Individual lot owners will provide attenuation and treatment options for the 1EY runoff. The on-site flows can be detained and treated with a variety of methods including shallow landscaped bioretention basins for hardstand runoff, rainwater tanks for roof runoff and on-site soak wells for areas unlikely to receive polluted runoff.

The most effective method in implementing best practice in industrial precincts is to ensure that pollution sourced from work areas does not discharge into the stormwater infrastructure. Practices that land managers and owners can undertake involve roofing work areas, directing wash-down water to storage or onsite effluent systems, and controlling activities undertaken in areas that link with the stormwater infrastructure. The guiding principles and practices in the construction and management of industrial lots should be an intention to separate areas subject to pollutants and contaminants from paths that would transport water to the stormwater infrastructure. The developer will encourage structural separation, and the local government agencies will be encouraged to ensure elements are included for building application approvals.

Furthermore facilities will be encouraged to be constructed to ensure that contaminated wastewater is separate from uncontaminated wastewater, such as clean stormwater or cooling water, and sewerage.

EDUCATION

Education of employees is very important to ensure that they are knowledgeable about the different systems and potential impacts on the environment that their workplace could have. It is essential for the management of water quality within the subject land that employees are educated on the following:

- The difference between the stormwater and on-site treatment systems for each business;
- Do not sweep or dispose of litter or waste into gutters or drains, and keep the footpath, gutter and outside areas near their business free of litter. This includes providing adequate refuse storage for litter and cigarette butts;
- Where possible, all waste skips and bins should be stored in a designated area with a roof and surrounded by toe walls to prevent any leakage entering the stormwater system;
- Lids on bins and skips should be kept closed to stop loose litter being blown away. This also stops rain getting in which can wash oils, solvents and chemicals out of rags and into the stormwater;
- Spills from loading and unloading operations are a common source of stormwater pollution. Where possible conduct all activities with the potential to pollute water (e.g. loading and unloading, transfer of materials) within roofed and bunded areas or indoors;
- Storage of potential pollutants, including precautions in case of leakages, should be in secured areas. The storage may require roofing, a physical barrier for leaks to leave the storage (e.g. a lip at openings) and possibly a bund if appropriate.
- When moving, pumping, loading or unloading liquids make sure that a spill kit is available for use in case of a spill; and
- How to handle materials to reduce waste and prevent spills.

CONTAMINANT RISK MANAGEMENT

The greatest risk to contamination of the natural environment from the subdivision will be industrial waste which can include petroleum hydrocarbons, heavy metals, surfactants, toxins and/or salts (DoW, 2009b). Details in regards to wastewater management, including contamination risks have been documented in the Section 13 Water Supply & Wastewater Management.

As previously mentioned, structural separation and education will be paramount to minimising the risks of contamination from any of the lots within the subdivision. The Western Australian Business and Environment Manual developed by the WA Chamber of Commerce and Industry and the Centre of Excellence in Cleaner Production provides an online resource. The manual is designed to assist WA businesses to successfully manage their environmental issues together with their business operations. Importantly it provides information relating to environmental legislative requirements and obligations at local, State and Commonwealth level for a range of industry practices.

Statutory requirements, approvals and managing agencies are outlined in environmental guidelines, codes of practice and Water Quality Protection Notes for a range of businesses and activities in Western Australia. Generally the Department of Environment and Conservation, Department of Water and Department of Health are the three major State government agencies involved in waste management and contaminated sites.

Contingency plans and emergency responses should also be developed where appropriate for the industry on the lot. The DoW's WQPN 10: Contaminant Spills – Emergency Response is a useful reference for lot owners.

BIORETENTION GARDENS

At the time of development, bioretention gardens and swales will be constructed within the road reserves of the development. On road systems that don't have an adjoining swale, bioretention gardens are to be constructed and sized to 2% of each equivalent impervious feeding catchment. The bioretention gardens will be designed and constructed according to the latest FAWB Adoption Guidelines for Filter Media in Biofiltration Systems and the Stormwater Management Manual for WA design guidelines, and in consultation with the Shire engineers.

The bioretention garden will be planted with appropriate native species, which should only require irrigation during the initial 2 to 3 years of establishment, depending on the seasons. They should require no fertiliser application and irrigation demands should be met by stormwater alone, after this initial establishment period, with possible subsequent watering only in drier years. The gardens will be designed to assist in the removal of nutrients and sediments from stormwater before the water reaches the groundwater. The indicative design for the gardens composes a filter media of amended soils to 500mm below the surface, with an average particle size of 0.5mm. A plastic root barrier will also be incorporated to provide a vertical separation layer from surrounding soils to assist in maintaining adequate moisture levels for species planted in the gardens and assist with nutrient reduction. The plants will also assist with nutrient absorption because of the surface area provided by their roots for the formation of bio-films and nutrient uptake. Where practical, saturated zones should also be incorporated in the base of the bioretention gardens.

LANDSCAPING

Landscaping within private lots and public areas (including road reserves and drainage reserves) is to have a focus on utilising native species that will require minimal watering and fertiliser application. By implementing this strategy, the landscaping will not contribute to the pollution of the groundwater or surface water generated on the site. Furthermore, by utilising native plants with a high ability to absorb excess nutrients, the landscaping can help remove nutrients within the swale and basin systems, as well as take up nutrients from the groundwater. This can help reduce the overall load of nutrients leaving the site.

MONOTIORING

Pre and post development monitoring of surface and groundwater quality is to be undertaken.

The pre development monitoring will provide a clear picture of the site and the quality of water flowing across the site and through the groundwater. This can be used to set a base line for future monitoring as well as assist with developing any tailored treatment mechanisms to improve the existing and future water quality.

The extent and details of the monitoring programs is dependent on the treatment trains employed throughout the development. Detailed drainage plans for the development will be constructed at the relevant subdivision stage, and from these detailed plans post development surface quality monitoring requirements will be determined in consultation with DWER and the Local Government. It is expected that the surface water quality samples would be required at all dispersal points and typically event based.

The water quality target of 0.1 mg/L for total phosphorus and 1.0 mg/L for total nitrogen are the targets that have been adopted in the Peel-Harvey water quality improvement plan, and are considered appropriate guidelines for new industrial areas. It should be noted however that the current agricultural land use is likely to contribute legacy nutrients above this level for a significant portion of time during and after the land use is changed to industrial. For this reason the main focus for each sub catchment will be to see a continual downgradient in the level of nitrogen and phosphorus recorded. Further monitoring is to take this into account and set current benchmarks from which future post development water quality should be measured against.

Further investigations will be required at each Urban Water Management Plan stages to determine refined monitoring requirements.

11 WATER DEPENDENT ECOSYSTEMS MANAGEMENT

The main water dependent ecosystems (WDE) influenced directly by the development of the subject land are the CC wetland 14945 and the degraded waterways that traverse the subject land. There are also a number of downstream and nearby significant WDE that have the potential to be influenced by water management on the subject land. Stormwater and groundwater will be managed so that the significant WDE areas retain hydrologic regimes comparable to pre-development. The water quality of the flows into these ecosystems will be managed through the treatment of surface and groundwater. Section 10 of this LWMS details the water quality management for the development. Protection of the ecological functions of the receiving natural environments from the development is detailed below, and visually portrayed in Figure 21 and 22.

MANJEDAL BROOK – MID NORTHERN ECOLOGICAL LINKAGE,

The Manjedal Brook and its associated Conservation Category wetland will be protected through the use of appropriate buffers and restoration works within the wetland and its associated buffer. Appropriate buffers and works are outlined in more detail in the Wetland Management Report within Appendix B. As a summary, the wetland itself is to be revegetated with understorey species to complement the existing overstorey native vegetation. The surrounding buffer will also be revegetated, with these species grading from riparian species to dryland species as they move up and away from the wetland area. These revegetation works will take place once good weed control has been achieved.

To the north of the wetland, the existing degraded channel may be diverted. This is to assist with brining the channel into the Mid Northern Ecological linkage that is to traverse the unmade Leiopold road reserve. It will also assist with providing a suitable buffer between the main channel and the future industrial development to the north. The indicative realignment can be seen in Figure 21 and 22.

Erosion control at key locations within the current main channel is also to be undertaken.

It is proposed that the wetland will be accessible by pedestrians, however general vehicles will be excluded. Appropriate gates systems will be installed to allow for emergency and maintenance vehicles, who's access throughout the site is to be via a perimeter access track. The fence system will also assist with minimising litter entering the wetland.

The length of Manjedal Brook that traverses the site after the recognised Conservation Category wetland area will be enhanced within the MUC along the unmade Leiopold road reserve. As part of this process the waterway will be configured to act as a stable waterway and will be planted out with appropriate native species. This will enhance the ecological functioning of the waterway compared to its current characteristics of being a weedy drain with erosion issues and limited native species. The waterway and surrounding area will be designated as an ecological linkage, providing a corridor from Oakland Drain to the Manjedal Brook system to the east of the subject land.

SOUTHERN AND MIDDLE ECOLOGICAL LINKAGES

To further enhance the ecological connectivity of the district, ecological linkages will be developed to accommodate the 2 main drainage lines to the south of Manjedal Brook. These systems are effectively low flow, ephemeral constructed drains and currently have little ecological functioning. The most southern waterway will keep its current course for its eastern portion, before being realigned along Sparkman Road. The middle drain will be aligned to the future proposed road network, before being aligned to the south of the current Scott Road. This realignment will be composed of a vegetated swale within a MUC. It will be planted and landscaped in a similar fashion to the far northern ecological linkages.

FAR NORTHERN ECOLOGICAL LINKAGE

To further enhance the ecological connectivity of the district, the major drainage swale that is to be constructed along Bishop Road, will also be constructed so that it acts as a riparian ecological linkage. This swale replaces the degraded drain that occurs just to the south of Bishop Road. It will be planted and landscaped in a similar fashion to the southern ecological linkage.

BIORETENTION SYSTEMS

The bioretention systems within road reserves and on private lots will also act as ephemeral wetlands and provide habitat values for fauna, especially avifauna and herpetofauna. This will be due to their use of native species for the plantings and the seasonal nature of their water regime, which will mimic small wetland depressions, commonly see on the Swan Coastal Plain.

GROUNDWATER TREATMENT

Groundwater captured by the subsoil system will be directed to the planted swales. These swales will provide an opportunity for the treatment of groundwater discharged to them. Furthermore, the groundwater will assist with the growth of the plants within the base of the swale, helping to increase the wetland/waterway attributes of the swale system. This treatment of groundwater will also assist with improving the quality of water prior to it leaving the site and entering downstream sensitive environments.

DOWNSTREAM WDE

The downstream WDE's will be protected primarily through the management of water on the site. This will include the release of stormwater at pre development rates up to the 1%AEP. Stormwater and groundwater will also be treated so that the water leaving the site will be of an adequate quality to support the ecological functioning of the downstream ecosystems. See Section 10 for more details on water quality management.

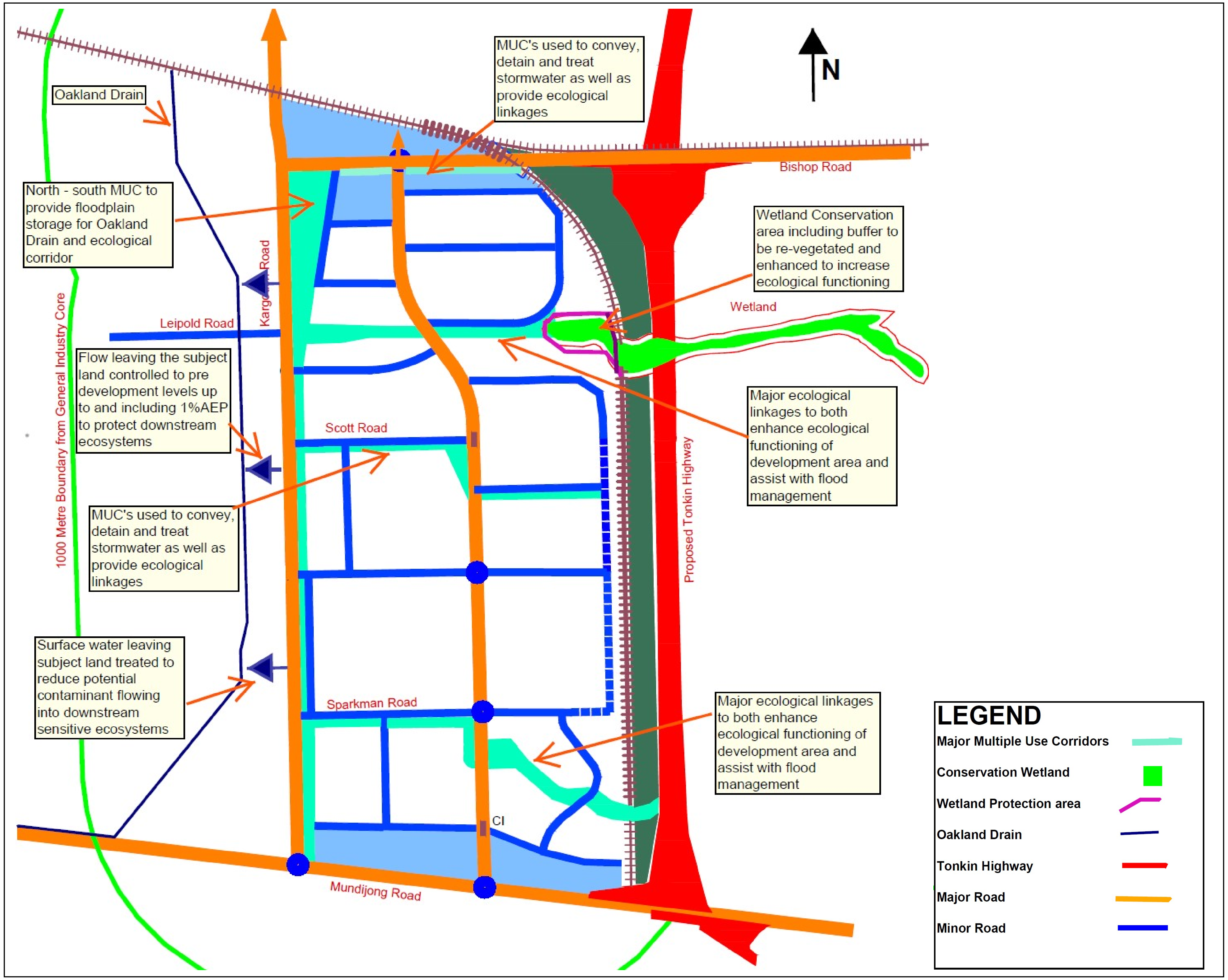


Figure 21 Water Dependent Ecosystem Management

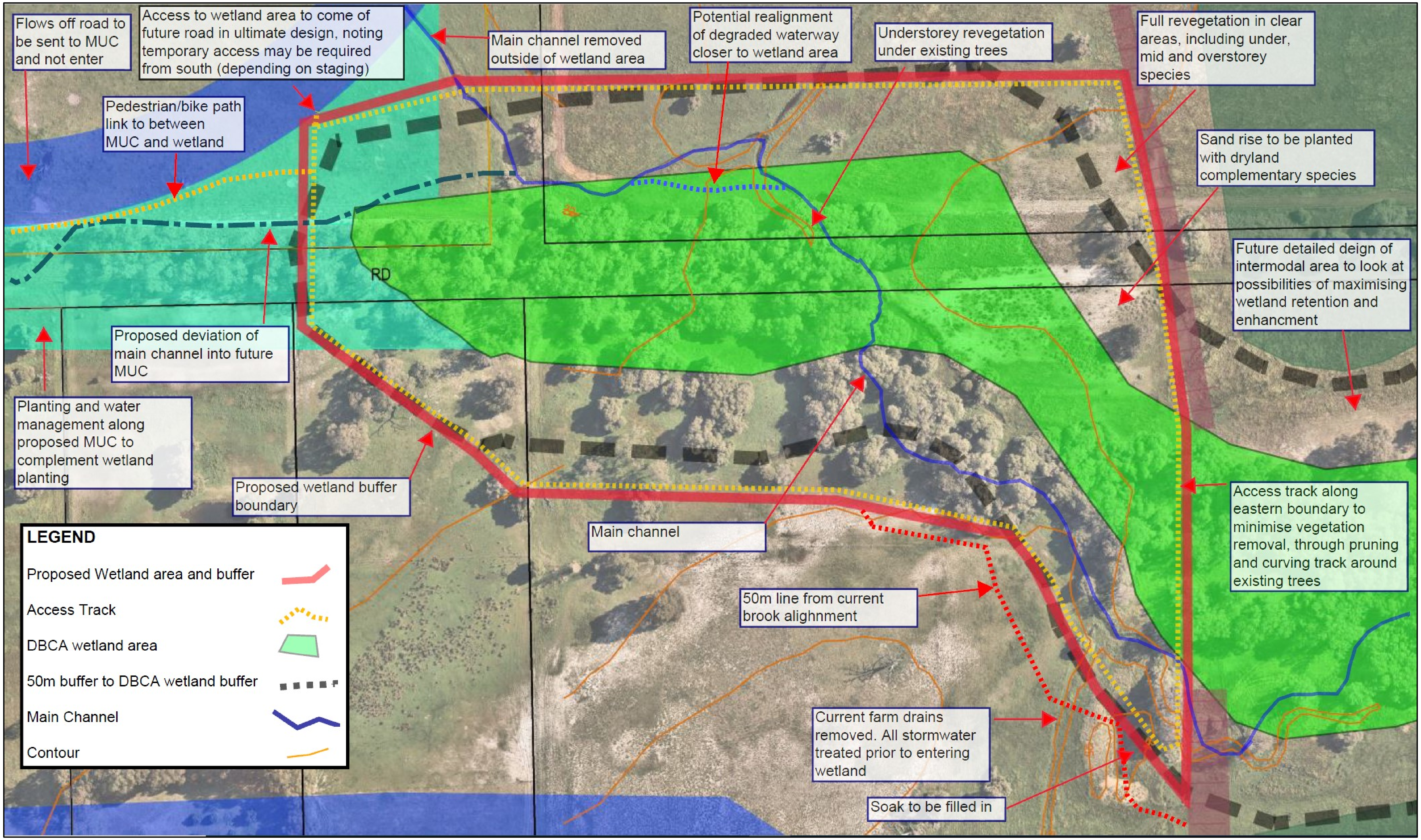


Figure 22 Wetland Management Plan

12 GROUNDWATER MANAGEMENT

The focus of groundwater management for the development area is to maintain groundwater as close as possible to existing average maximum levels, which has been defined as the CGL for the site, while maintaining adequate separation from infrastructure. There may be some modification of groundwater levels within the site; however, the areas that feed the Conservation category wetland on Manjedal Brook will be maintained at levels that support key wetland functions.

Furthermore groundwater will be managed to achieve a high water quality.

Opportunities are also to be explored to utilise excess groundwater within the superficial aquifer that is generated due to the lower evapotranspiration of the site post development.

INFRASTRUCTURE SEPARATION

Appropriate separation between lot levels and the CGL will be achieved across the entire subject land. The separation will be achieved through three main methods: use of porous clean fill where necessary; open swales and sub-soil pipes.

The distance between sub-soil pipes will be determined by the permeability of the soil within that section of the development. Within the proposed 2ha lots, there may be a requirement for both boundary and internal subsoil within each lot, so as to minimise mounding. These subsoil systems are to discharge to the roadside swales and drainage network. The swales and roadside subsoil system will also control groundwater throughout the development area.

The swales will generally be set at the CGL level and will assist in groundwater control. There may be minor modifications at a local lovel in the order of 200-300mm, so as to achieve suitable longitudinal grades on the swales. Subsoil drains would also discharge at just above the CGL level to the swales to ensure the subsoils remain free draining between storm events. Indicative subsoil inverts, either from lots or side roads, into the major swale network are shown in Figure 23.

With this configuration, mounding of groundwater can be kept to approximately 0.4m. An indicative lot layout showing how groundwater levels are to be controlled can be seen in Figure 10.

By maintaining the groundwater at a level similar to the current average maximum levels, the development will have minimal impact on the groundwater dependent ecosystems that exist on the subject land. Groundwater will still be fed into the wetland systems and the downstream Oaklands Main Drain.

FILL MINIMISATION

Certain areas of industrial lots require less fill to function without being impacted upon, or adversely impacting the groundwater. These are areas that don't contain significant infrastructure such as buildings or soakwells. These areas of lower fill requirements include, parking areas, laydown areas and general vehicle movement areas. The drainage basin areas are also able to utilise less fill, provided they are designed to have their bases close to the groundwater and are near a subsoil network. By being close to the groundwater, the basins can actually function similar to an ephemeral wetland.

The building envelopes should require a maximum of 1.0m of fill/separation to the groundwater. The surrounding lot area may only require 0.3m of fill above the maximum groundwater mound (in the middle of the lot). For the spacing of subsoils suggested, this equates to an average fill height of 0.7m (assuming the groundwater is traditionally at the pre development soil surface). On the edges of the lot, the depth to groundwater will be less, tending to be closer to 0.6m -0.7m. These are the areas where stormwater basins/soakwells and buildings etc should preferentially be located.

Porous clean fill will be used where necessary to achieve the required separation. Any fill of imported sands will require compaction to relevant standards. The sand fill will be required to have a high permeability to allow water to easily infiltrate down and into the original soil layer.

A diagrammatic representation of a typical 2 hectare industrial lot, with the boundary subsoil network can be seen in Figure 10. Internal subsoil layouts are to be determined as part of the UWMP and Building Application.

LOWERING OF GROUNDWATER LEVELS

Minor lowering of groundwater to below the existing annual maximum level can assist with minimising fill. This may be an option for areas away from significant natural environments such as the Manjedal Brook and associated wetlands. Lowering would be in the order of 200mm-300mm below the maximum level and mainly be in relation to achieving suitable grades on the swales, to facilitate throughflow.

The risk of Acid Sulphate Soils will need to be carefully considered as well, although if the levels are only slightly reduced below the maximum and don't impact the minimum levels, then there is unlikely to be significant impact on both the production of ASS and the mobilisation of acidic groundwater and pollutants mobilised by the increase in acidity. The potential to lower groundwater levels will be limited on the subject land, due to the flat nature of much of the land and the invert of the existing drainage points, which currently control groundwater discharge when it is at its peak. This discharge is controlled by the existing on site drains and the swale drain along the boundary roads.

Due to these limitations, the calculations of fill required for the site have assumed that the AAMGL will be very similar to the post development CGL. The CGL has been assumed to be at the natural surface of the site. As detailed design is undertaken, there may be opportunities for localised lowering of the groundwater to a small degree in the order of 200-300mm.

QUALITY MANAGEMENT

Groundwater quality will be improved through the use of soil amendment products incorporated into the development's bioretention systems. This will provide treatment of all surface water runoff collected within the drainage network prior to infiltration into the groundwater. These products bind nutrients and other contaminants that are mobile within water infiltrating from the surface. Groundwater entering the swale network will also receive treatment as it traverses along it.

ASS MANAGEMENT

Subject to further investigation, the impacts of any actual ASS or potential ASS would be integrated with the works on the site through a detailed ASS Management Plan. These will be undertaken on a needs basis as part of subdivision. Deep sewers are the most likely activity to disturb ASS if any are present on the site. The current 2ha development will not include reticulated sewer, minimis ethe ASS disturbance risk. Vacuum or pressure sewer systems may be used to avoid this issue as part of future subdivision to smaller lots, subject to future detailed design. It is not expected that ASS issues will occur on-site that conventional methods cannot adequately manage.

MONITORING

Pre and post development monitoring of groundwater levels and quality will be undertaken. The extent and details of the monitoring programs is dependent on the extent and depth of fill required across the development, and any other intrusions of the development on the groundwater management. As a general direction, each area of subdivision will need to undertake detailed level monitoring for 2 seasonal peaks (assuming at least one of the seasonal peak shows water coming to the surface or at least matching previously modelled levels). These detailed levels and the invert of the discharge point into the swale network will then be used to set Controlled Groundwater Levels for each subdivision area.

Detailed earthwork and engineering plans for the development will be constructed at the relevant subdivision stages, and from these detailed plans post development groundwater levels and quality monitoring requirements will be determined in consultation with DWER and the Shire.

Monitoring of the groundwater's quality at the sub-soil discharge points and selected bores will suffice for post-development quality monitoring

PUMPING AND REUSE OF GROUNDWATER

Pumping of the superficial groundwater for potential reuse is assumed to not impact the peak groundwater level as the system may fail during critical periods of heavy rain. It may however provide an option for generally keeping the groundwater down. It can also provide a water source for use within the subject land or nearby. This usage is detailed in Section 13.

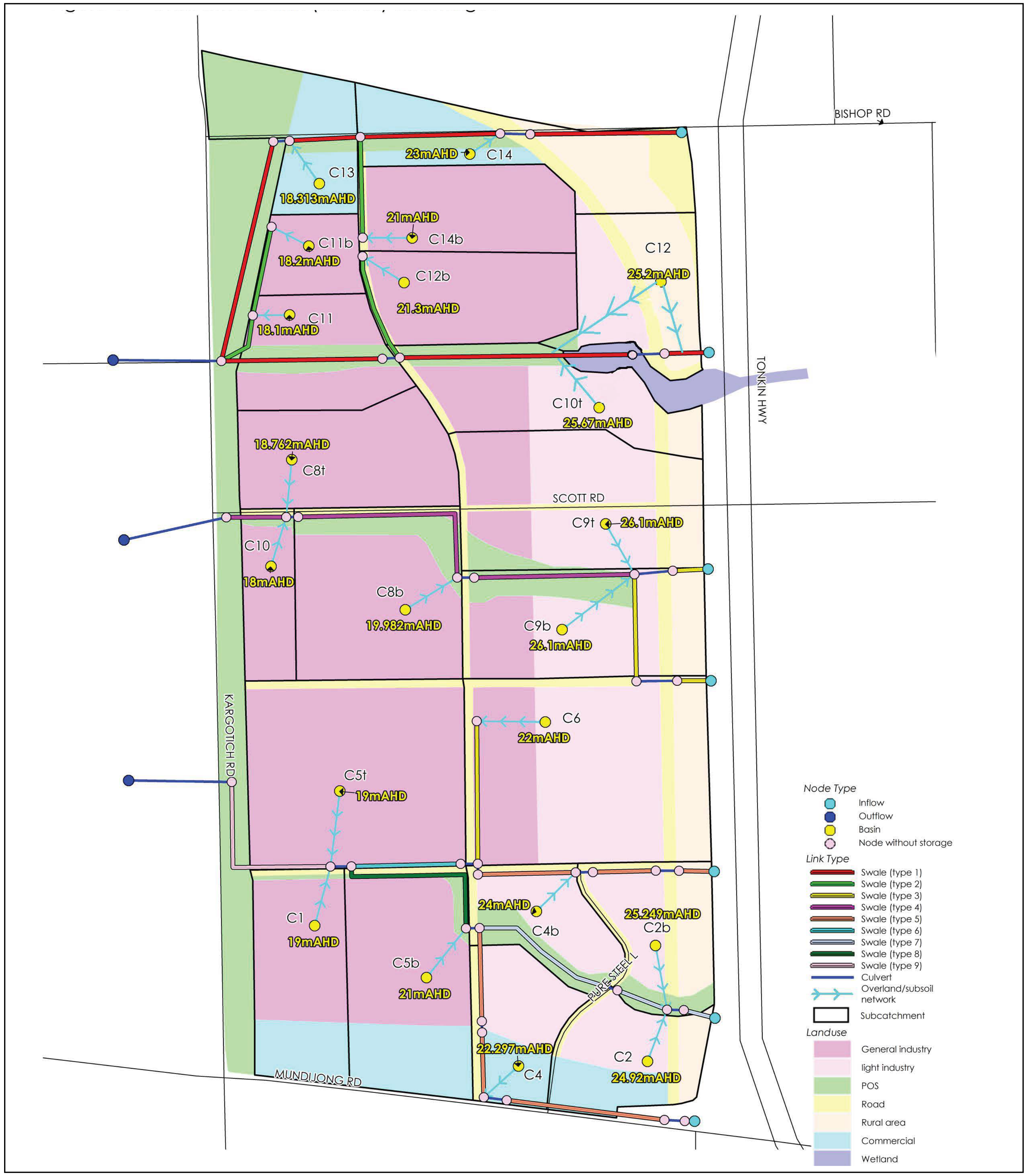


Figure 23 Indicative subsoil discharge heights along the major swale network.

13 WATER SUPPLY & WASTEWATER MANAGEMENT

13.1 WATER SUPPLY

STANDARD MAINS POTABLE

The Water Corporation has advised that potable water may be accessed from Mundijong town site. There may be limited capacity for some industrial processing. This source may be able to supply the early stages of development.

The Serpentine trunk main is located approximately 1 kilometre to the west of the investigation area. This may be accessed for potable water to source the subject land, subject to approvals from the Water Corporation. Another possibility is establishing an elevated reservoir on the scarp to supply the greater area. As part of the elevated reservoir option, it is expected that a distribution main will extend to the site with reticulation connections servicing the development. It is also likely that this distribution main will connect into the existing Mundijong network to reinforce its water supply plus service.

There will be significant capital expenses related to the supply of the area with larger volumes of standard potable water. Alternative options are therefore proposed below to assist with the early small scale (large lot) stages of development.

ALTERNATIVE WATER SUPPLY

Stormwater

There is the potential to harvest storm water for processing. This water could potentially be used for industrial uses and non potable uses within each lot.

Rainwater

There is likely to be significant areas of impervious roof catchment throughout the subject land. This represents an opportunity to harvest and reuse relatively clean water on a lot by lot basis. All rainwater tanks will need to comply with the future Local Area Plan.

Due to the higher quality of this water, there is the potential to investigate the option of aquifer recharge.

Treated recycled Wastewater

As part of producing the DWMS liaison was undertaken with the Water Corporation. At this point in time the Corporation is not proposing to construct a wastewater treatment facility within the site, or for that matter anywhere in the locality in the near future. that would allow for water to be treated to a level where it could be reused on site.. The Corporation has also stated that relative to other industry, industry at West Mundijong is unlikely to generate significant demand for processing water, especially as 2ha dry industry lots. On this basis it is unlikely that a business case could be developed and supported for installation of infrastructure to enable re-use of treated wastewater at Mundijong

Subject to further feasibility, individual lots may still be able to treat their on lot wastewater for reuse. This will be on a lot by lot basis.

Groundwater

There is the possibility to utilise groundwater resources from both shallow and deeper aquifers located under the subject land. These will be subject to licences granted through DWER and will relate to the allocations available at the time.

Within the superficial aquifer there is potential to harvest the increase volume of groundwater that is often generated by development of land from agricultural to industrial. This extra water is due to the potential for increase infiltration and reduced evapotranspiration, leading to a build up of water stored within the soil profile. This can be further enhanced through the use of fill which increases the level of available storage height prior to running off the land.

This extra groundwater can be harvested through pumping and/or subsoil drainage piping. This water may be able to harvested during peak groundwater flow periods (late winter to early spring), either for immediate use of storage.

A secure storage system would need to be developed in conjunction with this option. Further investigation will be needed as part of the relevant UWMP, should a particular development area want to undertake this process. The extraction may also require a groundwater licence for using the superficial aquifer groundwater.

Managed Aquifer Recharge System

A Managed Aquifer Recharge System may be a viable option to store clean water from the subject land for later use within the development or in nearby areas. One options is to collect excess roof runoff and inject this into an appropriate deeper aquifer. This would also assist with controlling excessive groundwater rise within the superficial aquifer, by reducing the volume of water being infiltrated on site. The disperse nature of the 2ha lot configuration means that at this point in time that any proposal would be on a lot by lot basis.

Rainwater would require treatment prior to DWER agreed standards prior to injection into an aquifer. The comparatively clean quality of roof rainwater may make this a viable source. The economics of the treatment may however mean that at a lot by lot basis, that tank storage is more viable.

Other sources may also be viable for aquifer injection but are likely to require further treatment to minimise the risk of polluting the chosen aquifer.

A detailed investigation will need to be undertaken into the viability and details of this option. The study should adhere to the Managed Aquifer Recharge Policy developed by DWER.

13.2 WASTEWATER

MAINS SEWER

Currently, the subject land is not connected to deep sewerage.

There Scott Street wastewater pumping station location is to the east of the subject land. Advice to date is that this will not take water from the subject land. Should this change in the future, it is likely the area required for the pumping station and its buffer may increase. The plant would also be uphill of the subject land, requiring pumping of effluent to this point.

This wastewater is to be sent from Mundijong to the East Rockingham wastewater treatment plant.

The future wastewater planning, when lots are subdivided below 2ha, will need to consider the types and flow rates of wastewater that will be generated from the industrial area and the suitability of these for discharge to the Water Corporation's wastewater system. Some industries may require their wastewater to be pre treated prior to discharging to the Water Corporation system. Should an agricultural food precinct be developed, there is likely to be a demand for a wastewater system that can accommodate high flows.

ON SITE TREATMENT AND DISPOSAL

The 2ha development option that is being used to inform this LWMS allows for on-site effluent disposal to be undertaken for dry industries. The high groundwater within the subject land needs to be taken into account as part of each lot's on site disposal. Figure 10 shows how the disposal are for these larger lots can be set back from the swale network by a minimum of 100m. The disposal areas should also be lifted to allow a minimum of 1.5m from the disposal base through to the maximum groundwater level within the post development lot. This will allow the development to comply with the *Government Sewage Policy 2019*. The Shire is to review all building applications to make sure that each lot complies with the Policy.

The onsite treatment and disposal is to be in keeping with the requirements of 2019 Government Sewage Policy by the Department of Health (DoH) and DWER's Water Quality Protection Note (WQPN) 51 – Industrial Wastewater Management and Disposal.

This is to include a Site and Soil Evaluation of each development area as part of the subdivision process.

These systems will also be assessed against the Local Area Plan to be developed.

As a summary, the on site effluent disposal systems are to be:

- appropriate systems for the site fill and existing soils;
- requirement for installation to be a minimum of 5m from foundations;
- located so that there is no mobilisation of nutrients or other contaminants into subsoil systems;
- A minimum of 100m from off lot drains and waterways
- be designed to not sheet contaminated surface water to the on lot drains/basins.
- Appropriate for the volume and quality of the water being treated, as well as taking into account likely future expansions.

The onsite disposal systems will require careful design to ensure all objectives are met.

GREYWATER RE-USE SCHEMES

The greatest potential for grey water reuse on this site is at the individual lot level. With appropriately designed on-site effluent treatment systems, the treated effluent may possibly be reused on each lot's landscaped areas or other fit for purpose uses. The feasibility of this option should be undertaken at the building licence stage and on a lot by lot basis.

REGULATIONS

Any of the above schemes where non-drinking water is used will need to comply with the Guideline for the approval of non-drinking water systems in Western Australia, by DWER.

The schemes will also need to comply with the Australian Guidelines for Water Recycling where relevant.

There may also be the need for a licensed operator depending on the characteristics of the scheme, such as schemes that cross lot boundaries. This may include having the scheme approved through the Economic Regulation Authority.

Approval by other relevant authorities which may include DoH, DWER, DBCA and the Local Government Authority, may also be required.

These aspects should be further refined as part of the UWMP's developed for each section of the subject land.

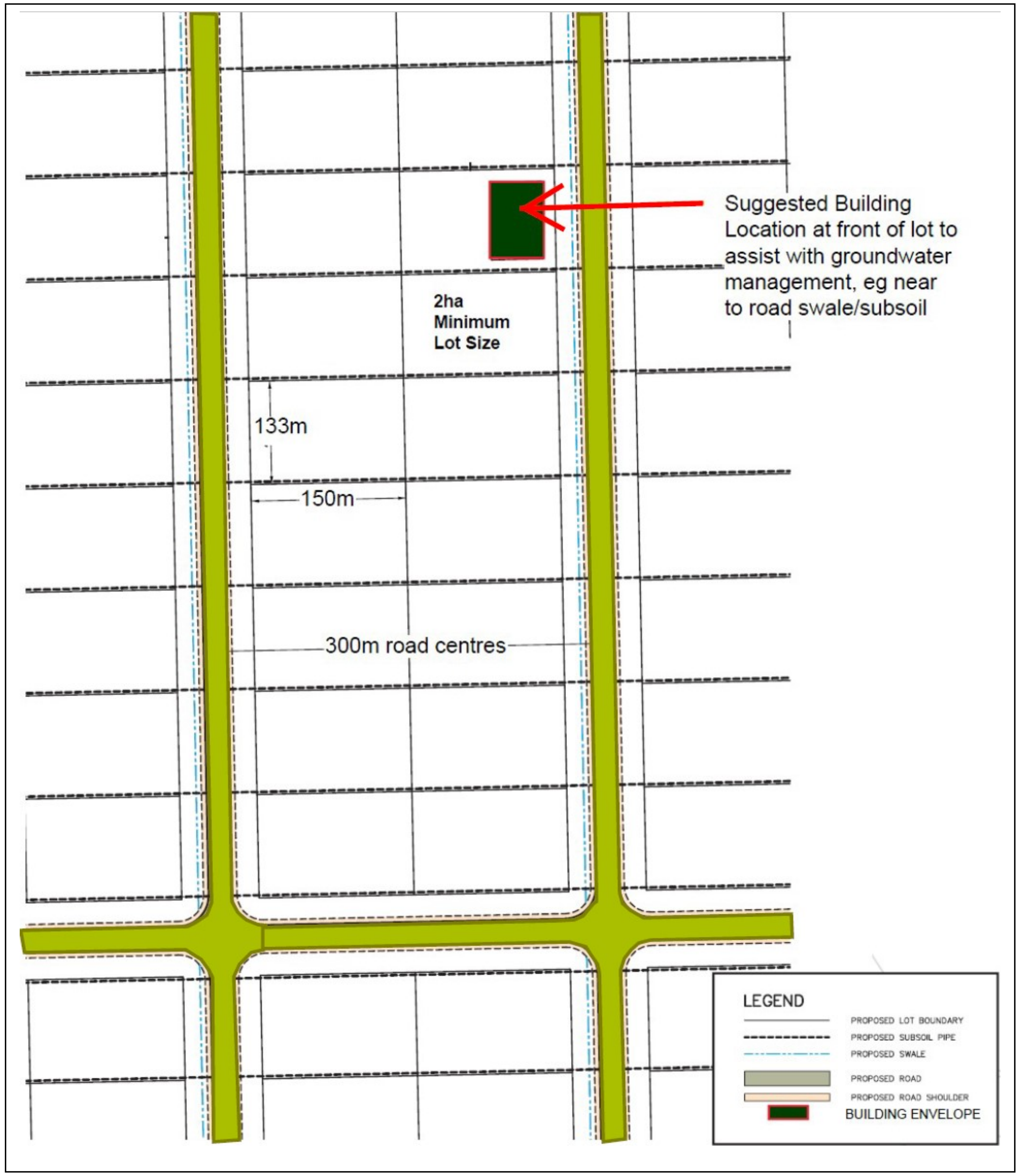


Figure 24 Typical subsoil and swale alignment to control groundwater

14 WATER CONSERVATION

According to the State Water Plan of 2007 by the Western Australian government 16% of the state's total water consumption in 2005 was by the commercial and industry sector. The Plan did not set a goal for this sector, unlike the 100kL objective per person set for residential areas.

The state government of Western Australia does however require all businesses that use more than 20,000kL of scheme water per year to participate in the Water Corporation's Waterwise Business Program. This Program involves:

- Undertaking a water management assessment annually with the Water Corporation;
- Developing a 5 yearly Water Efficiency Management Plan (WEMP); and
- Annual review of WEMPs and reporting the progress against the water savings action plan.

These are requirements are under the Water Agencies (Water Restrictions) By-laws 1998 and are mandatory. The WEMP involves the preparation and implementation of water consumption targets over a 5 year period. The business has to monitor water usage throughout each year of the plan, and a report is to be submitted to the Water Corporation annually.

There is an opportunity as part of this process to develop ways to manage, recycle and conserve water within individual businesses and even sectors of the industrial park.

EDUCATION AND AWARENESS

Business owners are be encouraged to promote water efficient behaviour amongst employees through awareness raising material and opportunities. Possible measures to encourage water efficient behaviour may be:

- Installing signs at all water using fixtures;
- Installing shower timers to encourage shorter showers where these facilities are provided;
- User education for dishwashers, washing machines and glass washers to ensure there is a full load, where these are provided;
- Include water conservation practices in staff or tenant inductions;
- Ensure water conservation or management is continually brought up at meetings;
- Promote their businesses water-saving initiatives or outcomes within the local community;
- Encourage employees to identify water-saving measures; and
- Offer an incentive scheme to encourage water-saving innovations and ideas.

Further details are to be developed in the relevant UWMP's

RAINWATER TANKS

Businesses are to be encouraged to install rainwater tanks, with a level controlled air gap, to reduce the quantity of water consumption from the water mains. The water may be used for a variety of fit for purpose uses, related to the industry and feasible treatment levels.

A suitable tank size should be determined according to the roof area of the buildings on a lot and the water usage practices and applications by the business.

ONSITE INFILTRATION and STORMWATER DISCHARGE

The sites stormwater that is directed to the bioretention gardens and swales, as well as the water infiltrated to the groundwater will assist with providing irrigation to the sites landscaping. The use of this water for direct and indirect irrigation of these plants offsets the need for other water sources to be used to provide irrigation of the subject lands landscaping plant.

WATERWISE LANDSCAPING AND REVEGETATION

Natural rainfall alone should be sufficient to maintain Waterwise landscaped areas once established. Front of lot landscaping and street reserve landscaping is to be composed of waterwise plantings suited to the local environment.

Details on appropriate species and areas of planting/landscaping are to be established as part of future planning for the site and reflected in the UWMP.

In general all major swale networks are to be developed using a mixture of native understorey (sedges, rushes, groundcovers), mid storey (riparian shrubs) and trees. The sedges and rushes would generally be planted at approximately6plant/m^2 in the wettest parts of the swales. Higher up, groundcovers at 1/m^2 are to be planted. Approximately 1 shrub every 3m^2 and 1 tree every 10m^2 should also be planted. The planting area is to extend across the swales and at least 1m out from the top of the banks. Planting on he base of the swale needs to take into account the need for flood flows to move through the system.

All planting will also need to take into account bushfire management, which will likely require areas along the swale where only understorey planting is used, in combination with cross overs, to provide strategic firebreak areas.

The bioretention gardens will be composed of a sedge/rush understorey at approximately 6plants/m2, with shrubs or tree species being planted at around 1 plant/5m^2. The exact configuration will depend on the size, shape and location of the treatment structures.

The wetland revegetation will be composed of full restoration planting. This is outlined in the Wetland Management Report, with further refinement to be undertaken as part of the subdivision of the surrounding area.

The source of water for any landscape irrigation is also to be outlined in the UWMP, noting that there is no proposed longterm landscape irrigation proposed on the road reserves and MUC. The landscaped areas of lots, as well as the MUC could potentially be watered from groundwater, treated wastewater, harvested stormwater or rainwater. The wetland restoration will likely only receive watering during establishment as required, most likely by tankering in of water during summer, with associated hand watering.

The Shire of Serpentine Jarrahdale will be the manager of the MUC and Manjedal Brook wetland system in the longterm, with the implementation and initial maintenance undertaken by the relevant developer. The Shire may coordinate the implementation of the MUC, especially the main one along Kargotich Road, subject to how the land is developed. This will assist with making sure the area is available for drainage/flood storage as part of the relevant stage of development.

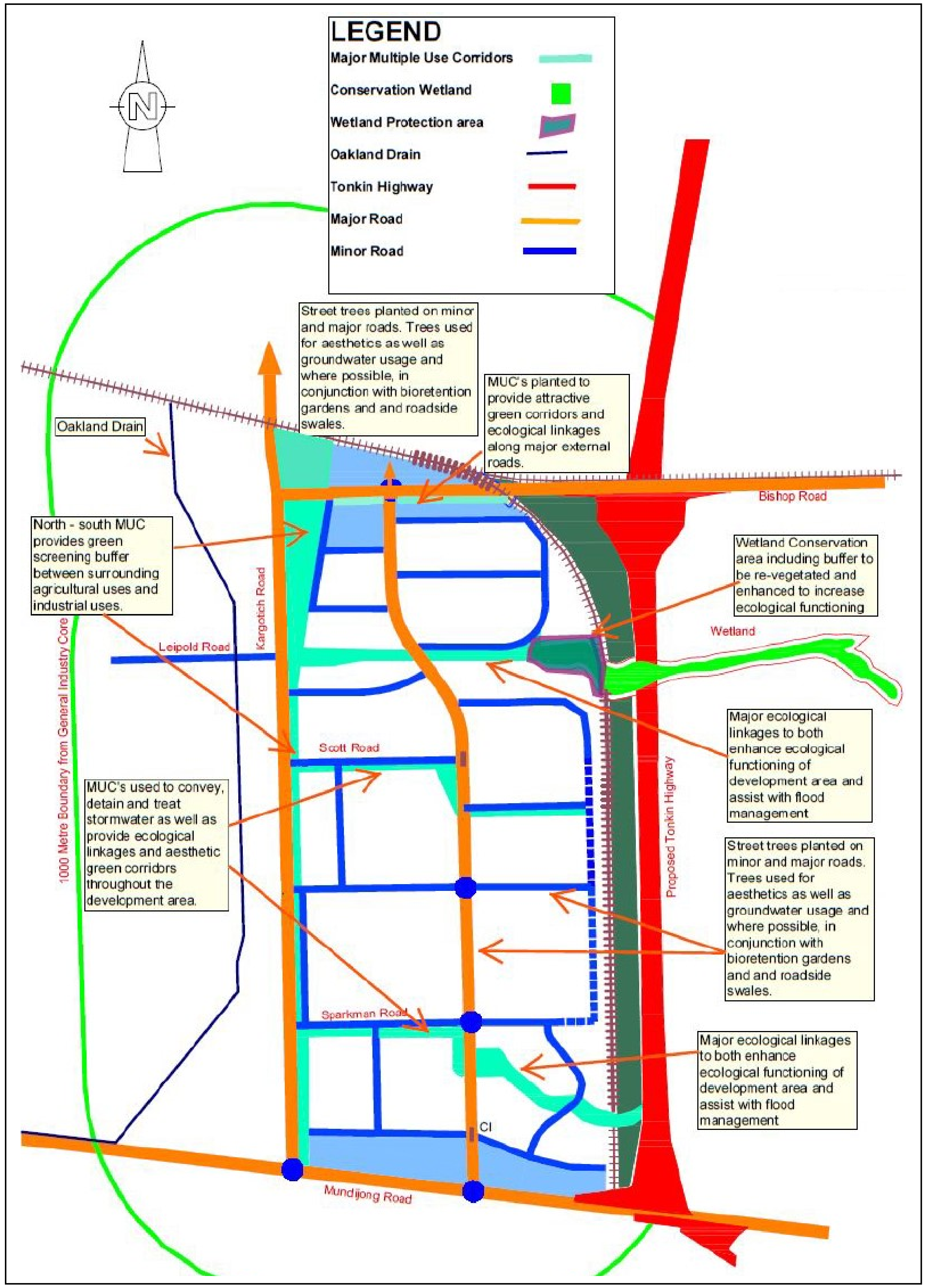


Figure 25 Overall Landscaping concept

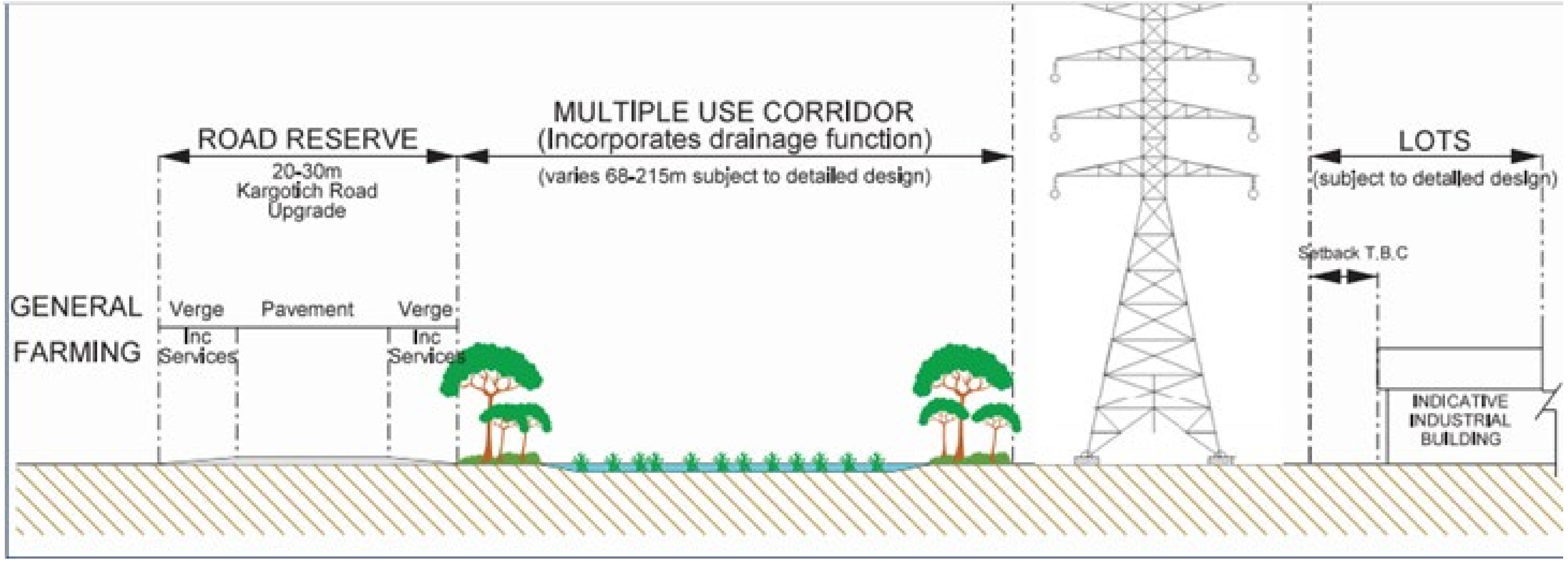


Figure 26 Indicative Multiple Use Corridor landscaping concept

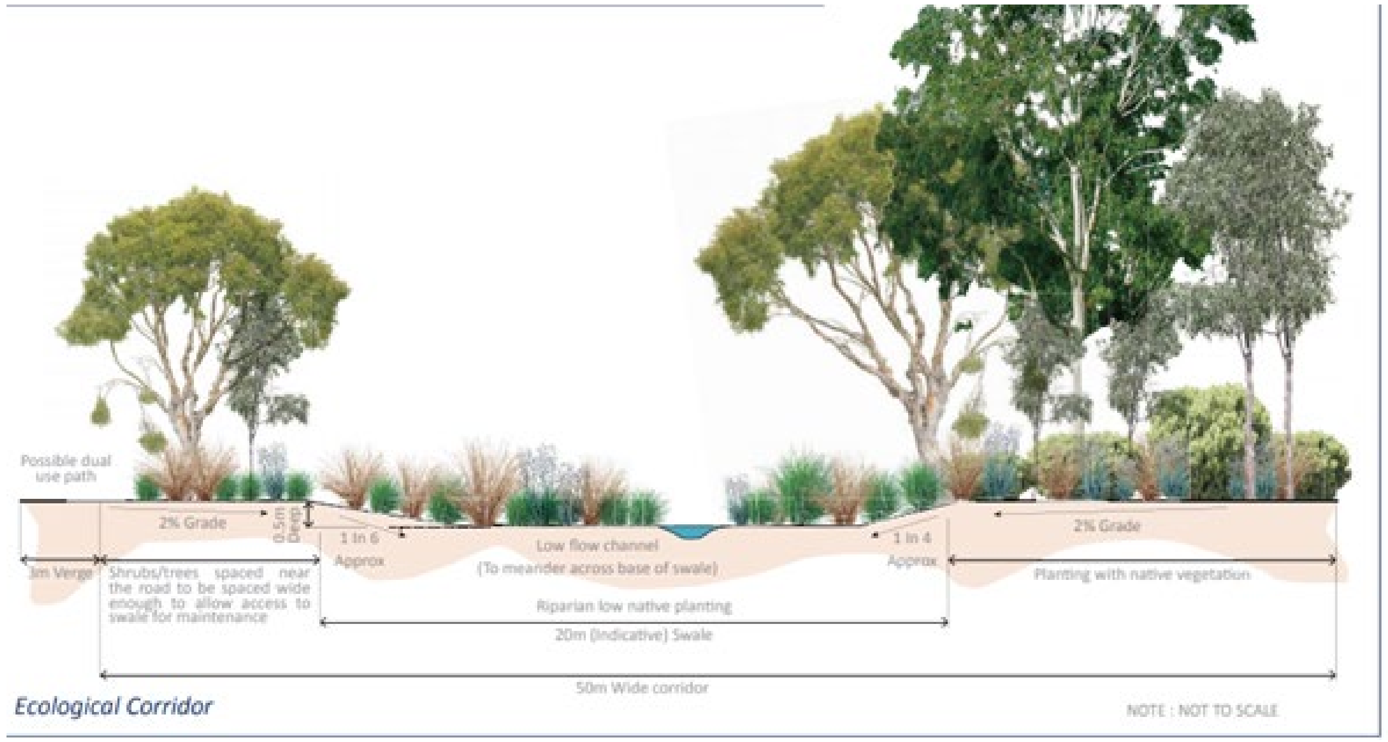


Figure 27 Indicative Ecological corridor

15 IMPLEMENTATION FRAMEWORK & MONITORING

15.1 PRE-DEVELOPMENT

GROUNDWATER

Pre-development monitoring for the subject land will need to include a minimum of 2 years of groundwater levels and quality. The focus for the monitoring is to determine the maximum and minimum levels of groundwater throughout the year and general quality. These results are to be compared against more regional data produced by DWER and surround developments. Each UWMP area is to undertake its own groundwater monitoring, unless it can prove that the data collected at nearby locations or as part of an overall study is sufficient.

The indicative minimum locations for sampling are shown in Figure 28. These bores should be a minimum of 3m below the surface. There may be some modification of the exact locations, depending on how each UWMP is undertaken.

The quality parameters should include the following:

Physical

Electrical Conductivity (EC), pH, salinity, temperature and Alkalinity.

Chemical

Nitrate (as NO3), Ammonia (as N), Total Nitrogen, Total Phosphorous, Filterable Reactive Phosphorous (P), and metals (Al, As, Cd, Cr, Cu, Fe, Mn, Pb, Zn).

SURFACE WATER

Monitoring of quality within the main waterways that traverse then land is recommended. This should happen for a minimum of 2 year prior to development, with a focus on the period that the waterways are flowing. At least 2 samples per site should be collected each year. Samples are to be collected at the point at which the waterways enter and exit the subject land. The indicative locations for sampling are shown in Figure 25.

The tested parameters should include:

Physical

Electrical Conductivity (EC), pH, Dissolved Oxygen (DO), salinity, temperature, Oxygen Replacement Potential (ORP) turbidity, total suspended solids and Alkalinity.

Chemical

Nitrate (as NO3), Ammonia (as N), Total Nitrogen, Total Phosphorous, Filterable Reactive Phosphorous (P), and metals (Al, As, Cd, Cr, Cu, Fe, Mn, Pb, Zn).

WETLAND

A Detailed Management Plan should be produced for the Conservation Category wetland 14945. This is to include information on the current condition so be used a base for post development monitoring. The assessment should include indicative hydro regimes, flora present, vegetation complexes, weed issues and likely fauna habitat. As part of the surface water and groundwater monitoring regimes, sampling points are to be set up so that they can provide data on the hydro regimes for the wetland.

15.2 CONSTRUCTION PHASE

Installation of drainage control structures is to occur ahead of the construction phase of the development. This will include the use of water sensitive design techniques such as sediment curtains, hydro-mulching and temporary detention basins to maintain the quality of the water leaving the development area during construction. The collection pits will be monitored for any damage, including sediment build up and litter accumulation during, and at the completion of, construction to ensure the pit's effectiveness is not diminished post-development.

All contractors working on any future development of the site will be made aware of their responsibilities under the Aboriginal Heritage Act 1972 with regard to finding potential archaeological sites. In the event that a potential site is discovered, all work in the area will cease and the DIA should be contacted.

On lot stormwater infrastructures will also need to be approved by the Shire as part of the relevant Building licence. This will include making sure the correct volume of storage is achieved and that the discharge of groundwater and stormwater matches with the road lot connection points.

15.3 POST-DEVELOPMENT

WSUD INFRASTRUCTURE

Routine monitoring within the development area that checks the status of key functional WSUD elements is to be undertaken to ensure they meet specified design requirements. This will include:

- ensuring the inlet and outlet structures are free of debris;
- vegetative cover of the systems is maintained;
- sediment build up is not impeding the functionality;
- erosion is not present;
- soils are not compacted;
- litter is removed; and
- hydrocarbons are not present in the system.

Monitoring of the established WSUD elements operations can provide important insights on the likely performance of them in pollution reduction and stormwater management functionality. Inspection of the WSUD elements will be undertaken by the developer until an agreed upon time between developers and the Shire. The indicative timeframe is for 2 years after the completion of works with inspections every three months. This is to be reviewed as part of each UWMP. Table 8 summaries the particular items to monitor and the purpose of monitoring, the trigger signs that require immediate action and the maintenance action required.

Compared to traditional engineered structures for stormwater runoff management, the WSUD elements will only require minimal routine maintenance many of these related to a landscaping and ecological corridor maintenance nature. The most common maintenance is the removal of weeds, debris and siltation. The most time intensive period of maintenance for a vegetated WSUD system is during plant establishment (which typically includes two growing seasons), when supplementary watering, plant replacement and weeding may be required.

It is recommended that vegetated WSUD elements are monitored by personnel with floristic knowledge and/or qualifications, as they will be capable of identifying evasive species within the natively vegetated WSUD systems. Furthermore, personnel in charge of monitoring should have a good understanding of principles and the functional design of the WSUD elements and the treatment system. The maintenance activities prompted through monitoring activities will generally require coordination between landscape and civil services.

The WSUD elements will be constructed and utilised in different stages so that the functions of the WSUD elements are protected from elevated pollutant loads generated from a developing catchment.

Maintenance inspections should be scheduled to be conducted after a significant storm event. Inspections should focus on ponding time for the different systems, unequal surface flow distribution, sedimentation and scouring, as well as deposition of coarse litter.

Performance monitoring of WSUD elements via detailed water sampling and testing for contaminant concentrations has not been scheduled at this stage. The exact parameters and monitoring schedule is to be further detailed in the LWMS and subsequent UWMP for the site.

GROUNDWATER

Groundwater monitoring may be required post development to determine that the development is not impacting on nearby significant wetlands through changes in levels or poor water quality. The exact parameters and monitoring regime will be determined by the final land uses. For this reason, further details on post development monitoring are to be developed as part of the UWMP.

SURFACE WATER

Surface water monitoring may be required post development to determine that the development is not impacting detrimentally on the surface water quality leaving the site. Sampling points should be set up at the discharge points form the subject land or on site significant wetlands. These should be checked against established guidelines and the quality of water entering the site from upstream. The exact parameters and monitoring regime will be determined by the final land uses. For this reason, further details on post development monitoring are to be developed as part of the UWMP.

WETLAND

The monitoring of the wetland is to be related to the rehabilitation works and the monitoring of water resources above. A Detailed Wetland Management Plan will outline the appropriate monitoring regime. This should be done at the UWMP. Preliminary concepts are outlined in the Attached Wetland Management Report (Appendix B).

15.4 RESPONSIBILITY AND REPORTING

The developers of the land will be fully responsible for the monitoring and reporting of all aspects listed above. Advice should be sort from the DWER, DBCA and Shire on exact parameters and regimes.

All information collected from monitoring programs, should be recorded and provided in an agreed format, prepared by the developer, to the relevant authority. If a trigger value for a contingency action is reached, a more detailed report on the occurrence, its impact and proposed action to prevent recurrence is to be compiled by the developer and submitted to the relevant authority.

15.5 GOVERNANCE

INTERNAL DRAINAGE NETWORK

The Shire will take over governance of the entire internal drainage network, outside of individual lots. These are to be handed over after they have been developed to a suitable standard by developers. The Shire will manage compliance of on lot water management through details set out in the Local Area Plan. This will also be used to assess building and lot development applications.

Furthermore, the Shire will coordinate the implementation process of the large MUC along Kargotich road, so that the fold management and associated uses are provided for all future industrial uses. This will be undertaken through a Developer Contribution Scheme process.

MANJEDAL BROOK WETLAND

Manjedal Brook Wetland will be managed in the longterm by the Shire of Serpentine Jarrahdale As the associated degraded Manjedal Brook waterway is to be realigned into the swale network, this will also be managed by the Shire. The developer of the surrounding lots will be responsible for implementing the actual on groundworks to rehabilitate the wetland.

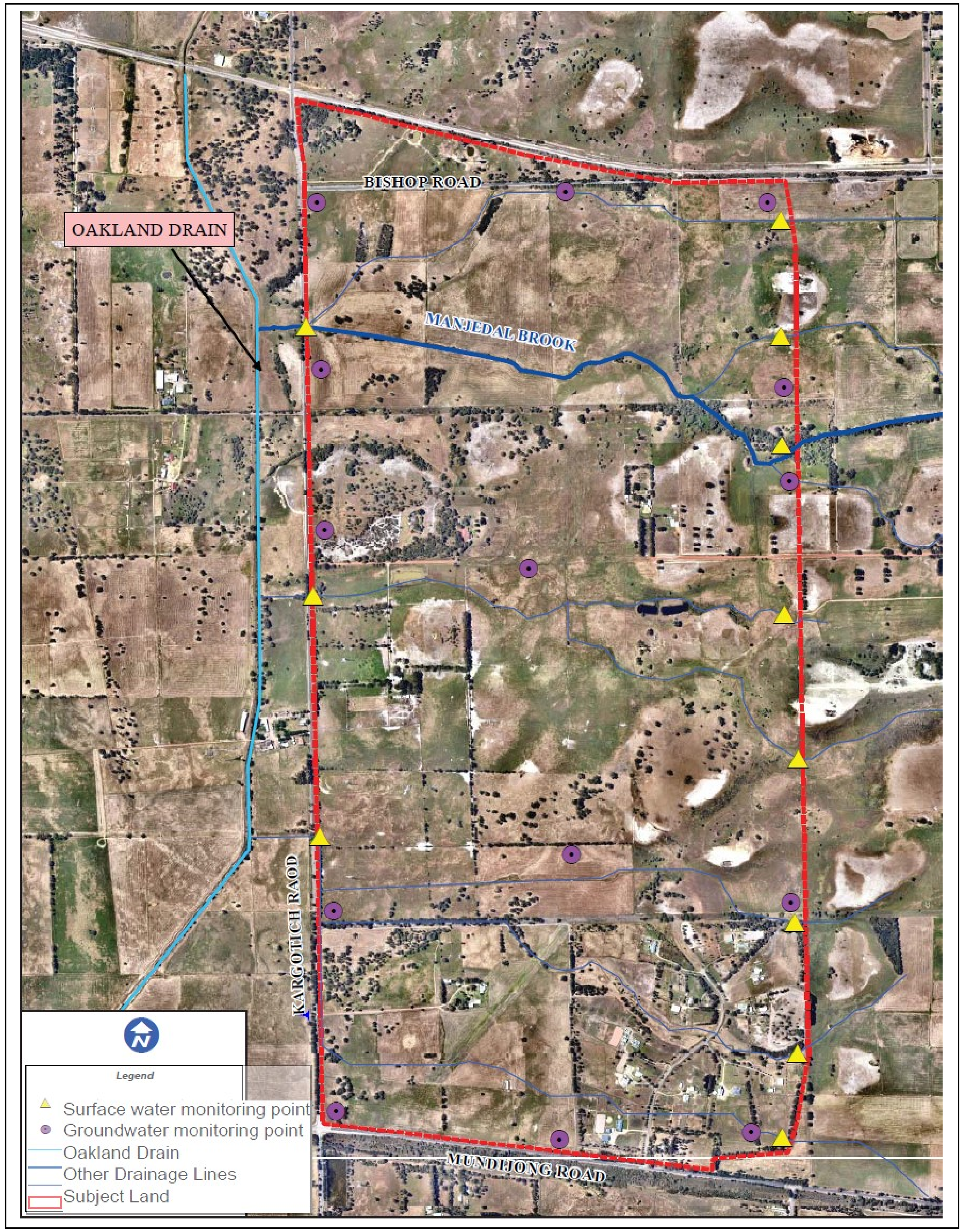


Figure 28 Indicative monitoring points

Function	Item to Monitor	Purpose of Monitoring	Trigger for Immediate Action	Maintenance Action Required	Monitoring Frequency	Responsibility
PRE-DEVELOPMENT						
Groundwater	Quality	To determine pre-development quality to assist with setting base lines for the subject land.	NA	NA	Minimum of two samples a year for 2 years	Developer
	Levels	To determine pre-development levels to assist with setting AAMGL for the subject land.	NA	NA	Monthly sampling over 'winter' period, 3 monthly over summer. Minimum of 2 winterss.	Developer
Surface Water	Quality	To determine pre-development quality to assist with setting base lines for the subject land.	NA	NA	Minimum of two samples a year for 2 years	Developer
CONSTRUCTION PHASE & POST-DEVELOPMENT (more details on this section to be provided in UWMP)						
Groundwater	Quality	To determine post-development quality to assist with determining if site is meeting guidelines.	Values siginificantly outside recommended guidelines	Determine cause and rectify	Minimum of two samples a year for 2 years	Developer
	Levels	To determine post-development levelsy to assist with determining if site is meeting guidelines.	Values siginificantly outside recommended guidelines	Determine cause and rectify	Monthly sampling over 'winter' period, 3 monthly over summer. Minimum of 2 winters.	Developer
Drainage Management Systems	Structural Effectiveness (inlets, traps and outlets)	Inspection for debris, litter and sediments surrounding structural components.	Debris, litter or sediments causing blockages or impairing functions.	Remove any debris or blockages. Inspect system for any erosion related issues.	Every 3 months	Developer until handover to the City/Shire
	Erosion	Inspection for erosion.	Presence of severe erosion or erosion impairing functions.	Investigate, identify and rectify the cause of the erosion. Replace filter media as required.	Every 3 months	Developer until handover to the City/Shire
	Sediment and Silt Build Up	Inspection for sediment and silt accumulation within pits, on the surface of bioretention systems and within basins.	Accumulation of large volumes of sediments and/or silts in pits or on the surface (according to City standards).	Investigate, identify and stabilise cause of sediment source. Remove accumulated sediments and replace filter media or plants removed.	Every 3 months	Developer until handover to the City/Shire
	Compaction	Inspection of filter media for compaction.	Water remains ponding longer than designed in bioretention system after a storm event.	Investigate cause of compaction. If localised, remove top 500mm of filter media, break up the filter and then return to system without any compaction. If extensive seek expert advice.	Every 3 months	Developer until handover to the City/Shire
	Weeds	Inspection for the presence of weeds.	Weeds are noxious or highly invasive or if weeds cover more than 25% of area.	Manual removal or targeting herbicide application, with waterway approved products.	Every 3 months	Developer until handover to the City/Shire
	Plant Condition	Inspection of vegetation health and cover, and presence of dead plants.	Plants dying or a pattern of plant deaths.	Investigate cause of plant deaths and rectify. Infill plantings may be required.	Every 3 months	Developer until handover to the City/Shire
	Organic Litter	Inspection for the presence of organic litter (e.g. leaves) on surface.	Litter coverage is thick or extensive, or detracting from the visual appearance of the system.	Investigate source of litter and undertake appropriate response, e.g. alter landscaping maintenance practices, community education). Remove litter.	Every 3 months	Developer until handover to the City/Shire
	Rubbish/Litter	Inspection for the presence of litter.	Litter is blocking structures or detracting from the visual appearance of the system.	Identify source of litter and undertake appropriate responses. Remove litter.	Every 3 months	Developer until handover to the City/Shire
	Oil/Hydrocarbons	Inspection for the occurrence of oil on surface.	Oil coverage persists for more than 3 weeks, and is thick.	Notify the EPA of the spill and clean up requirements.	Every 3 months	Developer until handover to the City/Shire
	Surface Water Quality	Sampling of water quality (TSS, TN & TP) at discharge (outlet) points.	0.1mg/L for TP and 1.0mg/L for TN.	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination. More detailed assessments may be required.	Every 3 months	Developer
POST-DEVELOPMENT ONLY						
Water Conservation	Water Consumption	Review and report on WEMP to the Water Corporation.	Determined by WEMP and Water Corporation.	Determined by WEMP and Water Corporation.	Yearly	Business Owners
Groundwater	Quality	To determine post-development quality and testing to be done at sub-soil discharge points.	0.1mg/L for TP and 1.0mg/L for TN.	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination.	Minimum of two samples a year	Developer
	Levels	Monitoring required to sub-soil drainage system is operating as designed.	Levels exceeding controlled groundwater level.	Undertake appropriate responses to address the issue.	Monthly sampling over 'winter' period.	Developer (agreed handover)

Table 8 Monitoring and Maintenance

16 RECOMMENDATIONS FOR FUTURE STUDIES

For future development of the land past the Structure Planning stage the following additional studies may be required to support the subsequent UWMP's;

- ASS investigation
- Detailed Wetland Management Plan
- Detailed Earthworks and Services Strategies
- Alternative water supply and treatment options
- Managed Aquifer Recharge assessment (as relevant)
- Detailed Drainage Design

Groundwater investigation

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Appendix AWEST MUNDIJONG INDUSRIAL MODELLING REPORT

Appendix BWEST MUNDIJONG WETLAND MANAGEMENT REPORT

APPENDIX C GROUNDWATER ANALYSIS SUMMARY

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